

# A Tale of Two Cities: Software Developers Working from Home During the COVID-19 Pandemic

DENAE FORD, Microsoft Corp.

MARGARET-ANNE STOREY, University of Victoria, Canada

THOMAS ZIMMERMANN, Microsoft Corp.

CHRISTIAN BIRD, Microsoft Corp.

SONIA JAFFE, Microsoft Corp.

CHANDRA MADDILA, Microsoft Corp.

JENNA L. BUTLER, Microsoft Corp.

BRIAN HOUCK, Microsoft Corp.

NACHIAPPAN NAGAPPAN, Microsoft Corp.

The COVID-19 pandemic has shaken the world to its core and has provoked an overnight exodus of developers that normally worked in an office setting to working from home. The magnitude of this shift and the factors that have accompanied this new unplanned work setting go beyond what the software engineering community has previously understood to be remote work. To find out how developers and their productivity were affected, we distributed two surveys (with 3,634 responses)—weeks apart to understand the presence and prevalence of the benefits, challenges, and opportunities to improve this special circumstance of remote work. From our thematic qualitative analysis and statistical quantitative analysis, we find that there is a *dichotomy* of developer experiences influenced by many different factors (that for some are a benefit, while for others a challenge). For example, a benefit for some was being close to family members but for others having family members share their working space and interrupting their focus, was a challenge. Our surveys led to powerful narratives from respondents and revealed the scale at which these experiences exist to provide insights as to how the future of (pandemic) remote work can evolve.

## 1 INTRODUCTION

*Charles Dickens' "A Tale of Two Cities" begins, "It was the best of times, it was the worst of times." Adapting Dickens' line to leading an engineering team during the global pandemic, I'd say "We're doing very well, we're barely hanging in there." — Shane O'Flynn [1]*

Software engineering is a complex knowledge based technical task that requires intense periods of focused, uninterrupted work [2], while coordinating and collaborating with other developers and stakeholders [3]. Despite a need for intense periods of coordination, collaboration and communication for managing intricate dependencies within and across systems, there are compelling success stories of how developers can effectively develop high quality complex software in a distributed fashion. Successful open source communities, globally distributed software projects and fully remote software companies are all testaments to distributed and remote work. Decades of engineering tools (such as version control and continuous integration tools) and knowledge sharing tools (such as email, Stack Overflow, and Wikipedia) were conceived and designed by developers for developers to manage the collaborative and distributed nature of software engineering [4].

Despite having rich tools to support distributed development, many software companies believe that there are significant advantages to working in a co-located fashion, with many advocating for close proximity among developers (such as in shared team rooms) [5]. Some of the claimed benefits

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Authors' addresses: Denae Ford, denae@microsoft.com; Thomas Zimmermann, tzimmer@microsoft.com; Christian Bird, cbird@microsoft.com; Sonia Jaffe, sonia.jaffe@microsoft.com; Chandra Maddila, chmaddil@microsoft.com; Jenna L. Butler, jennbu@microsoft.com; Brian Houck, Brian.Houck@microsoft.com; Nachiappan Nagappan, nachin@microsoft.com, Microsoft Corp., 1 Microsoft Way, Redmond, WA, 98052; Margaret-Anne Storey, mstorey@uvic.ca, University of Victoria, POBox 3055, STN CSC, Victoria, BC, Canada, V8W 3P6.

for co-location are seamless coordination, increased creativity, faster learning and easier to manage projects [6, 7].

There are numerous studies that give insights about the benefits and challenges of distributed corporate development work compared with co-located development [8–10], but these studies tend to focus on specific teams or investigate the velocity or quality of the code developed using quantitative analysis of system trace data. They do not capture the experiences of developers across a large company that have had to switch (over night) from a mostly co-located mode to remote work from home. And yet this is what happened for many developers worldwide with the pandemic forcing technology companies to close their offices.

The COVID-19 pandemic has undoubtedly been a worldwide human and economic disaster, but it has also led to interesting and some unexpected revelations about how we work, play and live. Although working from home during a pandemic is not the same as working from home during “normal times”<sup>1</sup>, it is nevertheless an opportunity to study the results from a “natural experiment” and compare the benefits and challenges developers may experience in terms of their development productivity in these two modes. We are not alone in studying software development during the pandemic as it unfolds and we discuss these ongoing studies in Section 2 and later compare our findings with these other studies in Section 8. Our work adds a new perspective that dives deeper into the narratives which reveals a tale of two cities.

In our paper, we report the dichotomous experiences of engineers (developers and program managers) working from home (WFH) during the pandemic. We share their very early experiences, and their experiences after several weeks of working from home. Our initial survey uncovered the main benefits and challenges they faced, and the second survey revealed the frequency/impact of those benefits/challenges. From the second survey, we also uncovered developers’ self-reported changes in productivity since WFH and how the benefits and challenges they experienced associate with those changes in productivity. Finally we share developer suggested improvements that can be made to support the WFH experience (as shared by the engineers in our study).

Of note is that many of the factors we uncovered were seen as a benefit for some, but as a challenge by others. These differential experiences were in some cases driven by engineers’ personal contexts (e.g., if they have school age children or space for a home office) and characteristics of their work (such as reliance on team members). However, some factors were experienced as both a benefit and a challenge by some of the the same participants (such as time flexibility)

The main takeaways from our paper are as follows:

- Productivity, when measured using engineering system data, appears to be stable or slightly improved, but some developers, at least initially, appeared to thrive and report being more productive, while others face significant challenges with remote work and feel they are not as productive.
- Some factors (such as schedule flexibility, proximity to family members and more time for work) lead to dichotomous experiences across developers and even by individual developers.
- Organizations can support remote work by firstly understanding the varied experiences of developers, the challenges their employees may face and that there are actionable recommendations they can follow to support developers working from home now or in the future as part of hybrid model.

Our paper is organized as follows. In Section 2 we provide a background of literature that has studied developer performance, productivity and remote development work. In Section 3 we describe the methodology we followed for the two surveys we conducted over the first few months of the pandemic. In Section 4 we discuss the change in productivity reported across the surveys. In

<sup>1</sup><https://twitter.com/shanselman/status/1252040170783641600>

Section 5 we report the main benefits encountered and in Section 6 we report the main challenges encountered as developers working from home. Section 7 summarizes the key recommendations that developers suggested organizations should follow to improve the situation for developers working from home. In Section 8, we delve into the main factors and discuss how these may play a role in the dichotomous experiences of developers. We also discuss how engineering system output data can help triangulate the impact of work from home and how the pandemic may shape the future of remote work once the pandemic is over. Section 9 discusses more recent related works about programmers during the pandemic. Finally, Section 10 concludes our paper.

## 2 BACKGROUND

There has been extensive research that compares distributed/remote development work with co-located work and many studies that investigate developer performance and productivity. We summarize the key findings from these prior works below. Some of the factors we uncover overlap this earlier research, but the abrupt change for individual developers and the entire organization to working from home reveal new benefits and challenges of working from home, as we will discuss later in the paper.

### 2.1 Working Remotely

Remote work has been adopted by many large technology organizations because of the advantages that working remotely provides to its employees. For instance, remote work provides workers with the opportunity to engage with a globally distributed team introducing a wide range of perspectives to the project. Another advantage that comes with remote work is the flexibility of *how* to work. Specifically, workers have autonomy over when to engage and disengage with colleagues providing unique opportunities for deeper concentrated work [11]. Focused time to work is often challenging when colleagues face unscheduled interruptions [12]. Remote work also provides the flexibility of *where* to work, granting workers the ability to work from many parts of the world—which if well supported can lead to distributed teams being just as effective as collocated teams [9].

Despite the benefits with remote work, there are also several challenges that remote work presents for workers. For example, the ability to build trust with colleagues while working remotely is critical for collaboration [13] but can be harder to achieve with remote work. Close proximity, in-person work provides opportunities for unplanned interactions in-office that would build trust. Interactions in remote settings must now be intentional or it will affect social capital across distributed teams [14]. In remote settings, there is a need for more devoted time, resources, communication channels, and events to foster relationships. Although remote work implies the ability to work from any location, working remotely has often been synonymous with working from home—which has its own set of challenges. Some of the challenges with working from home include supporting family members who may be sharing the same working space. For example, Heisman’s interviews with remote workers at GitHub identifies how they have been able to take advantage of flexible work hours and support groups to support their children [15].

Of note is that there are a few multinational technology companies who have been supporting a work environment that is “remote-first” [16] before the pandemic. Some of these companies have shared their best practices to support other organizations. For example, in 2017 Stack Overflow shared a blog about how their organization has created a successful remote work environment. In this post, they proclaim that the most important aspect that has contributed to their success is having an employees whose job is be a point of contact for all remote work related questions [17]. This article further describes how effective it has been for someone in the organizations leadership to advocate on behalf of remote workers.

Similarly, GitLab, an all-remote DevOps technology company, released an inaugural remote work report to reveal the state of distributed work and explore the future of remote work [18]. This timely report was released only days after King County employees were instructed to work from home (see Figure 1). The report shares research conducted by a third party company that provide insights from over 3,000 remote workers from across four countries in a variety of industries and roles where they have the opportunity to work remotely. Some of the key takeaways from this report are *all-remote work is surging*, *remote work can foster a better sense of work life harmony*, *allowing remote work provides a hiring advantage*, and that “*remote $\neq$ alone*” meaning that remote work does not have to mean workers are isolated—reporting several in-person gatherings that can be supported by companies. Days later in response to COVID-19, GitLab produced a “Remote Work Playbook” [19] where they describe strategic tactics to help support their more than 1,200 remote workers across 67 countries feel the most supported and what other newly remote companies can do for their newly transitioned remote workers. This playbook outlines guidelines on how to align values with expectations, how to manage remote teams, how to identify tools for effective communication, and how to encourage a healthy remote work lifestyle.

## 2.2 Developer Performance and Productivity

Understanding developer productivity in software engineering has been an important topic seeing great interest from research and industry, as improving developer productivity may lead to faster development speed, higher quality code and also higher developer satisfaction. A concern during the work from home shift during the pandemic is that both developer productivity and their well-being may have been negatively affected. Existing research brings insights about developer performance, productivity, satisfaction and developer well-being.

In terms of performance, system engineering activity metrics can provide important signals about developer activity and productivity. Wagner and Ruhe’s review of the literature summarize studies that use performance measures such as *lines of code* or *function points* as proxies to productivity [20]. However, within the area of organizational behavior, performance and productivity are acknowledged to be related [21], with higher levels of performance leading to higher levels of productivity, they are also recognized as distinct concepts. Indeed, many researchers and practitioners emphasize that developer productivity cannot and should not be measured by engineering metrics alone as development work is not mechanized work that can be measured using system measures alone. In fact, doing so may be detrimental to the overall and long term development objectives [22]. For example, developers spend time mentoring newcomers, reviewing each other’s work informally, and learning new skills.

Through their systematic literature review, Wagner and Ruhe [20] also identified 51 factors that influence productivity. In addition to the identified technical factors that seem to dominate productivity studies in software engineering, they also distilled a number of soft factors that focus on aspects such as organizational culture and working environment.

Using a different lens, Meyer et al. [23] investigated how developers perceive and think about their own productivity. Through a survey and subsequent observations and interviews, their study brought to the surface that developers’ sense of how productive they are may be distorted by how many interruptions and context switches they experience. Other research about developer productivity reported that the quality of one’s work environment plays a major role [24] while the effectiveness of a manager [25] is also an important factor on productivity.

More recent research expanded these factors to include additional factors that may influence productivity and satisfaction or be used in certain contexts to predict productivity. From an earlier study [26] we conducted with developers at Microsoft, the factors that more closely associated with one’s satisfaction with their productivity included *job satisfaction*, *doing impactful work*, *having*

*autonomy over one’s work, the ability to complete tasks, the quality of the engineering system, ability to complete tasks, personal technical skills, and their work environment.* Predictive factors [27] included *job enthusiasm, peer support for new ideas, and getting job feedback*, while “use of remote work to concentrate”, showed the lowest variance across three large software companies.

### 3 METHODOLOGY

We investigated the experiences of software engineers at Microsoft during the height of the COVID-19 pandemic in the United States using a set of online surveys. Figure 1 outlines the timeline of our study from March–May 2020.

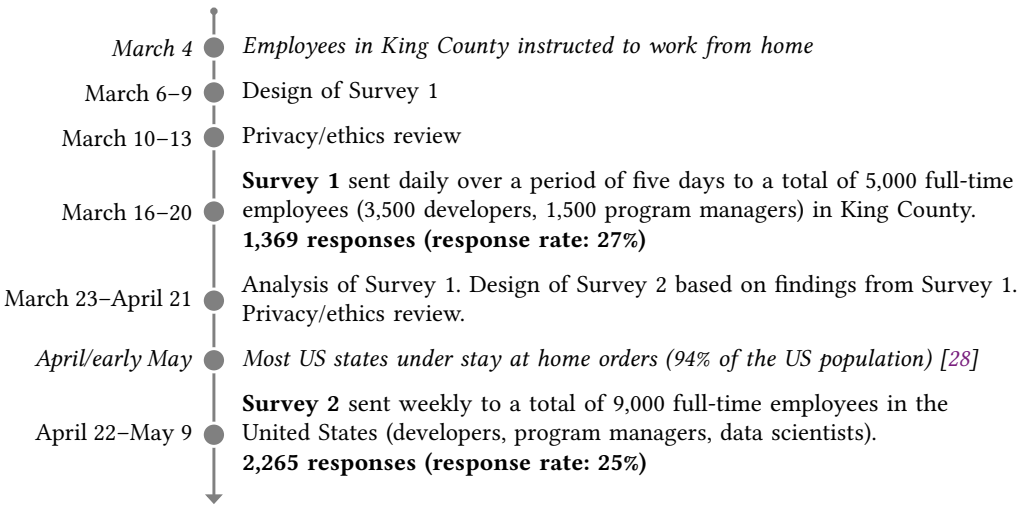


Fig. 1. Timeline for our multi-survey study

**Research Context.** The first presumptive positive COVID-19 case in King County (which includes the Microsoft headquarters) was reported on February 29, 2020. In the late afternoon of March 4, Microsoft informed its employees that “*Consistent with King County guidance, we are recommending all employees who are in a job that can be done from home should do so*” [29]. On March 11, the schools were closed in Washington State (which was made permanent for the school year on April 8) and many other restrictions were introduced during April. By April 27 the outbreak has reached its peak in Washington State. Some restrictions on outdoor activities were later lifted but social distancing was still recommended. The pandemic also affected the rest of the US: at the end of March, 42 states and a total of 308 million people (94% of the US population) were under stay at home orders [28]. At the time of writing this paper, Microsoft and other large tech companies had extended the work from home recommendation until at least the Fall of 2020 and in some cases even until Summer 2021 [30, 31].

**Research Questions.** To understand the effect of WFH on software engineers, we posed the following research questions:

**RQ1** How has engineers’ self-reported **productivity changed** since WFH?

**RQ2** What are the **benefits** engineers experience when working from home? How have these benefits affected productivity since WFH?

**RQ3** What are the **challenges** engineers face when working from home? How have these challenges impacted productivity since WFH?

**RQ4** What **recommendations** should be made to companies whose engineers may wish to work from home?

To answer these research questions we distributed two anonymous surveys to understand the experiences of software developers during the pandemic, their prevalence, and the effect on their work.

### 3.1 Survey 1: Washington State (1,369 responses)

Our first survey was designed to understand the types of experiences software developers were having during the pandemic. In this survey, we included a closed-answer question on how productivity has changed with a five-point scale for the responses. Through a following open-ended question, participants were asked to explain their response.

- Compared to working in office, **how has your productivity changed?** (Q13) <sup>2</sup>  
(*significantly less productive / less productive / about the same / more productive / significantly more productive*)
- Please share details about your answer to the previous question on how your productivity has changed. (Q14)

Although there has been previous research to understand which factors affect developer productivity (as discussed above), we anticipated that different benefits and challenges may be more relevant in this period of unexpected and mass transition to working from home for an entire organization. Therefore, the first survey was mainly exploratory to investigate if new factors did emerge through several open ended questions as follows:

- What is **good** about working from home? (Q15)
- What is **bad** about working from home? (Q16)
- What **challenges** have you encountered working from home? (Q17)
- What could be **improved** about how we do work from home at Microsoft? (Q22)

In addition, the survey included questions about Internet connectivity, interruptions and distractions, work times, meetings, and commute. The full survey is available as supplemental material [32].

*Survey Distribution.* This survey was distributed to Microsoft employees in King County during the week of March 16, 2020 (approximately two weeks after the advice to work from home). Each day the survey was sent to randomly selected 1,000 employees in King County, for a total of 5,000 employees (3,500 developers, 1,500 program managers). We received 1,369 responses for a response rate of 27% (comparable to the response rates of many other software engineering surveys [33, 34]). To encourage participation, survey respondents could enter a raffle of multiple \$100 Amazon.com gift certificates. No reminder emails were sent.

*Data Analysis.* For the open-ended responses to this first survey, we used an open-coding approach, iterating and refining through multiple rounds of independent coding of an initial sample of responses. We coded all of the open-ended questions listed above, and across multiple questions codes for positive aspects of working from home (benefits, RQ2), negative aspects of working from home (challenges, RQ3) and improvements (RQ4) emerged.

After several iterations coding and discussing codes, we finalized a unified coding scheme with codes, code definitions and code categories (see Appendix A). We applied these finalized codes to a random selection of 400 responses (see Table 8). No new codes emerged during this process. To

<sup>2</sup>Q13 indicates the question numbers in our survey instrument



improve the reliability of our codes, an external researcher used our coding scheme to code a subset of our sample (100) showing an agreement of 81.9%.

The final coding scheme contained 32 codes organized into the following six themes. (The complete list of codes and descriptions can be found in Appendix A.)

- *Beyond work* – effects of work from home on non-work aspects of respondents life such as proximity to family, distribution of finances, and access to food.
- *Collaboration* – Aspects of collaborative tasks of respondents including challenges being creative with others, being blocked waiting on others, and a range of interactions with co-workers.
- *Communication* – Work related communication including channels used, frequency, duration, planned versus ad-hoc, and the result of missing communication.
- *Well-being* – Responses related to the welfare of respondents, including changes to flexibility of schedule and location and the effects of working from home on health (physical, mental, and emotional) and personal comfort.
- *Work* – Responses related to a direct effect on respondents’ technical work output. This included codes related to productivity, motivation, and factors affecting focus and distraction.
- *Work environment* – Aspects of the setting in which the respondents accomplish their work when working from home including the existence or lack of reliable internet connectivity, ergonomically-sound furniture, satisfactory hardware, and dedicated space.

Note that some responses were coded with multiple codes when participants raised multiple points. For example, the following response was assigned multiple codes:

1. Avoiding commute, hence more productive, save on fuel (environment friendly).  
2. Comfort of home (Take a nap of about 20 mins in the noon which powers up my rest of the day work) 3. Avoid time spent in getting ready to office (10-20 mins per day) (P1269)

CommuteEcologicalImpactPersonalComfortBreak

We show the frequency of the main codes from the 400 responses in Table 8 in the Appendix, however, these counts do not represent an accurate description of which benefits or challenges may be more important, and which ones may affect productivity more or less as these are open-ended questions.<sup>3</sup>

3.2 Survey 2: United States (2,265 responses)

To investigate the importance and frequency of the reported benefits and challenges from the first survey and their association with self reported productivity, we designed and deployed a second survey. Rather than open-ended questions we included closed answer questions for the factors that emerged from our coding of the first survey. These closed questions asked about benefits and how important those benefits were to the respondent, as well as challenges and the impact of those challenges. In addition, this second survey inquired about additional benefits and challenges.<sup>4</sup>

<sup>3</sup>Quantifying inherently qualitative data such as responses to open-ended questions carries some limitations. For example, when the Pew Research Center asked about the single issue that mattered most in deciding how participants voted for president, 35% responded the economy in an open-ended question; however, when the economy was explicitly offered in a multiple choice question, 58%, more than half, chose the economy. <https://www.pewresearch.org/methods/u-s-survey-research/questionnaire-design/>

<sup>4</sup>If a question was identical between Survey 1 and Survey 2, we use the same question number (e.g., Q13). For a closed answer question in Survey 2 that was based on an open-ended question in Survey 1, we append an asterisk (\*) to the question number (e.g., Q15\* is based on Q15).

- Compared to working in office, **how has your productivity changed?** (Q13)  
(*significantly less productive / less productive / about the same / more productive / significantly more productive*)
- What **benefits** have you experienced working from home and how **important** are these benefits? (Q15\*)  
(*I don't experience this benefit / I experience this benefit but it's \*not\* important to me / I experience this benefit and it's \*important\* to me / I experience this benefit and it's \*very important\* to me*)
- What work-related **challenges** have you experienced working from home and how **impactful** are these challenges? (Q17\*)  
(*I don't experience this challenge / I experience this challenge but it's a \*minor issue\* for me / I experience this challenge and it's a \*major issue\* for me*)
- What could be improved about working from home (WFH)? Choose up to three (3) items. (Q22\*)

As items for the questions, we identified a list of 15 benefits (B1..B15), 20 challenges (C1..C20), and 12 improvements/suggestions (S1..S12) based on the thematic analysis of the responses to Survey 1. The items were displayed in random order within a question. The full survey is available as supplemental material [32].

*Survey Distribution.* This survey was distributed to 9,000 engineers (consisting of developers, program managers and data scientists) across the entire US over a period of three weeks (a different sample of 3,000 employees was selected for each week). There was no overlap between the samples in Survey 1 and Survey 2. We received 2,265 responses for a response rate of 25% (comparable to the response rates of many other software engineering surveys [33, 34]). To encourage participation, survey respondents could enter a raffle of multiple \$100 Amazon.com gift certificates. No reminder emails were sent.

Collecting data across three weeks, and using the same question as in the first survey, allowed us to compare the answer to the closed question about change in productivity so that we may be able to detect if there were any significant changes in productivity (RQ1) as people adapted to or found it harder to working from home over time.

*Data Analysis.* For the quantitative data in the second survey, we present descriptive statistics about the selected benefits and their importance, and the challenges and their impact.

We also considered the association of the benefits (Q15\*), challenges (Q17\*), and suggested improvements (Q22\*) with the reported changes in productivity (Q13). We used Wilcoxon Mann Whitney and Fisher Exact Value tests [35] to check for statistically significant differences. To reduce false discoveries due to multiple hypothesis testing, p-values were adjusted with the Benjamini Hochberg correction [36].

To identify benefits and challenges that are most strongly related to productivity and analyze whether there are important interactions between them, we use a *least absolute shrinkage and selection operator (Lasso)* analysis [37]. We ran two analyses: for benefits (Q15\*) and for challenges (Q17\*). In both analyses, the dependent variable was whether a participant reported that productivity stayed the same or (significantly) increased. We include as potential explanatory variables direct effects and interactions for whether a respondent reported each benefit as important or very important (for the analysis of Q15\*) or each challenge as a major issue (for Q17\*). The Lasso approach selects the most important variables by running a least-squares regression while penalizing the absolute value of the coefficients. Therefore, a variable is only included if it explains enough of the variation in the dependent variable. As a standard practice, we use the maximum lambda (penalty parameter) that gets a mean cross-validation error within one standard error of the minimum. After



the Lasso analysis, we run a standard linear regression with the selected variables to get coefficients that are not shrunk by the penalty procedure.

### 3.3 Limitations

We describe the threats to validity and limitations of our study.

*External validity.* Single-case empirical studies have historically been shown to contribute to scientific discovery [38] and delivered insights in the social sciences [39, pp. 95]. The company we studied employs tens of thousands of software engineers that work on diverse products across many domains (operating systems, databases, cloud software, software tools, to productivity software) and use many tools and diverse processes. By studying a single company we were able to control for many factors that otherwise may influence the employee experience during the pandemic such as the region and the company’s response to COVID-19. We do not claim that our results are representative of the views of all software engineers and companies in general.

It is important to keep in mind that remote work during a pandemic is not the same as regular remote work. While some findings will be specific to the pandemic (e.g., lack of childcare as a challenge because schools and day cares were closed), not all findings are specific to the pandemic. We discuss implications of our work for the future of remote work in Section 8.3.

As with any survey, there may have been non-response bias, i.e., the results might not be representative of the population because the participants disproportionately possess certain traits which affect the outcome. In addition, our survey was advertised as a “Work From Home Survey” and therefore could have been subject to self-selection bias, e.g., participants might have been more likely to participate in the survey if they were more strongly affected by work from home (negatively or positively). To reduce non-response and self-selection bias, we kept the surveys as short as possible, were transparent about the survey length (single-page survey), provided an incentive to participate (raffle), and kept the surveys anonymous.

*Construct validity.* Although we could have used existing surveys that inquire about developer productivity and their experience working from home (see Section 2), we recognized from early reports that new factors specific to the pandemic were playing a bigger role in developer productivity and experience (such as not having child care and stress of the pandemic). Nothing like this has happened before and so we used an initial open ended survey to study the factors emerging during this phenomenon and conducted a second survey to quantify the change in productivity and frequency/impact of challenges/benefits encountered.

Measuring perceived productivity with a single question has limitations. We chose single response items to keep the survey length reasonable because shorter questionnaires have been found to receive higher response rates [40]. Self-rated, single-item response items for productivity have also been found to correlate with objective productivity measures for software engineers [27].

*Internal Validity.* There are additional biases from our survey. Respondents may have shared what they wanted management to hear (in particular in terms of suggested improvements but also for benefits and challenges) and the wording of our questions may have led to certain responses. Furthermore, our analysis may have been biased by our own experiences (as we were also working from home). We tried to offset these somewhat by having additional coders and having experts review our survey.

Finally, our study involves a single research method (a survey). However, we tried to offset this limitation by considering the findings from other ongoing studies at the company using different methods (including objective quantitative analysis of system data).

Table 1. Changes in self-reported productivity based on the responses to the question “*Compared to working in office, how has your productivity changed?*” (Q13, Q13’) The responses to Survey 2 are further broken down by week: April 22–25 (W1), April 26–May 2 (W2), and May 3–9 (W3).

	Survey 1	Survey 2	W1	W2	W3
Significantly more productive	■ 8%	■ 11%	13%	10%	10%
More productive	■ 22%	■ 26%	23%	28%	26%
About the same	■ 32%	■ 32%	31%	30%	34%
Less productive	■ 32%	■ 26%	26%	26%	24%
Significantly less productive	■ 6%	■ 6%	7%	6%	6%

4 CHANGE IN PRODUCTIVITY

In this section we address the research question “How has engineers’ self-reported productivity changed since WFH?” (RQ1). In both surveys, we asked participants how their productivity has changed compared to working in office. The results are shown in Table 1.

- In both surveys, the majority of participants reported that their productivity has not changed or has even improved (62%-68%). However, a substantial portion of participants (32%-38%) reported that they are less productive
- The percentage of people reporting to be less productive consistently dropped over the study period: from 38% in Survey 1 to 30% in the last week of Survey 2. This suggests that some (but not all) people found ways to restore their productivity to the original levels.

Ralph et al. [41] found evidence that developers have lower perceived productivity while working from home during the COVID-19 pandemic. Our findings also support this result but offer a more nuanced view: initially in Survey 1, more people reported lower productivity (38%) than higher productivity (30%); however, this later changed in Survey 2, when more people reported higher productivity (36%) than lower productivity (30%). Similar observations have been made by Forsgren [42] and Bao et al. [43]. We will discuss these paper in more detail in the related work (Section 9).

It is important to recognize that at an *individual* level, people are affected differently by work from home: productivity can decrease, stay the same, or improve depending on a variety of challenges and benefits. In the next two sections, we discuss the higher level themes in terms of the challenges and benefits experienced that emerge from our qualitative analysis of additional survey questions.

5 BENEFITS

In this section we address the research question “*What are the benefits engineers experience when working from home? How have these benefits affected productivity since WFH?*” (RQ2). To identify the benefits, we analyzed the responses to the open-ended questions in Survey 1 and to quantify the association with productivity we used the responses to Survey 2.

5.1 Survey 1: Benefits Experienced Working from Home

Respondent identified a wide range of benefits and many respondents identified multiple benefits working from home. In this section, we discuss themes that were frequently mentioned in Survey 1 or later emerged as significant in the productivity analysis based on Survey 2.

**Commute.** Most respondents pointed out benefits related to their well-being. In particular, over half of the participants mentioned the lack of commute as a positive aspect of working from home.

☛ *No commute worries. I can focus on my job instead of checking the traffic reports and worrying.* (P908)

On average, respondents reported a daily, round trip commute of 67 minutes (median 60 minutes), which is comparable to other people living in the Puget Sound area [44]. In extreme cases, respondents mentioned a daily commute of more than four hours. *"I love saving the 14-18hrs/week of commuting and being home when my daughter gets home from school."* (P791)

The time saved on commute led to a wide range of other benefits. It allowed respondents to work more (**Work hours**) but also spend time with their families (**Family, children, pets**) and focus on healthy activities such as physical exercise and more sleep (**Healthy habits**).

☛ *More time with Kids due to reduced commute times. Can workout more when the sun is out.* (P48)

☛ *Removes the stress of a 30 minute commute to work and saves that wasted time for either more sleep or more work. Let's me sleep in a bit and work in a more rested state than if I got up earlier due to the commute.* (P1127)

☛ *My health has improved. I am getting more sleep and rest, since there is no commute involved. I can work at my own pace, in a more comfortable environment (my home).* (P529)

**Schedule flexibility.** Another frequently mentioned benefit was schedule flexibility. Working from home allowed respondents to plan their day more freely and work at different times than they did before. Activities that required respondents to be physically present at home at certain times were easier to do, for example, accepting deliveries, laundry, or physical exercise.

☛ *I can dictate my own schedule, take breaks when I want to, prioritize self-care throughout the day (running errands, taking a quick nap, exercising, calling family + friends)* (P267)

☛ *Working from home gives me more flexibility to do things when I take 10 minutes break twice a day. I can finish up loading the laundry or dishwasher, I can lie down to straighten up my back if I wish without compromising the productivity.* (P833)

☛ *I can sometimes take a break and do some chores that are often more difficult to do later in the day (e.g. laundry, where all the machines are usually being used in my building).* (P445)

The flexibility in schedule often led to seamless integration of work and life, where participants completed chores while waiting for builds or during short work breaks.

☛ *Sometimes an idea clicks in the middle of the night, and with wfh, implementing that idea is literally 2 seconds away* (P593)

☛ *Being able to quickly task switch for other non-work related tasks and quickly return to work.* (P289)

☛ *I feel like I can solve problems more easily since I don't feel constrained by a clock. I can start a job and cook dinner, then come back to check the job results while I leave something in the oven or when I'm done cooking.* (P215)

**Focus and Interruptions and Distractions** were the second and third most frequent codes. Fewer distractions and interruptions at home made it easier for respondents to concentrate and focus for longer periods of time. Having fewer meetings, the ability to continue work during remote meetings, a quiet work environment, and more control over interruptions further contributed *"Undistracted focus time."* (P1263) of the respondents.

☛ *I get interrupted less and am able to focus on tasks more without distraction.* (P161)

☛ *More focus time, ability to go heads down without distractions of being in an open office constantly or needing to move focus rooms every hour if I am working on something that requires prolonged quiet time. (P1194)*

☛ *Less distraction from others, especially coming from an open office scenario. Teams meetings for some meetings where very little participation is required lets you continue to work while “attending” and listening in, which is better than being idle in a conference room. (P691)*

☛ *There were plenty of distractions at work too with my office set up. So obviously colleagues interrupting me is easier to manage now as you have to answer the teams chat or email or phone call vs. someone just coming into your office or dragging you to a meeting. It feels more in my control now. (P223)*

**Work Environment.** Several respondents pointed out that they preferred their environment at home compared to office, for example, because the environment is more quiet, more spacious, has a window, more sunlight, or closer bathrooms. Respondents also liked having more privacy and more control at home, for example, over the room temperature or decorations, which is more difficult in shared environment.

☛ *I enjoy the relaxing nature of being in the comfort of my own home. I like being able to use my nice chair at home, and other nice comforts my home can offer. [...] My wife is the only other person here, and she respects my zone while I’m working and gives me a nice quiet environment. (P617)*

☛ *The environment is much nicer. It is quiet with few distraction than my normal open office. I also have a window which gives me natural light and a nature view neither of which are present in my open office. This helps improve my mood and makes me more productive. (P1203)*

☛ *My apartment is much less dreary than the office. Visuals and decorations are not just about “looking cool”, but have a deep effect on how well/fast/creatively/how long I can think. In contrast the office has mostly blank white walls, no windows, and every hallway in the building is identical. Just being in the monotony of that environment is mentally draining, which drops my productivity. (P146)*

☛ *I work in an open floor area and had to always be careful what was on my screens that others shouldn’t see, no concerns now with that. (P333)*

Participants also enjoyed the ability to wear comfortable clothes, listen to loud music, and work on their own pace (**Personal comfort**) in their their home work environments.








☛ *I’m in the comfort of my own home (I can wear lounge clothing, play music, etc). (P325)*













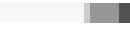
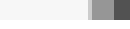

☛ *No need makeup, suitable dress, and few unnecessary social except meeting. Saving time. Not worry about if anyone will look at me when the moment don’t want to be looked. More concentrate on work. (P371)*

☛ *I feel more comfortable and have more privacy. I feel less pressured to do work and get to work on my own pace. (P442)*

**Family, Children, and Pets.** Respondents liked being close to their families, children, and pets. They appreciated being able to see them during breaks or lunch and that they can take care of family needs when needed.

☛ *Being at home with family, especially with a toddler and baby. I get to spend a bit of time each day every few hours to just say hi and be around them, even if just for a few brief minutes. (P79)*

Table 2. Benefits in Survey 2. The column *Distribution* refers to the distribution of responses that (from left to right) do not experience a benefit (light gray , experience a benefit and consider the benefit as unimportant (gray , important (dark gray ) or very important (darker gray ). The column *Prevalence* indicates the percentage of respondents who experienced the benefit (  ) while the column *Importance* describes the percentage of participants who indicated this benefit to be important or very important ( percentage of  with respect to  ). The column *Delta* reports the difference in the average productivity change when a benefit was experienced vs. when it was not; statistically significant differences ( $p < .01$ , with Benjamini-Hochberg correction [36]) are indicated with an asterisk (\*). To compute the *Delta* column, a response “significantly less productive” was coded as -2, “less productive” as -1, “about the same” as 0, “more productive” as +1, and “significantly more productive” as +2. The benefits are sorted and numbered in descending order by column *Prevalence*.

	Benefit	Distribution	Prevalence	Importance	Delta
B1	Less time on commute		96	82	0.31
B2	Spending less money		84	66	0.42 (*)
B3	Flexible work hours		81	82	0.40 (*)
B4	Closer to family		81	85	0.34 (*)
B5	More comfortable clothing		80	48	0.37 (*)
B6	Reduced health risks		72	88	0.24 (*)
B7	Better focus time		62	93	1.15 (*)
B8	Less distractions or interruptions		55	87	1.03 (*)
B9	More time to complete work		52	80	0.78 (*)
B10	More breaks		52	64	0.02
B11	Better work life balance		50	95	0.59 (*)
B12	Better work environment		48	81	1.06 (*)
B13	More efficient meetings		46	87	0.59 (*)
B14	More control over work		37	87	0.68 (*)
B15	More physical activity		34	91	0.54 (*)

☞ *Work breaks are fulfilling if you have family members around. (P1265)*

**Money.** Several participants pointed out that working from home saves them money because of no commute and eating home-made food.

☞ *I save money on food because I’m eating more out of the refrigerator than spending money on lunch every day. (P221)*

☞ *No wasted time & money on commute. (P72)*

## 5.2 Survey 2: Relation between Benefits and Productivity

From the themes that emerged in Survey 1, we inferred a list of 15 characteristic benefits (B1..B15) that we included in Survey 2. The results are displayed in Table 2. The benefits are sorted and numbered in descending order of frequency.

*Frequency and importance of benefits.* We make the following observations from Table 2 about how the prevalence and importance of benefits:

- The *Prevalence* column shows the frequency of the benefits. The most frequently reported benefits (B1-B5) were *less time on commute* (96%), *spending less money* (84%), *flexible work hours* (81%), *closer to family* (81%), and *more comfortable clothing* (80%).

Table 3. Results from the Lasso regression analysis. The dependent variable was whether a participant reported that productivity stayed the same or increased. The explanatory variables are the direct effects and interactions for experienced benefits that were considered as important or very important.

Benefit	Coeff.	Std. Error
Constant (Intercept)	0.393***	(0.014)
Better focus time (B7)	0.223***	(0.023)
Less distractions or interruptions (B8)	0.147***	(0.023)
Better work environment (B12)	0.051	(0.056)
Less time on commute (B1) <i>and</i> Better work environment (B12)	0.101*	(0.057)
Less time on commute (B1) <i>and</i> More time to complete work (B9)	0.096***	(0.021)
Observations	2,104	
R <sup>2</sup>	0.260	
Adjusted R <sup>2</sup>	0.258	
Note: *p<0.1; **p<0.05; ***p<0.01		

- The *Importance* column shows the percentage of participants who indicated a benefit to be important or very important if they experienced it. Almost all benefits were rated as important by most participants who experienced a benefit. The benefits rated most frequently as important were *better work life balance* (95%, B11), *better focus time* (93%, B7), and *more physical activity* (91%, B15). The benefits rated less frequently as important were *more comfortable clothing* (48%, B5), *more breaks* (64%, B10), and *spending less money* (66%, B2).

*Relation between benefits and productivity.* Table 2 shows in the *Delta* column the difference in productivity change (with -2 for “significantly less productive” to +2 for “significantly more productive”) when a benefit was experienced vs. when it was not. We make the following observations:

- All benefits had a positive delta on productivity change. This means that respondents who experienced a benefit, on average also reported being more productive when working from home. The delta was small for the benefit *more breaks* (+0.02, B10).
- Not all benefits had a statistically significant productivity delta: there was no statistical difference in productivity change for the benefits *less time on commute* (B1) and *more breaks* (B10).
- The benefits with the highest productivity delta were *better focus time* (+1.15, B7), *better work environment* (+1.06, B12), *less distractions or interruptions* (+1.03, B8). All of these have been found to be significant predictors of productivity in the past [2, 24, 26, 27].

*Lasso analysis.* We ran a Lasso analysis to see which benefits were most strongly associated with productivity change in a combined model and to check whether interactions between the benefits matter. The regression results with the Lasso-selected variables, shown in Table 3, are similar to the pairwise relationships. The likelihood that people’s productivity stayed the same or improved was increased by the benefits of *better focus time* (+22.3%) and *less distractions or interruptions* (+14.7%). The coefficient for *better work environment* at home was not statistically significant, however, the interaction between *better work environment* and *less time spent on commute* (+10.1%) was marginally significant. People who reported benefiting from both *less time spent on commute* and *more time to complete their work* were also more likely to report that their productivity remains the same or increased (+9.6%).



## 6 CHALLENGES

In this section we address the research question “*What are the challenges engineers face when working from home? How have these challenges affected productivity since WFH?*” (RQ3). To identify the challenges, we analyzed the responses to the open-ended questions in Survey 1 and to quantify the association with productivity we used the responses to Survey 2.

### 6.1 Survey 1: Challenges Experienced Working from Home

The survey respondents shared a wide range of challenges and many respondents indicated they experienced multiple challenges working from home. In this section, we discuss challenges that were frequently mentioned in Survey 1 or later emerged as significant in the productivity analysis based on Survey 2.

**Connectivity.** Of all the challenges, problems with connectivity was the most frequent challenge shared. This included access to remote desktops, special access work stations, and internet bandwidth. Respondents mentioned they experienced slow connections due to a high number of users on their internet connections:

☛ *Periodic internet disruption due to wi-fi router and modem resetting due to 2 VPN connections for my wife & I, and our kids being online for school work. (P1013)*

Internet connectivity speed went beyond one’s home internet and became a challenge when a colleagues’ internet connection was not as resilient.

☛ *Remote desktop connectivity issues. Coworkers with spotty internet quality are hard to meet with. (P691)*

Respondents also described work-a-rounds they used to rectify their connectivity issues:

☛ *The VPN / Remote tools are not great, crashes often. I especially dont want to Intune my personal device, so working remotely have been challenging with the redmonds gateway down more than 50% of the time, and the WVD features crashing / disconnecting / not allowing correct alt-tab etc. (P37)*

Although many have attempted to find resolutions, at times the connectivity issues they experienced felt like it was something out of their control.

**Family, Children, Pets.** One of the most frequent challenges respondents shared was with proximity to family life. Being physically co-located with family members, housemates, children, or pets encouraged some to change their work habits:

☛ *Staying focused, especially with young kids around. Normally I would only work from home for a few hours occasionally after the kids went to bed. That is the only time I currently feel like I can be productive. (P531)*

The additional interactions with family have even to be more mindful of supporting family “child care schedules”(267). Respondents also mentioned how there was an implicit expectation of being engaged that often felt at odds with work:

☛ *Family in the house means there is also expectations from them to spend time or help around. (P338)*

The challenge of being physically present with family, but mentally focused on other tasks is an experience that was hard to resolve.

**Communication Channels.** Another frequent challenge that respondents reported having was with the channels they use to communicate with their team members. One issue with communication channels was increased friction to get a hold of a colleague in comparison to simply walking over to their office:

☛ *The hardest thing has been that standard communications/questions and general collaboration take about 2-3 times as long. Something I could just pop over to someone's office to ask now requires an online chat or an email and the response is much slower.* (P267)

Likewise, there is also, for some a higher frequency of using instant messages which made some participants feel like they should be highly responsive at all times:

☛ *I also feel like there is no "down time" away from work. I constantly get emails/messages/asks and sometime I have to respond right away.* (P384)

Managing multiple communication channels and the expectation to be very responsive on many of these channels presents an additional layer of interactions that does not adapt to every respondents working style.

**Work Environment.** During the pandemic, most respondents work environments were their homes, however the experience drew comparable challenges with in-office work settings.

☛ *Tuning out distractions (which is a similar problem I've faced working in Open Spaces), finding the space to set up my home workspace.* (P1233)

Many respondents were also not prepared to work from home and have improvised their work settings:

☛ *I did not own a desk and chair so currently improvising with dining table. Not sure if I want to invest in or have space for expensive home office equipment. I miss having multiple screens but do not have space at home to set up.* (P930)

As respondents missed their work office settings, they found themselves under new constraints ranging from financial to square footage when trying to create a comparable home office setting.

**Interruptions and Distractions.** When software developers are working in office, interruptions and distractions often came from colleagues stopping by their desk. In a remote work setting, respondents described the advantage and disadvantage of only being available online:

☛ *Interruptions and concentration as I can [only] be reached on Teams and by email vs someone walking over for a question. Harder to keep tabs on direct reports.* (P333)

However, in this special remote work environment, a new set of distractions emerged from people they live with (e.g., spouse, children, etc): "Constant distractions especially from kids who are bored at home" (P552). For some respondents, this created a similarly distracting environment they had to manage in open office settings:

☛ *Tuning out distractions (which is a similar problem I've faced working in Open Spaces), finding the space to set up my home workspace.* (P1233)

**Healthy Habits.** When respondents described challenges with reduced physical activity, they often mentioned their movements between physical meeting locations which no longer happen: "Sitting for a long time is hard on the body. At work, I'm up and around, moving more. At home all meetings are online so I never (hardly) move...." (P72). When respondents did find an opportunity to move, it was either only to the restroom or for more coffee so that they can sit down for longer periods of time:

☛ *Since I don't do my daily bike ride I sometimes feel I just sit the whole day, and only do very few steps to the toilet [and] coffee machine* (P867)

The reduction in what participants referred to as healthy habits also affect their work-life routines.

**Work-life Balance and Routine.** Respondents described their work-life boundaries blurring outside of the typical 8 hr work day and late into the evenings: "Unless I impose a strict regimen, I

Table 4. Challenges in Survey 2. The column *Distribution* shows the distribution of responses that do not experience a challenge (light gray ■), experience this challenge as a minor issue (gray ■), and experience this challenge as a major issue (dark gray ■). The following column *Prevalence* indicates the percentage of respondents that experienced the challenge (■), while the column *Impact* describes the percentage of participants that indicated this challenge presented a major issue (percentage of ■ with respect to ■). The column *Delta* reports the difference in the average productivity change when a challenge was experienced vs. when it was not; statistically significant differences ( $p < .01$ , with Benjamini-Hochberg correction [36]) are indicated with an asterisk (\*). To compute the *Delta* column, a response “significantly less productive” was coded as -2, “less productive” as -1, “about the same” as 0, “more productive” as +1, and “significantly more productive” as +2. The challenges are sorted and numbered in descending order by column *Prevalence*.

Challenge	Distribution	Prevalence	Impact	Delta
C1 Missing social interactions		83	49	-0.62 (*)
C2 Lack of work-life boundary		78	48	-0.52 (*)
C3 Poor ergonomics		70	52	-0.47 (*)
C4 Less awareness of colleagues work		65	36	-0.65 (*)
C5 Less physical activity		65	51	-0.40 (*)
C6 Difficult to communicate with colleagues		57	34	-0.67 (*)
C7 Insufficient hardware		57	40	-0.38 (*)
C8 Connectivity problems		54	35	-0.38 (*)
C9 Poor work life balance		51	45	-0.45 (*)
C10 Too many meetings		51	43	-0.09
C11 More distractions or interruptions		49	37	-0.99 (*)
C12 Lack of a routine		47	38	-0.67 (*)
C13 Fewer breaks		44	35	-0.09
C14 Friction with collaboration tools		44	22	-0.38 (*)
C15 Lack of motivation		42	36	-0.90 (*)
C16 Blocked waiting on others		40	28	-0.39 (*)
C17 Poor home work environment		40	34	-0.84 (*)
C18 Lack of dining options		33	24	-0.34 (*)
C19 Lack of childcare		27	58	-0.37 (*)
C20 Less time to complete work		24	36	-0.72 (*)

*feel like I am working for a lot more hours sometimes way into the night - the line between home and work gets far more blurry.” (P104)*

Respondents also reflected on routines they previously had to distinguish boundaries that are now lost:

☛ *To find my time boundaries. Very easily you can end up working much more hours because you don’t have the signals of “Time to leave the desk”, you don’t have the time to decompress your mind in traffic, for example. You just jump from personal to work tasks (and vice-versa) so fast. (P195)*

In summary, the lost transition time and lack of physical movement between work and home removed a boundary they had before.

In the next subsection of our paper, we report on the association of these challenge with the Survey 2 respondents’ productivity.

Table 5. Results from the Lasso regression analysis. The dependent variable was whether a participant reported that productivity stayed the same or increased. The explanatory variables are the direct effects and interactions for major challenges.

Challenge	Coeff.	Std. Error
Constant (Intercept)	0.886***	(0.012)
More distractions or interruptions (C11)	-0.358***	(0.026)
Lack of motivation (C15)	-0.214***	(0.026)
Difficult to communicate with colleagues (C6)	-0.110***	(0.025)
Missing social interactions (C1)	-0.086***	(0.019)
Connectivity problems (C8)	-0.082***	(0.023)
Less awareness of colleagues work (C4)	-0.050**	(0.023)
Less time to complete work (C20)	-0.070	(0.043)
Lack of childcare (C19) and Less time to complete work (C20)	-0.187***	(0.059)
Observations	2,106	
R <sup>2</sup>	0.294	
Adjusted R <sup>2</sup>	0.291	
Note: *p<0.1; **p<0.05; ***p<0.01		

## 6.2 Survey 2: Relation between Challenges and Productivity

From the themes that emerged in Survey 1, we inferred a list of 20 characteristic challenges (C1..C20) that we included in Survey 2. The results are displayed in Table 4. The challenges are sorted and numbered in descending order of frequency.

*Frequency and impact of challenges.* We make the following observations from Table 4 about how the prevalence and impact of challenges:

- The Prevalence column shows the frequency of the challenges. The most frequently reported challenges (C1-C5) were *missing social interactions* (83%), *lack of work-life boundaries* (78%), *poor ergonomics* (70%), *less awareness of colleagues work* (65%), and *less physical activity* (65%).
- The Impact column shows the percentage of participants that indicated a challenge to be a major issue if they experienced it. The challenges rated most frequently as impactful are *lack of childcare* (58%, C16), *poor ergonomics* (52%, C3), and *less physical activity* (51%, C5). The challenges reported less frequently as a major issue are *friction with collaboration tools* (22%, C14), *lack of dining options* (24%, C18), and being *blocked waiting on others* (28%, C16).

*Relationships between challenges and productivity.* Table 4 shows in the *Delta* column the difference in productivity change (with -2 for “significantly less productive” to +2 for “significantly more productive”) when a challenge was experienced vs. when it was not. We make the following observations:

- We found that all of the challenges were associated with lower productivity. For all but two out of the 20 challenges, the difference was statistically significant.
- The challenges with the largest reduction in productivity are having *more distractions and interruptions* (-0.99, C11), *lack of motivation* (-0.90, C15), *poor home work environment* (-0.84, C17), *less time to complete work* (-0.72, C20), *difficulty communicating with colleagues* (-0.67, C6), and the *lack of a routine* (-0.67, C12).

*Lasso analysis.* The previous analysis shows the relationship between individual challenges and change in productivity, but does not take into account the presence of multiple challenges and the interaction of two challenges, which can be particularly important for productivity. Therefore, we ran a Lasso analysis to see which challenges were most strongly associated with productivity change in a combined model and to check whether interactions between the challenges matter.

Table 5 shows the linear regression results for the Lasso-selected variables. People are substantially less likely to report that their productivity is the same or increased when they say that having *more distractions and interruptions* (−35.8%) or *lack of motivation* (−21.4%) were major issues; *difficulty communicating with colleagues* (−11.0%), *missing social interactions* (−8.6%), *connectivity problems* (−8.2%) and *less awareness of colleagues' work* (−5.0%) were also associated with a significantly lower probability of reporting unchanged or increased productivity.

The challenge *less time spent to complete work* was also selected by the Lasso algorithm, though the coefficient is not significant; however, when combined with a *lack of childcare*, the challenge is associated with a substantial and significant lower probability (−18.7%) of reporting unchanged or increased productivity.

## 7 IMPROVEMENTS

In this section we address the research question “*What recommendations should be made to companies whose engineers may wish to work from home?*” (RQ4). To identify these improvements, we first analyzed the open-ended questions in Survey 1 and to identify the most-requested improvements we used the responses to a closed question in Survey 2.

### 7.1 Survey 1: Improvements to the Work from Home experience

Respondents included several improvements that could be made to support their work from home experience. We briefly describe the most frequently mentioned improvements below. Survey 1 was sent within the first two weeks of employees working from home. Microsoft implemented many improvements throughout the pandemic to provide a better work from home experience to its employees, for example, employees facing school closures due to the pandemic were offered up to three months of paid parental leave [45] as well as resources and activities to support physical, emotional and financial well-being of employees.

**Hardware.** Although many respondents noted they were able to bring some equipment home or purchased some additional devices, the most frequent possible improvement noted by respondents in the first survey was related to hardware. Insufficient hardware was also noted as a key challenge as discussed (Section 6) and was mentioned by Ralph et al. in the Pandemic Programming study [41].

💬 *I think that this is a reminder that when employing individuals that need certain equipment both at an office and at home, that we come up with a way to fully equip both locations simultaneously. (P994)*

Many employees work with multiple monitors, and sometimes multiple machines. In contrast, when working from home, employees are sometimes limited to just a laptop or a desktop with a single monitor. Large and/or multiple monitor setups have been found to improve productivity in information workers [46]. Indeed, the most frequently requested type of hardware we noted in the second survey was either larger or more monitors. Developers also asked for more powerful workstations (especially those working on laptops at home) as well as peripherals such as mice, keyboards, and noise-cancellation headphones.

💬 *Employees should be provided with equipment to make the experience better for everyone: webcams, good noise-cancelling headsets, etc. (P1174)*

Employees were allowed to take any non-confidential property off campus to use at home after informing their manager.

**Connectivity.** Another frequently requested improvement was better Internet connectivity or improved VPN access from home, and many that mentioned this as an improvement in Survey 1 added that it was their biggest challenge to address: (*“Network connectivity is the biggest pain”* (P44). Some respondents indicated that ensuring good connectivity at home was expensive. Paying for upgraded home internet connectivity was also a key recommendation from the Pandemic Programming study [41].

☞ *Perhaps subsidize higher speed internet connections, or speak with the broadband providers to get better service in our areas. With multiple people at home, there’s only so much bandwidth to be shared.* (P79)

**Stipend/Budget for home office.** The third most frequently selected item was to have a stipend to purchase equipment for a home office, with just slightly more engineers requesting this as an improvement if they experienced lower productivity. Several tech companies, including Microsoft, have been offering such a stipend to their employees [47–49].

☞ *Provide employees a one time reasonable allowance to set up a home office such as sit/stand desk, ergonomic chair, allowance for monitors, budget for coffee/drinks/snacks.* (P86)

**Improvements to communication tools.** Once working from home, engineers were totally reliant on communication tools to collaborate with their colleagues and for meetings. Many noted specific improvements, including some that were engineering specific:

☞ *Support whiteboard drawing, support multi desktop sharing from multiple people and sharing on split windows or on my local multiple screens.* (P1277)

☞ *Add a bunch of developer specific features. A simple example is how do you go around the room in standup and know that everyone got to talk.* (P885)

**Provide more ergonomic furniture.** Many participants noted in the first survey that their furniture at home was not as ergonomic as their furniture at work (e.g., no standup desk, small desk space, less ergonomic keyboards etc.). To better support employees, Microsoft provides recommendations on how to setup physical workspaces in an ergonomic way and some stipends for the workspace.

Not being able to exercise as much was also an issue, as this respondent mentioned:

☞ *I also don’t have the ability to stand up and work since my home desk doesn’t move. This means that I’m sitting down even more every day, which also leads to back and neck pain and frustration.* (P1048)

A couple of respondents in our sample suggested treadmill desks as a possible improvement for WFH to address less of exercise.

For some respondents working from home goes beyond furniture, as one respondent noted:

☞ *If I am going to continue work from home, I need a new house/space from which I can work w/fewer distractions.* (P1224)

**Support for remote work post-pandemic.** In the first survey, many suggested that full or partial remote work should be supported after the pandemic and that they appreciated the opportunity to work from home and experienced a variety of benefits (as discussed in Section 5). In particular, several mentioned that working at home, at least some of the time, would help them be more productive:



☞ *Allow more people to do this long-term after this current crisis ends; I feel I'm more productive for it, I'm contributing better to my team, and keeping more people home will help us meet our sustainability and environmental goals as a company.* (P1297)

Some provided concrete suggestions for supporting WFH long-term:

☞ *Every team should treat their tech stack as if they had to work from home at least 2 days a week. This way things such as VPN, workstations, deploy pipelines, local builds, etc are naturally able to support remote workers. This will lead us to hiring better remote talent and allow us to institute remote working policies during health or environmental changes that hinder the ability of some workers to be in the office. That's what we've done and it's made our org more productive during the WFH period.* (P33)

**Provide guidance for working from home.** Many noted that curated guidance for working from home would benefit not just their own work but also the work of their colleagues. For example, on how to use different communication platforms, one respondent suggested:

☞ *Get some primers out so that people can feel comfortable in the space and know the use cases it's for. Lack of this knowledge keeps translating to inefficient use of email threads.* (P669)

Improving how knowledge is externalized is also more important when everyone is remote:

☞ *Encourage documentation as part of our culture. It's difficult to impossible to use libraries from within our org without directly talking to the repository owners. Now the only way to get information about these libraries is to send a message and hope they respond.* (P212)

Some respondents also noted that it isn't just about improving tools and processes for WFH, but there is a need for organization guidance regarding maintaining a positive work life balance:

☞ *Broad communication across the company to say "General work ends at 5:00 PM local unless business critical" as a way to force work/life balance now that work and life are in the same place.* (P696)

Microsoft continuously provided guidance, tips, and resources for employees working from home during the COVID-19 outbreak. In addition, communities were created to connect employees with colleagues around the world for tips and support on working from home.

**Other improvements.** Other improvements that were suggested by respondents were to *improve and encourage social interactions within teams; be more understanding of WFH scenarios beyond the pandemic; encourage people to be more responsive; minimize the number of meetings; and guidance for managers to manage WFH employees.*

## 7.2 Survey 2: Relation between Improvements and Productivity

From the themes that emerged in Survey 1, we inferred a list of 12 characteristic improvements (S1..S12) that we included in Survey 2, in which respondents could select up to three improvements. The results are displayed in Table 6. The table shows the frequencies for how often an improvement was selected by all respondents (column "All"), by respondents who reported a decrease in productivity (column "Low"), and by respondents who reported an increase in productivity (column "High"). The improvements are sorted and numbered in descending order of frequency by all respondents.

We make the following observations:

Table 6. Improvements in Survey 2. Participants could select up to three items. Column “All” indicates the frequency the improvement was suggested among all respondents, “Low” the frequency among respondents who reported a decrease in productivity, and “High” the frequency among respondents who reported an increase in productivity. Differences between the frequency for “Low” and “High” that are statistically significant with  $p < .01$  after Benjamini-Hochberg correction [36] are labeled with an asterisk (\*).

Improvement	All	Low	High
S1 Provide more/better hardware for home (more screens, more powerful laptop, etc)	41.6%	39.1%	42.7%
S2 Improve connectivity (fewer VPN drops, reimburse for faster internet)	41.5%	45.8%	35.5% (*)
S3 Provide a stipend for improving work from home environment	40.8%	42.4%	39.4%
S4 Make improvements to communication tools	33.1%	36.9%	29.3% (*)
S5 Provide ergonomic furniture	30.1%	17.2%	40.7% (*)
S6 Support remote work better during normal circumstances	22.3%	15.1%	30.7% (*)
S7 Provide guidance for successfully working from home (e.g., online meeting etiquette)	20.8%	23.7%	16.7% (*)
S8 Improve and encourage team socialization	16.8%	16.9%	15.8%
S9 Be more understanding of WFH scenarios beyond COVID-19	14.6%	15.7%	15.0%
S10 Encourage people to be more responsive	9.8%	8.9%	12.0%
S11 Minimize the number of meetings	5.8%	7.6%	3.8% (*)
S12 Give guidance to management on how to manage WFH employees	5.6%	5.9%	5.6%

- The most frequent selected improvement was to *provide more/better hardware for home* (41.6%), *improve connectivity* (41.5%), and *provide a stipend for improving work from home environment* (40.8%).
- Several improvements were more frequently selected by respondents who experienced a **decrease** in their productivity: *improve connectivity* (45.8% vs. 35.5%, S2), *make improvements to communication tools* (36.9% vs. 29.3%, S4), *provide guidance for successfully working from home* (23.7% vs. 16.7%, S7), and *minimize the number of meetings* (7.6% vs. 3.8%, S11).
- Several improvements were more frequently selected by respondents who experienced an **increase** in their productivity. The improvement *provide ergonomic furniture* was more than twice as likely to be selected (40.7% vs 17.2%, S5). This may be because more productive respondents were satisfied with other potentially pressing needs. The improvement *support remote work better during normal circumstances* was selected as twice as frequently (30.7% vs. 15.1%, S6). This may be because these respondents’ basic needs were met and they were focused on future needs and being able to continue to work from home.

## 8 DISCUSSION

Although the pandemic is an unusual (and hopefully will remain an uncommon) event in the lives of software engineers, this sudden work from home directive provides an opportunity to study what happens when engineers at a very large company are suddenly in a remote working condition with the rest of their team and entire organization. Engineering work is similar to knowledge work in general, but engineers may require highly intense periods of focus work but also rely on tight collaboration to develop modern software. As such, the pandemic and the force to working from home provides an interesting opportunity to understand more about developer productivity, but also to find guidance for developers that work remotely or for developers that collaborate with remote team members. As many companies are anticipating supporting much more remote work in the future (some claim they will be entirely remote), the findings from this study are important. We remind the reader that the context for this study is a large multi-national software company, and that our study focuses on engineers working in the US.

## 8.1 The Yin and Yang of Working from Home

As we saw earlier, for some developers that previously worked in office with their co-workers, certain factors that were mentioned as a challenge by some, were reported as a benefit by others. We even found that some factors (such as ability to focus, home work environment) that when they were reported as a challenge, they were associated with statistically significant lower levels of productivity, while if the same factor was reported as a benefit, they were associated with statistically significant higher levels of productivity.

These dichotomous experiences are expected as we see from extensive research around the world on people's experiences of lock-down (or social distancing) during the pandemic. Furthermore, divergent experiences are expected given the varied family life, living conditions/location, job characteristics and personality characteristics of our studied population. For employers and managers, knowing that "one size does not fit all" is critically important for the future of software development work.

The main divergent factors were:

- **ability to focus:** the number and nature of interruptions and distractions varied considerably, with some reporting more focus time at home (and higher levels of productivity), and others having less focus time (especially those facing interruptions with family members at home) and lower productivity. But even for those that appreciated fewer "randomizations" from colleagues since working from home, at the same time, they missed the knowledge and awareness they gleaned from these and other informal interactions;
- **work autonomy and motivation:** increased autonomy and control over tasks and timing increased motivation for some, but reduced motivation for others (and also their reported productivity);
- **work environment:** some appreciated the novelty of working from home, having natural light and more comfort at home and this was associated with higher productivity, while others missed their office work environment with extra amenities such as the cafeteria and reported lower levels of productivity;
- **meetings:** some felt there were too many meetings since WFH, and they missed face to face social cues and whiteboards, but others liked that meetings were shorter since WFH and the associated artifacts they could refer to later;
- **work life balance:** many appreciated having more time (due to no commute) and being able to use that for extra time with family or to do personal chores or for self care, but others also found it difficult to disconnect from work, worked too many hours and did not have healthy habits since working from home.
- **childcare needs:** having children with a need for childcare led to some surprising dichotomous experiences. From our analysis of the data from Survey 2, we saw that employees with children who had no difficulty handling childcare, less frequently reported a drop in productivity (20%) than employees without children (30%). However, for employees with children who had difficulties handling childcare, 40% reported a drop in productivity. We also found that employees who previously had children in school or childcare were MORE likely to indicate these major challenges: *lack of childcare, more distractions or interruptions, less time to complete my work*, and were LESS likely to indicate *lack of motivation* as a challenge.
- **social connections:** having fewer social connections was reported as a challenge for many but for others (a minority) they felt MORE connected to their team and appreciated online activities such as standups, social lunches, games, daily check-ins etc.

## 8.2 Triangulating the Impact of Working from Home

In this paper, we have presented insights based on surveys with self-reported data through the lens of individual productivity. This is just one of many possible analyses on how remote work affects productivity. To illustrate an alternative perspective, we show an analysis of productivity at the company data by mining software data collected through the engineering systems. For this section, we analyze trends across Microsoft to see how developer productivity changed during work from home. We compared the pull request counts during the pandemic (March/April 2020) with prior historical values during comparable periods of the fiscal year (March/April 2018 and March/April 2019).

Since the engineering workforce in Microsoft grew in numbers since 2018, we normalized the pull requests counts by the number of engineers to control for the growth. The number of pull requests per developer *opened* during the pandemic increased compared to previous year years: 4.4% compared to 2019 and +3.4% compared to 2018. Similarly, the number of pull requests *closed* per developer also increased: +4.0% compared to 2019 and +2.1% compared to 2018.

Different parts of the world went into “lockdown” at different times in March and April 2020. Microsoft has development teams spread across the world spanning all continents. In order to control for geographic differences, we further analyzed the pull request data for the three main Microsoft regions separately: *Puget Sound* in North America; *ASIA*, which includes China, India and Japan; and *EMEA*, which includes UK, Netherlands, Germany, France and Scandinavian countries. We observed that there was no discernible drop in the number of pull requests for all three regions, including when normalized by engineer count.

Overall we observe that there is no clear or significant drop (at statistically significant levels) in terms of the pull requests and pull requests per developer. This data analysis suggest that the pandemic has not significantly influenced productivity at the company level. While this particular analysis shows that productivity has been stable or has slightly improved on average, it is important to recognize that just focusing on the company level alone loses the nuance of how individual people are affected differently. This highlights the need to run a family of experiments that investigate work from home using different types of data and methodologies such as diary studies [50] and workplace analytics [51].

## 8.3 From Pandemic to Future of Work

The pandemic has been a major disruption and will change how engineers work in the future beyond the pandemic. Of course, this is not unique to software development and this disruption is visible in other professions, and for many kinds of knowledge workers. Many companies, software companies in particular, have announced either a shift to full remote work, or to partial remote work <sup>5</sup> in a hybrid fashion, where more developers may be allowed or encouraged to work from home several days a week. Working remotely is already norm for some companies, for example GitHub <sup>6</sup> and Automattic [52], and many highly successful open source systems have been designed, written and maintained by distributed developers, many of them volunteers [53]. Much can be learned from these existing success stories, but there is more to learn and many factors to consider in a future hybrid setting. An organization the size of Microsoft that has previously primarily relied

<sup>5</sup>See <https://www.forbes.com/sites/jackkelly/2020/05/19/after-announcing-twitters-permanent-work-from-home-policy-jack-dorsey-extends-same-courtesy-to-square-employees-this-could-change-the-way-people-work-where-they-live-and-how-much-theyll-be-paid/#4ac1881b614b>

<sup>6</sup><https://github.com/clef/handbook/blob/master/Employment%20Policies/Working%20Remotely.md>

on co-located work must now adapt and find new ways to work in this new hybrid world the pandemic has left behind <sup>7</sup>.

Remote work may suit many developers and projects, but there may be other aspects of software development that are negatively affected and the system engineering output data may not show those limitations. We already see signals from our survey that teams may face collaboration and communication challenges. In our first survey, one of our respondents noted that working at home does not provide the same information about the pulse of work but could be addressed by tools:

☞ *Automate team trends and share across the team, it's difficult to determine the real focus the team is trying to solve without seeing people stressing behind their desks (or not).*  
(P891)

And individuals that are part of a team, may be concerned that a lot of the work they do (such as helping others) may not be visible to the entire team, as one noted:

☞ *My biggest fear is being "out of sight, out of mind"* (P932)

Some reported addressing team work challenges through daily stand-up calls over video, virtual coffee hours and more impromptu meetings (which as we mentioned above was greatly appreciated by some participants). But some development activities, such as long term planning and creative aspects of development may be affected differently as some early work indicates [54]. These aspects of development work need to be studied in a longitudinal fashion, especially if work becomes hybrid for some developers. Managers should also be studied as they may face additional stress working from home and managing a team. For example, it may be harder for managers to give feedback (an important factor for developer satisfaction and productivity [26]) and maintain awareness of well-being and productivity of their team members. A shift to hybrid remote work will also have some societal implications, and our survey respondents recognized this and appreciated the positive effect on the environment less commuting may lead to.

## 9 RELATED WORK

We are not alone in studying the result of this almost overnight migration to working at home for software developers. In this section, we first review research papers that discuss findings from studies of developers at other technology companies. We then compare our study with this other research and summarize the similarities and differences with our study and findings.

### 9.1 Studies of Developer Productivity during the COVID-19 Pandemic

Although the pandemic occurred a mere few months ago, there are already preliminary findings from several studies on how software development has changed during the pandemic-induces working from home. We summarize three of these studies below. The first study uses a survey to understand the changes in developer well-being and how organizations may better support them. The other two mine engineering system data and analyze that quantitative data to understand changes in engineering performance metrics. Although some of these studies, are at the time of writing this paper under review, they provide useful early findings that are relevant to our survey.

**9.1.1 Pandemic programming: developer experiences and how companies can help.** Ralph et al. [41] conducted an online questionnaire with over 2,000 responses from developers around the world (the largest proportion of 22.7% were from Germany, followed by 16.4% from Russia, 12.2% from Brazil, and 4.4% from US). They aimed to understand how working at home during the COVID-19 pandemic

<sup>7</sup>For example from articles such as this one that discusses the advantages of remote work from an organization that was previously remote: <https://www.nytimes.com/2020/07/12/business/matt-mullenweg-automattic-corner-office.html>

affected developer well-being and productivity. The survey was run at the end of March 2020 and participants were primarily recruited through social media channels frequented by developers.

They found that developers' productivity and their well-being are suffering since working from home, and that well-being and productivity are closely related. Dealing with the pandemic and home office ergonomics affected well-being and productivity; women/parents/people with disabilities may be disproportionately affected. Their study leads to several recommendations how companies can support their employees: pay for home internet, help with home equipment, pay attention to employee emotional well-being and assure them that their reduced productivity is expected and will not negatively affect their job.

*9.1.2 GitHub study in the early day of COVID-19.* Forsgren et al., conducted an analysis of developer activity on projects hosted on GitHub in the early days of COVID-19 [42]. They considered both open source and private project data. They found the following key insights when comparing the first three months of 2020 to the same time period in 2019:

- Developer activity (pushes, pull requests, code review and commented issues) was mainly similar to or slight increased compared to last year.
- There was some disruption in the early days of work from home for enterprise projects but this quickly stabilized.
- Developer work days were longer by up to an hour per day with more work on weekdays and on weekends. They suggest this could be an indication of a risk of burnout.
- Collaboration had increased on open source projects (in terms of number of users and projects).

Their study is ongoing and from an engineering system performance point of view indicates that developers were staying productive even in this time of a pandemic. These findings align with the findings we found from analyzing system data at Microsoft (see Section 8.2).

*9.1.3 Baidu WFH Study.* Bao et al., studied the effect of the pandemic and working from home at one of the largest IT companies in China, Baidu [43]. They conducted a quantitative analysis of 139 developers' daily activities (over 138 working days). They found that working from home is associated with positive and negative changes in developer productivity in terms of the number of builds, commits and code reviews. They also considered the influence of different programming languages, project size/age/type and considered individual developers.

They found working from home was associated with negative changes for large projects and has different effects for different developers. Their data suggests that developer productivity may be more stable working from home than working onsite (less variation in their levels of productivity).

They also considered data from individual developers working from home and before work from home. They found that for the majority (approx. 85%) their productivity is about the same, but different for others (some are more productive, some are less). They asked developers to share feedback on their WFH productivity. The benefits that more productive developers reported were: working from home is exciting and energizing; developers can focus with fewer disturbances; WFH decreases transportation costs and saves time; WFH increases flexibility of when to work and improves work life balance. The challenges that developers with lower productivity included more home demands; a need for self discipline; and decreased collaboration with others. For the developers that found no difference with WFH, they experienced no barriers to completing their work, they could keep track of their schedule using online scheduling tools, and they found conferencing tools were powerful and effective for screen sharing.



## 9.2 Comparing our findings with other pandemic developer studies

Many of the factors that emerged from this study aligned with the factors from previous studies that aimed to understand developer productivity [26] or predict productivity [27] (see Section 2). But many new factors emerged (such as childcare and no commute) given the unique context of working from home since the pandemic.

A more relevant comparison, given the unique context of the pandemic, is to compare our research with studies that have been done since the pandemic forced developers to working from home (as summarized above). In Table 7 we compare our study directly with these other studies, specifically we compare the research questions posed, the research methods used, the data analyzed, the participants studied, the timing of the studies, the key findings and the main recommendations, with our study.

From this table, we see that in terms of method our research is closest to the paper by Ralph et al. [41], but our focus is on a cohort of developers from a single large organization (similar to the Baidu study). Our findings are more nuanced in terms of the differential experiences the factors we identify influence. Our research also paints a more positive picture when compared with the Ralph et al. study—this may be because the developers in our study may be well-supported in general.

We see convergence between the GitHub and Baidu studies in terms of engineering performance data we analyzed (as we discuss above in Section 8.2). Our study, through the survey, reveals many potential benefits, challenges and suggests many recommendations for an organization to follow while we see a mixed picture of terms of changes in productivity. Looking at data alone would not have informed the “tale of two cities” effect we reveal when we ask developers about their experiences.

## 10 CONCLUSION

The COVID-19 pandemic has been and continues to be a worldwide human and economic disaster, with many repercussions that are already evident, but with other effects that we can’t even yet imagine. One thing is clear, a return to business as it was before is unlikely, and many predict that the future of development work is likely to be either fully remote or for many some form of hybrid work. Thus, understanding what has worked well, and what has not gone well with remote work, is critical. We recognize that our study is only a start in understanding the implications of the pandemic on the software developer. In particular, new models of hybrid work are likely to lead to new challenges and benefits over remote work.

Our study reveals a “tale of two cities” – even in a company that has support in place for its developers and remote work – and delivers not just quantitative insights on how certain factors may be associated with higher and lower productivity, but also deeper insights into the narratives from these differential experiences. The improvements our study participants recommended shine some light on how organizations (and managers) may support their developers and we hope that the lessons learned from our study and other studies of development work during the pandemic will help others recognize and react to the disruptive changes we see unfolding in our industry.

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Table 7. Comparing the research goals, research methods, key findings and implications from the studies that have studied developers as they work from home during the COVID-19 pandemic.

	<b>GitHub COVID-19 Study</b> (Forsgren et al., 2020) [42]	<b>Pandemic Programming</b> (Ralph et al., 2020) [41]	<b>Baidu COVID-19 Study</b> (Bao et al., 2020) [43]	<b>Microsoft study</b> (This paper)
<b>Research questions/ goals</b>	Understand dev productivity, work cadence, collaboration during early COVID-19	Understand how WFH due to COVID-19 affects dev wellbeing and productivity	Understand impact of WFH on productivity	Understand benefits/challenges since WFH and factors that affect productivity over time
<b>Research methods</b>	Descriptive analysis of GitHub developer activity	Survey to test hypotheses of dev experience since WFH	Analysis of dev activity records and survey	Surveys (exploratory, quantitative)
<b>Population</b>	Open source projects and paid/enterprise accounts	Software developers anywhere in the world	Baidu developers in China	Microsoft engineers (devs and program managers in Puget Sound (Survey 1) and US (Survey 2))
<b>Participants/data</b>	Data from all open source/paid accounts	Approx. 2.25K survey responses from 53 countries (23% Germany, 16% Russia, 12% Italy, 4% USA)	139 devs' activities over 138 days	1,369 responses (Survey 1) 2,265 responses (Survey 2)
<b>Timing</b>	Jan - March, 2020 (compared with Jan-March 2019)	March 19-April 14, 2020	Dec 2019 to March 2020, compared with 2019	March 16-20, 2020 (Survey 1). April 22-May 9, 2020 (Survey 2)
<b>Findings</b>	<ul style="list-style-type: none"> <li>- Dev activity consistent or increased since last year</li> <li>- Work cadence changed (longer days/more weekends)</li> <li>- More collaboration (esp in open source)</li> </ul>	<ul style="list-style-type: none"> <li>- Change in wellbeing and productivity</li> <li>- Change in productivity depends on ergonomics/disaster prep</li> <li>- Change in wellbeing depends on ergonomics and fear</li> <li>- People with children have less ergonomic home offices</li> <li>- People with disabilities less prepared for disasters</li> </ul>	<ul style="list-style-type: none"> <li>- WFH has different impacts on dev productivity (varies by project age/type/language/size/metric)</li> <li>- Productivity of majority of devs when WFH is similar to onsite</li> <li>- For those that are more productive, they feel more enthusiastic/focused and have better work life balance</li> <li>- For those less productive they have more home chores, harder collab</li> </ul>	<ul style="list-style-type: none"> <li>- Main challenges of WFH: miss social interactions, poor work life boundary, poor ergonomics, less awareness of others' work, less exercise, difficult communication, for some lack of childcare</li> <li>- Main benefits of WFH: no commute, money, flexible hours, close to family, comfort at home, health, time</li> <li>- Identify the main challenges and benefits that explain both positive and negative changes in productivity</li> </ul>
<b>Implications/ recommendations</b>	<ul style="list-style-type: none"> <li>- Plan tool/process flexibility</li> <li>- Embrace collaboration</li> <li>- Anticipate burnout</li> </ul>	<ul style="list-style-type: none"> <li>- Pay for home internet charges</li> <li>- Care about employee wellbeing</li> <li>- Little consensus among devs what orgs can do to help</li> </ul>	<ul style="list-style-type: none"> <li>- WFH should be a choice</li> <li>- Project characteristics matter</li> <li>- Individual devs need different strategies if WFH</li> </ul>	<ul style="list-style-type: none"> <li>- Dichotomous experiences for same factors, support all/part WFH options</li> <li>- Provide better hardware, internet, stipend, software, guidelines, support</li> </ul>

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A CODEBOOK

We identified 32 codes in the following six themes.

<b>Beyond Work</b>
<i>Ecological Impact:</i> The impact of working from home on ecological factors (e.g. affecting the environment). The most common is less pollution due to not commuting.
<i>Family, Children, and Pets:</i> Factors related to pets, children, and family. This includes the proximity to them, interruptions from them, lack of childcare, and needing to help children who are doing school remotely from home.
<i>Food:</i> The impact of working from home on meals and snacks. This includes quality and quantity of food, access to food, diversity of food consumed, and the need to or opportunity to cook for one's self.
<i>House Work:</i> The impact of working from home on home-related tasks or activities such as laundry, paying bills, picking up packages, chores, and maintenance.
<i>Money:</i> The impact on money and spending. This may include spending less money due to not eating out or commuting as well as spending more money on groceries, setting up a home office, or upgrading internet.
<b>Collaboration</b>
<i>Blocks:</i> Comments about being blocked from making progress due to waiting on others to relay information, make decisions, or complete pre-requisite tasks.
<i>Collaboration:</i> Aspects of coordination or collaboration that are not explicitly about communication. This also includes general statements about collaboration such as "Collaboration is worse" or "It's hard to be creative with people".
<i>Meetings:</i> Explicit mentions of meetings, including frequency, duration, time of day, quality, size, formal versus informal, and communication channels used.
<i>Social Connections:</i> Non-work communication with co-workers (e.g. to help facilitate work bonds). This includes the difficulty of managing, forming, or maintaining informal and team relationships as well as feeling isolated and missing social connections.
<i>Team:</i> Team characteristics such as team culture, team social activities, team productivity, and team mood.
<b>Communication</b>
<i>Channels:</i> Discussions of the use of various communication channels such as Teams chats and calls, Email, instant messaging, including comments about them such as using too many tools, difficulty of use, and benefits of different tools. In addition, this includes comparisons of tools to working in office such as the lack of in-person communication or missing richness of communicating at a whiteboard.
<i>Communication Gaps:</i> Challenges around communication such as it being difficult to connect with particular people (for example, because schedules are more flexible), hard to communicate, missing communication, and miscommunication. This also includes lack of awareness of what others are working on.
<i>Formal Communication:</i> Formal communication such as scheduled chats that are work related.
<i>Informal Communication:</i> Unscheduled, informal, or ad-hoc communication that is work related. This includes the inability to drop by someone's office or run into someone in the break room as well as the use of tools (e.g. Teams) for frequent, short interactions.
<b>Well-being</b>
<i>Breaks:</i> Taking or needing more or less breaks (including meal breaks or walks); Reasons for less breaks such as having meetings are back to back
<i>Healthy Habits:</i> e.g., diet, explicitly saying being "healthy", physical activity (working out), walking between meetings; too much time on the computer; too much time at home
<i>Mental Health:</i> work related stress; personal stress, anxiety; burnout; fatigue; loneliness

- No Commute:* The impact of not having a commute. This includes benefits such as less wasted time, but also negatives such as missing reading on the bus or calling relatives on the drive into work.
- Personal Comfort:* The impact on working from home on personal comforts such as listening to music without headphones, wearing more comfortable clothes, or creating a more comfortable working space.
- Routine:* Any mentions of routine. May include "missing a routine" such as "I miss having breakfast every morning" or the importance of maintaining a routine.
- Schedule Flexibility:* The ability to and impact of working outside of the traditional "9-5" work day. This includes working outside of non-work hours as well as doing non-work related activities (e.g. laundry) during traditional working hours.
- Work Hours:* Whether the number of hours worked during the day stayed the same, went up or went down. For instance, "I get the same amount done, but I'm working 12 hour days to do it."
- Work-Life Balance:* Changes in boundaries between work and non-work life and the ability (or lack) to not let work concerns or responsibilities interfere with non-work activities.
- Focus:* The impact of working from home on the ability to focus, or the impact of various factors on focus time
- Interruptions and Distractions:* Interruptions or distractions (or the lack of them) when working from home, whether work related or not.
- Motivation:* Various intrinsic and extrinsic factors affecting motivation as well as differences or changes in motivation.
- Productivity:* Discussion of perceived productivity and the impact of various factors on productivity

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**Work Environment**

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- Connectivity:* The challenges of connectivity such as internet speed and latency, "remoting in" to a machine at work to accomplish work, using secured machines, connections to remote machines going up and down, and the need to reboot machines remotely.
- Environment:* Aspects of the physical work environment such as access to natural light, now having a window, dedicated (e.g. a study) vs non-dedicated (e.g., kitchen table) space, having privacy, temperature, more or less noise.
- Ergonomics:* The availability or absense of ergonomic furniture, often in comparison to the work office environment.
- Furniture:* References to furniture that do not mention or allude to ergonomics. Items such as whiteboards or bookcases are also included.
- Hardware:* Differences in displays (quantity and quality), and machines (also quantity and quality) as well as accessories such as mice, keyboards, headphones, and webcams.
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Table 8. Counts and Ranks of the Codes in Survey 1. The columns under *Counts* indicate the frequency of each code within questions “Please share details about your answer to the previous question on how your productivity has changed?” (Q14), “What is **good** about working from home?” (Q15), “What is **bad** about working from home?” (Q16), “What **challenges** have you encountered working from home?” (Q17), and all four questions combined (Total). The columns under *Ranks* indicate the rank of each code with respect to the other codes for Q14, Q15, Q16, Q17, and all four questions combined (Total). The most frequent code is #1.

Code	Counts					Ranks (#)				
	Q14	Q15	Q16	Q17	Total	Q14	Q15	Q16	Q17	Total
<b>Beyond Work</b>										
Ecological Impact	0	6	0	0	6	30	18	30	31	32
Family, Children, and Pets	65	61	38	61	225	3	6	9	3	3
Food	7	32	17	9	65	22	10	16	23	22
House Work	6	33	0	8	47	26	9	30	25	25
Money	0	11	1	1	13	30	16	28	28	31
<b>Collaboration</b>										
Blocks	3	0	14	1	18	28	26	21	28	29
Collaboration	12	3	38	16	69	19	22	9	20	20
Meetings	39	29	22	18	108	7	11	14	18	12
Social Connections	12	1	94	21	128	19	24	1	13	10
Team	7	1	8	1	17	22	24	26	28	30
<b>Communication</b>										
Channels	63	5	87	66	221	4	19	2	2	4
Communication Gaps	13	0	12	27	52	17	26	22	9	24
Formal Communication	0	4	16	14	34	30	21	19	21	26
Informal Communication	61	0	49	26	136	5	26	4	10	9
<b>Well-being</b>										
Breaks	19	21	17	20	77	14	14	16	15	19
Commute	46	229	5	0	280	6	1	27	31	2
Healthy Habits	7	27	48	21	103	22	12	5	13	14
Mental Health	17	45	22	9	93	15	8	14	23	15
Personal Comfort	3	48	0	7	58	28	7	30	26	23
Routine	7	0	12	4	23	22	26	22	27	28
Schedule Flexibility	21	71	1	25	118	13	4	28	11	11
Work Hours	25	16	45	20	106	12	15	8	15	13
Work-Life Balance	11	10	47	20	88	21	17	6	15	16
<b>Work</b>										
Focus	83	80	12	25	200	2	3	22	11	5
Interruptions and Distractions	193	91	87	35	406	1	2	2	6	1
Motivation	5	0	12	10	27	27	26	22	22	27
Productivity	31	24	16	17	88	11	13	19	19	16
<b>Work environment</b>										
Connectivity	34	0	34	99	167	10	26	12	1	7
Environment	39	63	26	57	185	7	5	13	4	6
Ergonomics	13	0	36	33	82	17	26	11	7	18
Furniture	16	2	17	33	68	16	23	16	7	21
Hardware	38	5	47	51	141	9	19	6	5	8