Understanding Developers Well-Being and Productivity: A Longitudinal Analysis of the COVID-19 Pandemic

DANIEL RUSSO∗, Department of Computer Science, Aalborg University, Denmark
PAUL H. P. HANEL, Department of Psychology, University of Essex, United Kingdom
NIELS VAN BERKEL, Department of Computer Science, Aalborg University, Denmark

Covid-19 has also led to far-reaching and long-lasting changes in people’s life, such as increased flexibility in work arrangements. In the present longitudinal study, we investigate over 24 months and six measurement points how the well-being, productivity, social contacts, and needs of software engineers changed over time. We found changes for a range of variables. Variables such as levels of well-being increased while anxiety and loneliness decreased during the pandemic. Symmetrically, indicators of well-being (e.g., quality of social contacts) increased when lockdown measures were slowly lifted. On the other hand, other variables, including boredom and productivity, remained constant. Additionally, we run a preliminary investigation into the future of work at the end of the pandemic. A thematic analysis revealed that some form of hybrid work is here to stay. Also, we found that having previously changed jobs and low job satisfaction was reliably associated with the intention to change jobs again, in case the work condition is not deemed adequate to developers’ needs. This suggests specific challenges for software organizations that need to tailor various work arrangements if they want to be attractive employers. We conclude this paper with several actionable recommendations.

CCS Concepts: • Social and professional topics → Computing industry; Management of computing and information systems: Project and people management.

Additional Key Words and Phrases: COVID-19, Longitudinal Study, Well-Being, Future of Work.

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1 INTRODUCTION

The COVID-19 pandemic and the subsequent lockdowns have likely been among the most disruptive events that most software engineers in Western countries faced during their lifetime. Suddenly, professionals started to work from home, potentially alongside family members. This peculiar situation is unprecedented in computer science history; thus, we need more information about the long-lasting impact of lockdowns on the well-being and productivity of software professionals.

The only related evidence comes from the effects of quarantined people in previous epidemic outbreaks, which suggests that isolation and lockdown measures are a huge burden to individuals’
well-being [11, 40] and productivity [58]. Indeed, well-being and productivity are two crucial aspects of our lives, particularly during extraordinary events: Well-being is a fundamental human right, according to the Universal Declaration of Human Rights, whereas productivity provides us with the earnings to maintain or improve our lifestyle. Health professionals have already identified some relevant predictors of well-being during harmful events [11, 29]. However, this research is often cross-sectional (i.e., not longitudinal), only includes a limited number of well-being-related variables, and focuses on well-being while ignoring productivity. The software engineering community also reacted quickly to this event by conducting an extensive study that found that home office ergonomics, disaster preparedness, and fear correlate with well-being and productivity [78]. However, Ralph et al. performed a cross-sectional study with only a few predictors. Pre-pandemic research on remote work [28] might provide some indications. However, such research is unlikely to be relevant during a global pandemic, with professionals locked down in their houses without childcare or usual welfare support provided during non-pandemic times.

For these reasons, it is essential to continuously and longitudinally investigate software professionals’ well-being and productivity across the COVID-19 pandemic (until spring 2022). By doing so, we aimed to achieve several goals. First, test whether well-being, productivity, and other relevant variables such as loneliness, social contacts, and need fulfillment changed over the course of 24 months since the beginning of the first lockdown in Spring 2020. Second, test whether well-being and productivity changed more for software developers who had experience in working from home, were living alone; and explore whether income, gender, age, and preference for working from home further interact with well-being and productivity over time. Third, turning to the future, investigating predictors of job satisfaction and intention to change jobs. Fourth, understand how to improve developers’ work-life balance while working from home in a post-pandemic setting and contribute to the nascent literature about the future of work. Hence, we formulate our research questions as follows:

**Research Question 1:** How and why have well-being, productivity, and other relevant social and psychological variables changed during the COVID-19 pandemic?

**Research Question 2:** How do software developers envision their future of work following the COVID-19 pandemic?

To answer our research questions, we sampled almost 200 globally distributed software engineers six times over a period of 24 months. We assessed their well-being and productivity in each of the six waves alongside 15 other variables. To guide our research design, we grounded our investigation in organizational [44] and psychological [84] theories, which are relevant to people’s well-being and productivity. For example, self-determination theory [84] assumes that human motivation can be divided into three basic needs, which are also linked with work motivation [35]: the needs for autonomy, competence, and relatedness. Additionally, we also included evidence from the remote work literature [1, 7, 55], and recommendations by health and work authorities [20, 23, 68].

This investigation is framed within an overarching research agenda regarding the Future of Work in the software industry. In particular, this work aims to monitor the effects on developers’ well-being and productivity during two years of the COVID-19 pandemic with a longitudinal design. In these years, we also published preliminary findings to provide early recommendations to professionals and organizations [82]. Additionally, we also looked more specifically into daily life practices of locked down software engineers [80] while also monitoring how different activities (e.g., bugfixing, coding, helping) impacts software engineers’ satisfactions and performance [81]. Finally,
we also investigated how the pandemic influenced Agile development methodologies, particularly Scrum [22, 96].

In this study, we analyzed our data using a range of different statistical approaches tailored to the specific questions. Specifically, to test whether well-being, productivity, and 15 variables, including loneliness, needs, and social contacts changed over time, we used 17 within-subject ANOVAs. We used a series of linear mixed-effects models to test whether the changes differed across people (e.g., for those with more WFH experience). To assess whether there are any mean differences between participants living in the UK and USA, we used a series of between-subject t-tests. We found that software engineers’ levels of well-being increased while anxiety and emotional loneliness decreased between April 2020 and April 2022. Productivity remained unchanged. Additionally, we found that only having previously changed jobs and low job satisfaction was reliably associated with the intention to change jobs again. Further, especially the need for competence and solidarity with the company was positively associated with job satisfaction. Moreover, the thematic analysis revealed that software engineers perceive hybrid work as the new norm in the tech industry. Finally, we found no mean differences between people living in the UK and USA for any of the 17 variables we measured across all six waves.

This article has the following structure. Section 2 discusses related work of well-being and productivity. The research design and analysis are then described in Section 3. Next, in Section 4, we discuss the results of our analyses, while we discuss implications and recommendations for professionals and software companies in Section 5. Finally, we conclude our work by outlining future research directions in Section 6.

2 RELATED WORK
Following the abrupt onset of the COVID-19 pandemic and subsequent lockdowns, COVID-19-related research has expanded rapidly. Health scientists started investigating countermeasures to reduce the spread and impact of the virus and studied the psychological and physiological effects on people living in lockdown conditions. Also, in the software engineering community, the effect of the pandemic on software developers has gained increased attention. After describing the state of the art of research on well-being and productivity in remote work, we focus on the software engineering contributions.

2.1 Well-Being and Productivity in Remote Work
There is a consensus that lockdown measures have a negative impact on well-being [11, 32, 60]. In particular, research shows that living in a lockdown can result in increased experiences of anger, depression, emotional exhaustion, fear of infecting others or getting infected, insomnia, irritability, loneliness, low mood, post-traumatic stress disorders, and stress [2, 43, 57, 63, 79, 91]. Additionally, fears of, e.g., infection [49, 76], lack of supplies or not being treated [101], and misleading or contradictory information [14] can result in significantly increased stress levels. Moreover, the psychological effects of being locked down may appear years after [11].

On the other hand, pre-COVID research shows that remote working is associated with an improved work-life balance, creativity, productivity, reduced stress, and low carbon emissions due to the absence of commuting [1, 5, 7, 18, 73, 95], even though recent studies challenge the claim that remote work leads to lower carbon emissions [13, 102]. Nevertheless, there are also some apparent drawbacks related to remote work, such as deteriorating collaboration and communication, loneliness, feeling of being constantly 'online,’ decreasing motivation, and distractions at home [51, 97]. Independent of whether the positive effects outweigh the negative effects, forecasts suggest that remote work will increase on a large scale in the next years [36, 73].
2.2 Software Engineering and COVID-19

Overall, the software engineering community has been quite active in researching pandemic-related aspects. We identified relevant work through Scopus.

The first works in this research area are from the late 90s with broader internet use. Pounder (1998) [75] was the first relevant contribution we identified, with an essay about security problems linked to telework. In the early 2000s, Guo (2001) [39] performed two qualitative surveys on software process improvement related to the distinctive nature of teleworking. Similarly, Higa et al. (2000) [45] studied how e-mail usage influences telework.

Afterward, there has been a twenty-year gap, with only two exceptions. James & Griffiths (2014) [48] developed a mobile execution environment to support a secure and portable working from home setting. Ford et al. (2019) [33] interviewed three transgender software engineers to explore the interplay of gender identity and remote work.

Following the start of the pandemic and the first lockdown, two research groups performed survey studies. Ralph et al. (2020) [78] performed a cross-sectional study of over two thousand globally distributed developers working from home during the pandemic where an a priori research model derived by literature was validated through Structural Equation Modeling. Russo et al. (2021) [82] went in the opposite direction. Rather than having a top-down model to validate, they employed an exploratory approach investigating the most relevant variables related to either well-being or productivity. They analyzed the data in a longitudinal design.

Microsoft has also been active in understanding the effects of the pandemic on its employees. Ford et al. (2020) [34] surveyed Microsoft’s developers twice. They found that the quality of family life and time improved, although remote work introduced a lack of focus, poor work-life boundaries, and communication and sync issues. Similarly, Miller et al. (2021) [65] performed two surveys in which they collected information about working from home and team-related issues. They found that communication and colleague interaction are relevant predictors of developers’ satisfaction and team productivity. Butler & Jaffe (2021) [12] conducted a 10-week diary study. Identified challenges from remote work were meetings, overwork, and physical and mental health. However, Microsoft developers appreciated more family time and work flexibility.

More recent studies focus on particular aspects of remote work. For example, Cucolas & Russo (2021) [22], with a Mixed-Methods research design, investigated how Scrum software development adapted to working from home. According to their results, the home-working environment is the most crucial variable for a software project’s success. Also, self-determination theory [84] (i.e., the need for autonomy, competence, and relatedness) is a valuable theoretical lens to improve working from home conditions, as they are linked with well-being [15], for example. Machado et al. (2021) [62] surveyed 233 Brazilian software professionals and investigated gender differences. They concluded that the pandemic affected women more negatively than men. In contrast, Russo et al. did not find any meaningful gender differences [82]. Documentation and setup in the initial months of the lockdown have also been perceived as especially struggling by developers, according to [94]. These authors claim for broader use of automated tools for remote work. Finally, consistent with the findings from Russo et al., Smite et al. confirm that, on average, perceived productivity has not changed significantly during the pandemic [88].

From a content perspective, approximately half of the papers are concerned with specific topics related to remote work: job security [48, 75, 94], process [39], work productivity [45, 88], and inclusion [33]. The other half of the papers focused on the well-being and productivity aspects of remote work [12, 34, 54, 62, 78, 82] and productivity related to project characteristics [22].
3 RESEARCH DESIGN

To design our research, we followed the ACM SIGSOFT Empirical Standards for Longitudinal Studies [77]. Consequently, we asked carefully recruited software professionals to complete the same survey six times, over a period of 24 months.

Due to the unpredictable evolution of the pandemic and state-prescribed lockdown regulations we could not plan data collection beforehand. Thus, we tried to follow the evolution of the pandemic. Wave 1 was collected between 26-30 April 2020, wave 2 between 10-13 May 2020, wave 3 between 24 February and 3 March 2021, wave 4 between 29 June and 5 July 2021, wave 5 between 20 December 2021 and 5 January 2022, and wave 6 between 6-12 April 2022. Wave 1 and 2 were only two weeks apart since we were initially only interested in the stability of predictors of well-being and productivity. Wave 3 was collected in late winter 2021 when the number of COVID-19 cases in most Western countries decreased again. Wave 4 was collected when a significant part of people in Western countries had received an offer to get vaccinated, wave 5 around Christmas 2021 when a new Covid-wave hit many countries, and wave 6 when cases dropped again in spring 2022. Unique randomized IDs were assigned to participants to preserve their anonymity and track their participation across all six waves.

3.1 Participants

We selected participants from a pool of over 500 software engineers previously identified [83]. These informants have been selected through a multi-screen process, where we assessed for representativeness through pre-screening (both in terms of computer programming experience and profession), competence screening (competency-based questions on software design and programming), and quality screening (attention checks). We narrowed this pool down to 192 professionals through additional screening questions. We did not live in countries with non-uniform COVID regulations (e.g., Germany, where initially the lockdown regulations were provided by the regions, not the federal government). In particular, we looked for informants working from home during the pandemic for at least 50% of their time. 192 software engineers completed the first survey ($M_{age} = 36.65$ years, $SD = 10.77$, range = 19–63; 154 men, 38 women), 184 participated in wave 2, 144 in wave 3, 125 in wave 4, 117 in wave 5, and 101 in wave 6. Overall, 72 participated in all six waves and completed all measures. A sensitivity analysis with GPower 3.1.9.4 [30] revealed that this sample size was sufficient to detect a medium effect size of $f = .15$ with a power of .95.

Demographic information is provided in Table 1. Twenty-nine participants were living alone at wave 1, 162 with other people. We ensured high data quality by recruiting participants from the data collection platform Prolific Academic [74] and compensated participants above the US’s federal minimum wage\(^1\). This compensation was used for all participants. Additionally, none of our participants failed any attention checks or completed the survey too fast, ensuring our data quality. The survey was run using the platform Qualtrics.

To collect the data, we attained ourselves to the ethical guidelines of the Declaration of Helsinki [69]. All participants were at least 18 years old, expressed their consent to participate in the study each time, and were free to withdraw at any point. All the authors completed formal training in research ethics for engineering and behavioral sciences.

3.2 Measurements

Well-being and productivity are two complementary variables of a healthy working environment. Not surprisingly, they are correlated, and greater happiness can cause greater productivity [72, 82].

\(^1\)Payments slightly changed during the years to adapt to new labor regulations and Prolific recommendations. We always used the suggested compensation by Prolific. As a reference, we paid our participants GBP 9.00/hour in the last wave.
Table 1. Overview of participant demographics across the six waves.

|       | N  | Men | Women | Age (mean) |
|-------|----|-----|-------|------------|
| Wave 1| 192| 154 | 38    | 36.65      |
| Wave 2| 184| 147 | 37    | 36.71      |
| Wave 3| 144| 112 | 27    | 37.56      |
| Wave 4| 125| 96  | 27    | 39.20      |
| Wave 5| 117| 91  | 22    | 40.12      |
| Wave 6| 101| 81  | 16    | 41.16      |

Especially in exceptional times, such as a pandemic, organizations should prioritize employees’ mental and physical well-being if they want to be productive. On the other hand, as suggested by Russo et al. [82], contributing to the organization’s value is essential for the sense of belonging or achievement of every developer. Therefore, productivity also contributes to professionals’ well-being [82].

Consequently, productivity and well-being are our two outcome variables (i.e., dependent variables). To identify relevant predictors (or our independent variables) of our dependent variables, we started from the insights of Russo et al. [82]. Namely, we included in this analysis only the 15 (out of 50) predictors which correlated with at least one of the two outcome variables (i.e., \( r \geq 0.30 \)) [82]. This was done to keep the number of predictor variables to a manageable amount and to focus on the most relevant variables.

All variables were measured using self-reported measures, which is very common in the literature [78, 83]. The internal consistency of the scales was quantified with Cronbach’s \( \alpha \) and ranged from satisfactory to very good. Values above .60 and .70 are desirable for exploratory and confirmatory research, respectively [41].

To measure the identified variables, we only used either validated scales or adapted items from scales used in previous publications with high reliabilities. The only exceptions were ‘productivity,’ ‘quality and quantity of communication with colleagues and line managers, and ‘daily routines’ for which we created our own items because we could not find existing scales suitable for our purposes. Responses were mainly given on 5-, 6-, or 7-point response scales, with higher values indicating a higher score on each variable. Every scale is briefly subsequently described with its name, reference, and reliability metrics (i.e., Cronbach’s alpha) across all six data collection waves. For detailed descriptions of the items, see Appendix A and Appendix B.

**Well-being.** We measured well-being with the 5-item Satisfaction with Life Scale [26]. Participants were asked to report their well-being using items such as “I was satisfied with my life in the past week” on a 7-point Likert scale (1: Strongly disagree, 7: Strongly agree). The Cronbach’s \( \alpha \) values to measure internal consistency for all six data collection waves were the following:

\[
\alpha_{Wave1} = .90, \alpha_{Wave2} = .90, \alpha_{Wave3} = .92, \alpha_{Wave4} = .94, \alpha_{Wave5} = .94, \alpha_{Wave6} = .95.
\]

**Productivity.** There is no agreement among researchers on how productivity can be measured. For example, measuring productivity in an allegedly objective way by using function points [98] has been criticized as detrimental in the long run [52]. Further, the objective approach is barely feasible if participants work in different areas since comparisons across work are very challenging. Therefore, other researchers advocated using self-reports [64], which has apparent shortcomings such as subjectivity. In the present research, we developed a subjective approach. We reduce socially desirable responses by making the survey anonymous. Specifically, we operationalized productivity as a function of time spent working and efficiency per hour, compared to a typical,
pre-pandemic week. This choice is because we wanted to investigate productivity while working remotely compared to being in the office. Since our measure does not allow us to compute internal consistency, we instead computed test-retest reliability by correlating the productivity scores at Wave 1 with those at time t2 ($r_{tt} = .50, p < .001$).

**Boredom** was measured with the Boredom Proneness Scale [29, 92]; $\alpha_1 = .87, \alpha_2 = .87, \alpha_{Wave3} = .92, \alpha_{Wave4} = .90, \alpha_{Wave5} = .92, \alpha_{Wave6} = .91$.

**Self-blame and behavioral disengagement**, two coping strategies, were measured with the respective subdimensions of the Brief COPE scale [16]. Cronbach’s α’s for self-blame were $\alpha_1 = .75, \alpha_2 = .71, \alpha_{Wave3} = .92, \alpha_{Wave4} = .92, \alpha_{Wave5} = .88, \alpha_{Wave6} = .90$, and for behavioral disengagement $\alpha_1 = .76, \alpha_2 = .71, \alpha_{Wave3} = .89, \alpha_{Wave4} = .91, \alpha_{Wave5} = .95, \alpha_{Wave6} = .92$.

**Distractions at home** was measured with an adapted version of the Generalized Anxiety Disorder scale [90]; $\alpha_1 = .93, \alpha_2 = .93, \alpha_{Wave3} = .94, \alpha_{Wave4} = .95, \alpha_{Wave5} = .93, \alpha_{Wave6} = .93$.

**Emotional and social loneliness** were measured with the De Jong Gierveld Loneliness Scale [38]. Emotional loneliness’ Cronbach’s α-levels were: $\alpha_1 = .68, \alpha_2 = .69, \alpha_{Wave3} = .68, \alpha_{Wave4} = .73, \alpha_{Wave5} = .70, \alpha_{Wave6} = .69$, and for social loneliness: $\alpha_1 = .84, \alpha_2 = .87, \alpha_{Wave3} = .90, \alpha_{Wave4} = .88, \alpha_{Wave5} = .91, \alpha_{Wave6} = .94$.

**Autonomy, competence, and relatedness** were measured with the psychological needs scale [86]. Need for autonomy’s Cronbach’s α-levels were: $\alpha_1 = .72, \alpha_2 = .76, \alpha_{Wave3} = .77, \alpha_{Wave4} = .78, \alpha_{Wave5} = .77, \alpha_{Wave6} = .79$; for Competence: $\alpha_1 = .77, \alpha_2 = .65, \alpha_{Wave3} = .77, \alpha_{Wave4} = .79, \alpha_{Wave5} = .77, \alpha_{Wave6} = .84$; and for Relatedness: $\alpha_1 = .79, \alpha_2 = .78, \alpha_{Wave3} = .78, \alpha_{Wave4} = .80, \alpha_{Wave5} = .77, \alpha_{Wave6} = .80$.

**Quality of social contacts** were measured with 3-items, two of which were adapted from the social relationship quality scale [6] and one was developed by us, $\alpha_1 = .73, \alpha_2 = .77, \alpha_{Wave3} = .76, \alpha_{Wave4} = .84, \alpha_{Wave5} = .80, \alpha_{Wave6} = .85$.

**Quality and quantity of communication with colleagues and line managers** were measured with a self-developed 3-item scale, $\alpha_1 = .88, \alpha_2 = .92, \alpha_{Wave3} = .93, \alpha_{Wave4} = .94, \alpha_{Wave5} = .94, \alpha_{Wave6} = .93$.

**Stress** was measured with the Perceived Stress Scale [21]; $\alpha_1 = .80, \alpha_2 = .77, \alpha_{Wave3} = .83, \alpha_{Wave4} = .78, \alpha_{Wave5} = .76, \alpha_{Wave6} = .80$.

**Daily Routines** were measured by a self-developed 5-item scale ($\alpha_1 = .75, \alpha_2 = .78, \alpha_{Wave3} = .81, \alpha_{Wave4} = .78, \alpha_{Wave5} = .82, \alpha_{Wave6} = .79$).

**Extraversion** was measured with a subscale of the Brief HEXACO Inventory [24]; $\alpha_1 = .71, \alpha_2 = .69, \alpha_{Wave3} = .75, \alpha_{Wave4} = .61, \alpha_{Wave5} = .68, \alpha_{Wave6} = .73$.

Additionally, to answer Research Question 2, we included the following measures in wave 6.

**Preference for working from home** was measured with a 2-item slider scale we developed with responses ranging from 0 to 100, $\alpha_{Wave6} = .88$.

**Resilience** was measured with the 6-item Brief Resilience Scale [89], $\alpha_{Wave6} = .89$.

**Solidarity with the company** was measured with the 3-item Solidarity subscale of the In-group Identification Scale [56], $\alpha_{Wave6} = .97$.

**Job satisfaction** was measured with the 4 highest loading items of the Generic Job Satisfaction Scale [61], $\alpha_{Wave6} = .85$.

**Disliking commuting** was measured with a 2-item scale we developed, $\alpha_{Wave6} = .54$.

**Intention to change jobs** was measured with a 2-item scale we developed, $\alpha_{Wave6} = .95$.

**Changed jobs** since March 2020 was measured with one item we developed whereby 0 represents no and 1 yes.
Perceived company preference was measured with a one item slider scale ranging from 0 (company wants me to go back to the office full-time) to 100 (company allows me to work from anywhere full-time).

3.3 Analysis
To answer our research question and perform the additional exploratory analysis, we used various statistical analyses. Below, we briefly describe and justify each of them.

Raw data, R-code to reproduce our analyses, and the zero-order correlations for all 17 variables, separately per wave and across all six waves, are included in our replication package on Zenodo.

3.3.1 Changes along the COVID-19 Pandemic. To test whether any change between the six data collection waves occurred, we ran a series of 17 repeated-measures ANOVAs, one per variable. This allowed us to test whether software engineers’ well-being increased, decreased, or remained the same. Additional to the common descriptive (means and standard deviations) and inferential statistics (F-value and $p$-value$^2$), we report as an effect size how many participants report a higher, lower, or equal level of any variable at Wave 6 compared to Wave 1. Given the number of 17 tests of variables, which are, however, mostly correlated with each other, we set our $\alpha$-level to .004. We only consider findings to be significant if $p < .004$. This threshold is, in our view, neither conservative nor liberal. However, other researchers might prefer a more conservative or liberal threshold. Therefore, we report the exact $p$-values, allowing researchers to select different thresholds. Subsequently, we ran a series of 17 (dependent variables) $\times$ 7 (moderators) = 119 linear mixed-effects models to test whether past working from home experience, living alone (yes vs. no), income, gender (women vs. men), age, preference for working from home and having changed jobs predicted to change over time in any of the 17 dependent variables. Given the large number of tests, we set our $\alpha$-level to .001.

3.3.2 Predictors of working from home. To test which variables were associated with working from home, we ran a series of correlations that included the developers’ preference for working from home, Changed jobs since March 2020, job satisfaction, solidarity, resilience, and intention to change jobs during our last data collection phase (i.e., wave 6 only). All 17 of the focal variables were measured in wave 6, as well as age and gender. Given the 24 tests, we set our $\alpha$-level to .004. Additionally, this approach allowed us to explore predictors of intentions to change jobs and job satisfaction.

We then tested whether the association of preference for working remotely with the intention to change jobs is moderated by company policy; we ran a moderated regression using the R-package interactions [59].

3.3.3 Between-group comparisons. Additionally, we compared people living in the United Kingdom and the USA (these were the two countries from which relatively most of our participants came) across all 17 variables and all 6 waves, resulting in $6 \times 17 = 102$ between-subject t-tests. We, therefore, adjusted our $\alpha$-threshold to .001. To address recent calls to report effect sizes that display similarities to avoid a one-sided focus on potentially small differences [42], we also report the effect size Percentages of Common Responses (PCR) alongside the more common effect size Cohen’s $d$. PCR is a measure of overlap between two groups (e.g., British and US-American people) and ranges from 0 (no overlap/similarities) to 100 (both groups overlap perfectly).

$^2$The F-value is a test-statistic that increases with larger mean-differences, lower within-group variability, or larger sample size. It is, for fixed sample size, inversely related to the $p$-value, which is used to determine whether our findings are statistically significant.
3.3.4 Thematic Analysis. Our research provided highly relevant measurements to screen the tendency of the lockdown among developers. However, from the current design, we could not grasp more nuanced phenomena, typically emerging through a qualitative investigation. Therefore, we performed a reflective thematic analysis with an inductive/deductive approach [8–10]. The goal was to understand the initial thoughts of software engineering about their professional future in a post-pandemic context.

Consequently, during the last wave, when all surveyed countries were out of lockdowns, we included a reflective question about the future of hybrid work. In particular, we asked “Many people expect that Hybrid Work is going to be the norm in the software industry. What are your thoughts on this?” In total, 103 informants provided a statement to our question. Data were then deductively categorized as positive, neutral, or negative sentiments toward hybrid work.

Afterward, we induced the individual codes into themes to grasp insights into personal beliefs of hybrid work.

4 RESULTS
In this section, we report the results of our analyses. Details of the performed tests are in the online supplementary materials.

4.1 Correlational analyses
In the first step, we tested for construct validity by correlating all 17 variables with each other separately for each data collection wave. Results of the zero-order Pearson and Spearman correlations were as expected across all waves. For example, well-being correlated negatively with stress, loneliness, and boredom and positively with the need for autonomy, competence, and relatedness, which is in line with the literature [27, 66, 82].

4.2 Changes along COVID-19 Pandemic
The results of the 17 repeated-measures ANOVAs are displayed in Table 2. Eight of the ANOVAs were significant at $\alpha = .004$. Well-being (Fig 1) increased, whereas emotional loneliness (Fig 6), generalized anxiety (Fig 5), and distractions at home (Fig 8) decreased. Behavioral disengagement decreased from wave 2 onwards (Fig 4). Interestingly, the quality of social contacts (Fig 9) showed a wave-form: It was lower during winter and early spring waves (i.e., April 2020, February 2021, and December 2021) than in later spring (i.e., May 2020, June 2021, and April 2022) when lockdowns were eased (i.e., in-person contacts were more accessible). No clear trend over time emerged for self-blame (Fig 3) and social loneliness (Fig 7). For well-being, for example, 62 developers reported higher levels at Wave 6 than at Wave 1, 28 lower levels, and 11 an equal amount of well-being (cf. Tab. 2). Interestingly, well-being increased between times 1 and 4, but then stayed relatively steady (Fig 1). In contrast, productivity remained stable over time (Fig 2).

In the next step, we ran 17 (dependent variables) $\times$ 7 (moderators) = 119 linear mixed-effects models to test whether past working from home experience, living alone (yes vs. no), income, gender (women vs. men), age, preference for working from home and having changed jobs predicted to change over time in any of the 17 dependent variables. We also included dependent variables for which we found no main effect (i.e., no change over time) because it is possible that, for example, productivity increased for those who were living alone but decreased for those who were not. However, none of the 119 interaction terms reached statistical significance at $\alpha = .001$, all $p$s > .005.

Note that the repeated-measures ANOVAs necessarily only included the 73 participants that took part in all six waves whereas descriptive statistics reported in Table 2 and Figures 1 to 9 all participants in each wave (e.g., 192 in wave 1) to improve prevision of the statistics we report in Appendix C.
Table 2. Within-subject ANOVAs for all 17 variables, significant variables at \( p \leq 0.004 \) highlighted. \( M_n \) represents the mean value of each wave and \( SD_n \) its standard deviation. Rows with a highlighted background colour indicate a significant variable.

| Variable            | M1   | SD1 | M2   | SD2 | M3   | SD3 | M4   | SD4 | M5   | SD5 | M6   | SD6 | F-value | p-value | Greater | Lower | Equal |
|---------------------|------|-----|------|-----|------|-----|------|-----|------|-----|------|-----|---------|---------|---------|-------|-------|
| Well-being          | 4.14 | 1.37| 4.34 | 1.29| 4.4  | 1.45| 4.7  | 1.45| 4.65 | 1.57| 4.62 | 1.47| 9.91    | < .001  | 62      | 28    | 11    |
| Productivity        | 0.99 | 0.42| 1.03 | 0.44| 1.07 | 0.44| 1.13 | 0.51| 1.05 | 0.39| 1.05 | 0.31| 2.36    | 0.039   | 52      | 36    | 10    |
| Boiredom            | 2.94 | 1.14| 2.93 | 1.16| 2.83 | 1.27| 2.77 | 1.18| 2.77 | 1.26| 2.69 | 1.18| 1.64    | 0.1474  | 32      | 61    | 7     |
| Behavioral disengagement | 1.8 | 0.94| 2.06 | 1.03| 1.88 | 1.11| 1.84 | 1.07| 1.91 | 1.15| 1.74 | 1.05| 3.79    | 0.0022  | 25      | 30    | 45    |
| Self-blame          | 1.81 | 0.99| 1.88 | 1.01| 2.28 | 1.29| 2.25 | 1.26| 2.31 | 1.26| 2.1  | 1.2  | 12.97   | < .001  | 40      | 27    | 33    |
| Distractions at home | 2.47 | 0.93| 2.44 | 0.9 | 2.41 | 0.96| 2.38 | 0.92| 2.35 | 0.91| 2.08 | 0.8 | 5.11    | < .001  | 23      | 49    | 27    |
| Generalized anxiety | 2.25 | 1   | 2.17 | 1   | 2.2  | 1.07| 2.1  | 1.06| 2.01 | 0.97| 1.97 | 0.96| 6.74    | < .001  | 28      | 58    | 13    |
| Emotional loneliness| 2.11 | 0.9 | 2.01 | 0.87| 2.1  | 0.91| 1.88 | 0.9 | 1.86 | 0.82| 1.67 | 0.75| 9.84    | < .001  | 20      | 58    | 21    |
| Social loneliness   | 2.64 | 1   | 2.56 | 1.02| 2.79 | 1.08| 2.73 | 1.04| 2.83 | 1.01| 2.55 | 1.14| 3.96    | 0.0015  | 30      | 47    | 22    |
| Need for relatedness| 3.5  | 0.83| 3.56 | 0.8 | 3.48 | 0.84| 3.59 | 0.82| 3.51 | 0.77| 3.54 | 0.82| 1.17    | 0.3205  | 47      | 46    | 7     |
| Need for competence  | 3.57 | 0.74| 3.58 | 0.73| 3.62 | 0.76| 3.67 | 0.74| 3.63 | 0.71| 3.76 | 0.75| 1.44    | 0.2982  | 56      | 34    | 10    |
| Need for autonomy   | 3.48 | 0.69| 3.51 | 0.73| 3.42 | 0.77| 3.51 | 0.77| 3.44 | 0.76| 3.46 | 0.72| 1.54    | 0.175   | 52      | 34    | 14    |
| Social contacts     | 4.11 | 1.09| 4.31 | 1.08| 4.07 | 1.12| 4.26 | 1.13| 4.11 | 1.12| 4.36 | 1.11| 3.98    | 0.0014  | 56      | 28    | 15    |
| Communication       | 4.53 | 1   | 4.29 | 1.19| 4.44 | 1.21| 4.38 | 1.2 | 4.36 | 1.17| 4.46 | 1.2 | 1.86    | 0.0096  | 39      | 38    | 18    |
| Stress              | 2.5  | 0.81| 2.52 | 0.8 | 2.52 | 0.88| 2.44 | 0.85| 2.49 | 0.81| 2.44 | 0.86| 1.28    | 0.2719  | 36      | 47    | 17    |
| Daily routines      | 4.68 | 1.56| 4.72 | 1.53| 4.83 | 1.58| 4.82 | 1.58| 4.84 | 1.48| 5.07 | 1.39| 0.79    | 0.5572  | 48      | 38    | 14    |
| Extraversion        | 3.45 | 0.79| 3.46 | 0.78| 3.47 | 0.8 | 3.46 | 0.71| 3.45 | 0.78| 3.44 | 0.8 | 0.42    | 0.8329  | 41      | 34    | 25    |

Fig. 1. Well-being across time. The red line displays the trend over time, whereas the box at each time point shows the range in which the middle 50% of the data falls. Responses were given on a 7-point scale ranging from 1 to 7.

4.3 Predictors of working from home

Only one of the variables was associated with the preference for working from home at \( \alpha = .003 \), the perceived preference of the company \( r(76) = .52, p < .001 \), indicating that developers select a company that matches their preference regarding WFH or adjust to the company’s preference.
Fig. 2. Productivity across time. The red line displays the trend over time, whereas the box at each time point shows the range in which the middle 50% of the data falls. Here, a productivity score of one indicates that productivity has not changed compared to pre-pandemic levels. Scores > 1 indicate that productivity increased and scores < 1 indicate that productivity decreased. The figure highlights an increase in productivity across the presented timepoints.

WFH was not associated with any other variables (Table 3). This suggests that people who prefer WFH have not and do not intend to change jobs more often than those who prefer WFH less. Also, preference for WFH was not associated with satisfaction with the company, solidarity with the company, or resilience.

We found a range of other meaningful associations among the variables we only measured in wave 6. First, having changed jobs between March 2020 and April 2022 predicted the intention to change jobs again. Further, general job satisfaction was positively associated with resilience, well-being, needs, social contact, communication, daily routines, and extraversion, as well as negatively with boredom, behavioral disengagement, self-blame, distractions, generalized anxiety, emotional and social loneliness, and stress. Solidarity with the company was positively associated with the same variables as job satisfaction. Resilience was positively associated with well-being, needs, quality of social contacts, communication, and extraversion, as well as negatively with boredom, behavioral disengagement, self-blame, distraction, generalized anxiety, emotional and social loneliness, and stress. Finally, the intention to change jobs was positively associated with boredom and negatively with autonomy.

To test which variables predicted intention to change jobs, we ran a multiple regression analysis with all variables measured only in wave 6 as independent variables since they are most directly relevant. We also included autonomy and boredom because they were most strongly associated with the intention to change jobs, age, and gender. Results showed that only low job satisfaction...
Table 3. Correlations of preference for working from home.

Note: Changed jobs since 03/2020 (0: N, 1: Y). Company preference for working in the office full time (0) vs working remotely full time (100). *p < .05, **p < .01, ***p < .001.

|                          | WFH | Changed jobs since 03/2020 | Job satisfaction | Solidarity to the company | Resilience | Intention |
|--------------------------|-----|----------------------------|------------------|----------------------------|------------|-----------|
| Working from home        | - .05 | - .05                       |                  |                            |            |           |
| Changed jobs             | - .04 | - .02                       |                  |                            |            |           |
| Job Satisfaction         | - .25* | - .16                       |                  |                            |            |           |
| Solidarity to Company    | - .11 | 0                           |                  |                            |            |           |
| Resilience               | 0    | 23*                         |                  |                            | .37***     |           |
| Intention to change jobs | .07  | .35***                      |                  |                            |            | - .16     |
| Well-being               | - .14 | - .02                       |                  |                            |            |           |
| Productivity             | - .03 | - .23*                      |                  |                            |            |           |
| Boredom                  | .13  | .14                         |                  |                            | - .35***   | - .42***  |
| Behavioral disengagement | .14  | .1                          |                  |                            | - .18      | - .3***   |
| Self-blame               | .13  | - .01                       |                  |                            | - .2       | - .26***  |
| Distraction              | .07  | .16                         |                  |                            | - .12      | - .33***  |
| Generalized anxiety      | .16  | .12                         |                  |                            | - .14      | - .3      |
| Emotional loneliness     | .11  | .09                         |                  |                            | - .21      | - .3***   |
| Social loneliness        | .17  | .07                         |                  |                            | - .49***   | - .39***  |
| Relatedness              | - .22* | - .02                       |                  |                            |            |           |
| Competence               | - .12 | - .11                       |                  |                            |            |           |
| Autonomy                 | - .14 | - .06                       |                  |                            |            |           |
| Social contact           | - .15 | - .01                       |                  |                            |            |           |
| Communication            | - .19 | .01                         |                  |                            | .31**      | .53***    |
| Stress                   | .08  | 0                           |                  |                            | - .35***   | - .32**   |
| Daily routines           | - .26** | - .11                       |                  |                            | .24        | .24*      |
| Extraversion             | - .16 | .13                         |                  |                            | .22        | .37***    |
| Age                      | - .13 | - .17                       |                  |                            | .08        | .03       |
| Gender (1: M, 2: F)      | .08  | .07                         |                  |                            | .01        | - .11     |

Table 4. Regression coefficients of variables predicting intention to change jobs

|                          | Estimate | Std. Error | t-value | p-value |
|--------------------------|----------|------------|---------|---------|
| (Intercept)              | 8.66     | 2.30       | 3.76    | 0.0004  ***|
| Working from home        | 0.00     | 0.01       | -0.20   | 0.8452  |
| Solidarity               | -0.19    | 0.14       | -1.35   | 0.1833  |
| Job Satisfaction W6      | -1.12    | 0.32       | -3.46   | 0.0010  ***|
| Commuting                | 0.01     | 0.13       | 0.11    | 0.9163  |
| Resilience               | 0.25     | 0.26       | 0.95    | 0.3459  |
| Changed jobs in the past | 1.20     | 0.38       | 3.16    | 0.0024  **|
| Company preference regarding WFH | 0.00 | 0.01  | -0.58   | 0.5618  |
| Age W6                   | -0.02    | 0.02       | -1.00   | 0.3199  |
| Gender W6                | 0.13     | 0.35       | 0.36    | 0.7185  |
| Boredom W6               | -0.10    | 0.21       | -0.49   | 0.6290  |
| Autonomy W6              | -0.23    | 0.36       | -0.64   | 0.5254  |

and having changed jobs predicted the intention to change jobs (Table 4). It is worth noting that the majority of developers reported a low intention to change jobs (median = 2.50 on a 1-7 scale, see section 3.2).

To test which variables predict job satisfaction, we again included the variables measured at wave 6 alongside the most strongly correlated with job satisfaction. Of the 14 predictors, only solidarity, $B = .18, SE = .05, p < .001$, distractions at home, $B = -.17, SE = .08, p = .04$, need for relatedness, $B = -.35, SE = .14, p = .01$, and communication with colleagues, $B = .31, SE = .08, p < .001$ were associated with job satisfaction (Table 5).
We then tested whether the association of preference for working remotely with the intention to change jobs is moderated by company policy for working remotely vs. returning to the office full-time. The interaction was significant, $B = -0.0004, SE = 0.0002, p = .043$. When the company preferred employees to work from the office, there was a positive association between their own preference for working remotely and intention to leave jobs, $B = 0.02, SE = 0.01, p = .05$. When the company’s preference was more flexible towards working remotely, this association was non-significant, $B = -0.01, SE = 0.01, p = .47$. This suggests that when the company wants their employees to return to the office but prefers working remotely, this can increase the intention to change jobs.

### 4.4 Between-group comparisons

The results of comparing people living in the United Kingdom and the USA in Table 7 (these were the two countries from which most of our participants came) across all 17 variables and all 6-time points. At Wave 1, our sample consisted of 63 people living in the UK and 52 in the USA. At Wave 4, 39 people living in the UK and 30 in the USA remained in the sample. None of the 102 between-country comparisons reached statistical significance at $\alpha = .001$, all $p$s $>.03$. Similarities between groups were large, mean PCR = 94.46, range = 77.30 – 99.92.
Table 6. Comparisons between women and men. M = mean, SD = standard deviation.

| Wave | Women M | Women SD | t-value | p-value | Cohen's d | PCR |
|------|---------|----------|---------|---------|-----------|-----|
| 1    | 3.80 ± 0.71 | 0.27 ± 0.11 | 5.04 | 0.0001 | 0.44 | 0.30 |
| 2    | 4.20 ± 0.66 | 0.28 ± 0.13 | 6.05 | 0.0000 | 0.47 | 0.33 |

Table 7. Comparisons between developers based in the United Kingdom and United States of America.

| Wave | UK M | UK SD | US M | US SD | t-value | p-value | Cohen's d | PCR |
|------|------|-------|------|-------|---------|---------|-----------|-----|
| 1    | 4.20 ± 0.66 | 0.28 ± 0.13 | 4.45 ± 0.59 | 0.30 ± 0.16 | 5.04 | 0.0001 | 0.44 | 0.30 |
| 2    | 4.20 ± 0.66 | 0.28 ± 0.13 | 4.45 ± 0.59 | 0.30 ± 0.16 | 6.05 | 0.0000 | 0.47 | 0.33 |

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4.5 Thematic Analysis
A vast majority of the surveyed informants reported a positive sentiment towards hybrid work in their future working lives (84.5%). They provided multiple reasons for this positive sentiment. A common motivation highlighted by the participants is the observation that the software industry is particularly well suited for hybrid work:

> It is an industry where this makes sense. I think this will end up becoming the norm also. [#19]

Others mention the possibility for a balance between more focused work at home and social interaction in the office:

> I like the idea of hybrid work because certain tasks get done faster in person, and it is easier to network in person compared to virtually. [#49]

Some professionals expressed the believe that hybrid work is more convenient for them and allow a better work-life balance:

> I enjoy hybrid work because I get to see and interact with coworkers [...] and spend more time with my family. [#58]

Management support is considered a key enabler of hybrid work. When organizations can involve developers and create a sense of belonging, informants are optimistic about the future outlook of hybrid work:

> Totally agree. [...] There is a sense of letting people work from home but making sure they are still motivated and feel a sense of belonging to the company. [#84]

All in all, there are several reasons why software engineers seem so positive. Companies might save resources on rentals and workspace management. At the same time, it is much more convenient for employees and improves work-life balance. Also, several respondents stated their belief that a hybrid work setting provides a tremendous productivity and well-being booster. Although project management changes are not trivial, they are considered addressable, especially with genuine support from management:

> I hope it will be because I prefer it. I feel there are benefits for companies as well, i.e., less demands on office space, no need to provide a computer, desk, and chair. I was often tired and listless due to commuting, and I think my company benefits from healthier and happier employees. In terms of programming, at home, I feel I can work uninterrupted but also take a walk, or make a drink, etc, if I need it to recharge my batteries. There are still challenges for companies, for example, in ensuring that the employees are on-task and productive. But this is just project management. My managers have been clear with me about deadlines and monitor my progress through regular meetings. It seems to work, I’m productive, and things get done. Also, at home, I get new ideas for how things can be improved, and I can look into them a bit and feed them back to my team. So you could argue that working from home makes me more creative and innovative. At work, it’s hard to be creative and innovative when you are being interrupted all the time, though I do understand that certain personality types do thrive in those very conditions. [#77]

A negative sentiment towards hybrid work is shared only among 6.8% of our informants. In those cases, there is a lack of trust in their organizations to restructure the internal processes and culture to fit hybrid work practices:

> Unlikely due to management culture. [#62]
Personal preferences do also play a role. Some are more acquainted with the office environment and perceive daily physical interaction with colleagues as pivotal for their productivity:

Personally, I prefer to be in an office environment. [...] It’s far better, in my opinion, to work in an office environment with others, even though I’m an introvert and like spending my free time on my own. [#95]

Finally, some developers have a neutral sentiment towards hybrid work (8.7%). Some of our respondents point to their local culture as playing a role in the adoption of hybrid work practices. Those with a flat hierarchy are more likely successfully work hybrid:

I think it depends from country to country. More progressive countries will likely keep some level of remote work, while more conservative countries will probably want people back in offices. [#2]

Similarly, company culture also plays a significant role in the likelihood of adopting hybrid policies:

There is also still this old school mentality of “if you’re not in the office at your desk, you’re not working” that is still pretty prevalent, at least where I am, so I can see that hybrid might work as a compromise for those business leaders who may not want to allow their workforce to be fully remote. [#8] (…)

The type of task or project software engineers have to perform can also be a variable where hybrid might be a suitable option:

It may be beneficial in some cases, depending on the type of project and, more importantly, the project phase (specs, coding, testing). [#40]

It depends on the role of the job. For managing hardware and servers, you do sometimes need to be there in person. For programming/coding and such like there is no need to actually be in an office, so this could be done 100% of the time from any location. [#78]

To conclude, there is a strong sentiment among developers that hybrid work will be the new norm in the tech industry. Several issues emerged from our informants. First, company culture and management support is a clear enabler or inhibitor for a hybrid transition. Second, type of task is considered a decisive factor when hybrid work agreements since some are not seen suited for it. Third, how face-to-face communication opportunities will happen in organizations and the threat of jeopardized contacts is a widely shared concern. Although developers feel confident working remotely, they also believe synchronization and alignment opportunities are crucial to performing the assigned task.

5 DISCUSSION

Building on the collected evidence and the previous literature, we discuss the implications of our investigation for software professionals and organizations. Furthermore, we explain the intrinsic limitations of this study and how we tried to cope with them.

First, however, readers should be aware that our findings are based on group-level inferences, which do not always generalize to the individual level. For example, the results of the within-subject ANOVAs inform us whether the average of a variable changed over time, not whether all individuals changed in the same direction. As seen in Table 2, while the well-being of 77 developers increased between Wave 1 and 4, the well-being of 38 developers dropped. Thus, it is approximately twice as likely to find a developer whose well-being increased instead of dropped. Interestingly, the change over time was not always linear. For example, emotional loneliness went down between Wave 1 and Wave 2, then slightly up again at Wave 3, before declining until wave 6. This might be because many countries started to (announce plans to) open up again around the time when we collected
the second wave. In contrast, the third wave was collected in February 2021: In the UK and USA, for example, in winter 2020/21, the deaths of many more people were associated with COVID-19 compared to spring 2020. During waves 4-6, more and more people got vaccinated, allowing more in-person interactions. We observed a similar pattern for the quality of social contacts. Similarly, there are a range of situational factors or variables which we have not measured, such as the perceived severity of local lockdowns or loss of a loved one (e.g., because of COVID-19) that would likely have explained additional variance in developers’ well-being and productivity. Nevertheless, we aimed to provide generalizable evidence with this longitudinal study. Our qualitative investigations (e.g., [12, 34, 65]) add to a nuanced understanding of individual phenomena. These and other studies should also be considered when drawing company guidelines since our recommendations will be partial.

5.1 Implications
Based on our results, we provide recommendations for the software engineering community (cf. also Table 8).

We found that developers’ well-being increased over time. We have no pre-pandemic data, so we can not assess how the lockdown initially impacted software professionals. It could be that their well-being went down in the Spring of 2020 and is now bouncing back to pre-pandemic times. This reasoning would align with previous research showing that people’s well-being usually bounces back after a significant negative event [71]. While research from the start of the pandemic (i.e., Spring 2020) indicates that developers’ well-being decreased initially [78], our findings provide a more positive outlook that developers’ well-being bounced back. Our findings also suggest that working from home does not negatively impact developers’ well-being: otherwise, well-being would not have increased as much. Our data show how well-being increased until June 2021 and then remained constant till the end of the pandemic (cf. Figure 1). Furthermore, working from home was in wave 6 uncorrelated with well-being. This indicates that software engineers learned to cope with the new enforced setting. As a confirmation to that, more relaxed public health policies implemented from the Summer 2021 did not affect significantly developers’ well-being.

Productivity remained constant during the pandemic. Although we report a slight increase in productivity over the six data collection waves (as plotted in Figure 2), and more people reported an increase in productivity compared to those who reported a decrease (cf. Table 2), the mean differences are non-significant ($p = .13$), indicating that the observed increase could very well be random and might not replicate. Since measuring productivity is non-trivial, we followed a previous study example [82] by measuring productivity as a self-reported function compared to the pre-pandemic period. Therefore, we conclude that software professionals’ productivity level remained the same throughout the lockdown and compared to the pre-pandemic time. This finding also contradicts previous research suggesting that the lockdown is detrimental to productivity [77], possibly because of differences in the research design (cross-sectional vs. longitudinal design) and operationalization of productivity (Ralph et al. [77] used a different measure of productivity). Alternatively (or additionally), we collected our sample approximately one month after Ralph et al. [77] and predominantly from relatively underrepresented countries in the sample of Ralph et al., who recruited most of their participants from Germany, Russia, and Brazil. Our results substantiate our previous conclusion that a hybrid or full remote working environment would not per se harm the productivity levels of developers.

Even though all typical welfare support (e.g., childcare, schools, and sports facilities) was closed, software engineers showed a high level of adaptation by keeping the same productivity levels and steadily increasing their well-being levels. Consequently, in a post-pandemic working from home context, with all support facilities normally running, working from home is very unlikely to
impact developers’ well-being negatively. Qualitative findings support this argument, suggesting that working from home significantly improved work-life balance [34]. Similarly, a large-scale cross-sectional study observed that 89% of the surveyed professionals would like to continue to work remotely (especially in a hybrid fashion), also in the future to come [99]. However, previous research regarding the impact of working from home on productivity is mixed. Some studies found that working from home is positively or unrelated to productivity [4, 25, 82], whereas other research found that working from home has some negative effects [37, 50, 67]). Interestingly, the studies which found that working from home is negatively associated with productivity were conducted in India and Japan, whereas those which found positive effects in the UK and USA. This finding provides some support for the individualism-collectivism hypothesis [46]: People in collectivist cultures might struggle more to work alone and prefer working in teams. However, this reasoning is highly speculative as the individualism-collectivism hypothesis has been increasingly challenged in recent years [93].

Software professionals felt less lonely and improved their social contacts. During the first lockdown in Spring 2020, many people had to reduce their social interactions abruptly [19]. As a consequence, this increased the sense of loneliness and isolation. Nevertheless, also, in this case, developers showed a high level of resilience. Indeed, we report a significant decrease in emotional loneliness and an increase in the quality of social contact. This is a possible indication that software engineers increasingly reached out to their social contacts when they felt lonely, thereby coping well with the challenging conditions of the pandemic. Similarly, the quality of their relationships increased. This is important because having a reliable social support network is an essential coping mechanism, especially in hard times and in moments of high stress [17, 100].

These findings are relevant for organizations planning to implement a hybrid or remote work policy. Software engineers showed a high level of resilience when coping with unexpected events. At the same time, their social network was of crucial support while working from home. This insight is also supported by previous research, where communication was found to be a relevant predictor for developers’ satisfaction during the lockdown [65]. Consequently, a proactive company policy of employee inclusion would sustain their well-being levels. This would require a particular effort from the middle management (because they are the direct company interface for each employee) to ensure that every team member can express themselves and maintain stimulating and nurturing relationships with their peers since even interacting with weak social ties (i.e., acquaintances) can improve people’s well-being [85].

Moreover, we also found that self-blame increased. This finding was unexpected and might relate to the phenomenon known as survivor’s guilt [47], which has been observed, for example, among caretakers of cancer patients and is positively associated with remorse [53]. We speculate that self-blame is positively associated with survivor’s guilt (e.g., of not having been affected by COVID-19) and remorse and might be stronger among those developers who experienced loss (e.g., a relative who died because of COVID-19). Mindful organizations might specifically offer employees psychological support to address guilt and remorse.

We found no mean differences between the UK and USA. We found high levels of similarities in how software professionals were impacted in the USA and the UK. This might be the result of the reliance of national health authorities on the World Health Organization, making lockdown measures fairly uniform between both countries.

Preference for working from home was only associated with developers’ perceived preference of the company regarding their WFH policy. Based on previous research on value change [3], we derive that both self-selection as well as socialization effects play a role here. Consequently, the preference for working from home might depend on self-selection (developers only start to work at companies that match their own preference) or socialization effects (developers preference
change while working at a company). Indeed, preference for working from home was not associated with satisfaction and solidarity with the company. This non-significant finding is in our view encouraging because it shows that people who prefer working from home are equally satisfied and solidary with the company as well as equally productive than developers who are less keen to work from home. Interestingly, we found that when the company preferred employees to work from the office, developers who preferred working remotely were more likely to change jobs. This suggests that a mismatch between employees and employers expectations regarding remote work can increase the chance of resignation.

This point is tightly connected to **the Future of Work**. Most our informants agree that it will be different from what it used to be before the pandemic. How different it will be is a question that will be asked with time. Right now, for the foreseeable future, there is a large consensus among our informants that there will be a number of different work arrangements. The first issue to mention is that organizations should account for individual differences between developers. Namely, when we performed cross-country comparisons, we had to acknowledge that the within-country variability outweighed the between-country variability. This is a strong indicator that suggests high personality differences, that can not be captured with one-fits-all solutions. In this regard, Smite et al., discuss the spectrum of different types of work arrangements based on two dimensions: work location (from fully remote to fully in-presence), and work schedule (i.e., fixed or flexible) [87]. However, to do so, a change in company culture and management support is an underlying assumption for our surveyed developers. More in detail, work arrangements should depend not only on individual preferences, but also on the type of task that has to be performed (cf. [81]). For example, a development team that is relying on pair programming practices, might agree on a flexible location setting, but their work schedules have to be fully aligned. The last big challenge is the set up of face-to-face communication opportunities among colleagues. Creating a sense of belonging and ownership is critical, especially for remote teams with a flexible schedule mode. In this regard, embedding activities within the project lyfeecicle aimed at “re-socializing” to align behaviors and norms needed to understand and work within a specific organization has proven effective [70].

### 5.2 Limitations

In the following section, we discuss the most relevant limitations of this work.

**Reliability.** For this investigation, we employed a six wave longitudinal design. Informants have been identified through a multi-stage selection screening to ensure they were representative of the software engineering population. Also, we computed an *a priori* power analysis to identify the minimum number of participants required to provide reliable conclusions. The internal consistencies (i.e., Cronbach’s *α*) ranged from satisfactory to very good.

**Construct validity.** For this study we used 15 variables previously identified in the literature that are related to well-being and productivity. For any variable, we used a dedicated measurement instrument. Construct validity was assessed by correlating all variables with each other, separately in each wave. The correlations were in the expected directions and in line with the literature [27, 66, 82].

**Conclusion validity.** We draw the conclusions based on a number of statistical analyses: within-subject ANOVA, between-subject t-tests. Further we performed a thematic analysis. To increase the trustworthiness of our results, we adjusted our alpha-thresholds to reduce the risk of false positives (i.e., Type I errors). In terms of data collection, some variations might have been out of our control since lockdown measures were not uniform in different countries. To address this issue, we only selected participants living in countries that during the first wave had similar regulations (we excluded, e.g., Sweden, Denmark). Nevertheless, minor variations in terms of rules happened during the pandemic in the different countries we had no control over. However, we report very similar
Table 8. Summary of key findings & recommendations

| Findings                                                                 | Recommendations                                                                                      |
|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|
| Developers’ well-being increased during the pandemic                   | Well-being consistently increased across all six time points, indicating that they bounced back from the negative impact the pandemic likely had on their well-being initially. |
| Productivity remained unchanged                                         | Developers’ productivity has not changed across all six time points.                                   |
| Developers felt less lonely and improved their social contacts in general| This suggests that developers managed to reduce their loneliness, presumably by improving the quality and quantity of their social interactions. |
| Self-blame increased                                                    | Levels of self-blame increased over time.                                                             |
| No country difference (USA vs UK) when dealing with the pandemic        | Our findings indicate that people living in the UK and the USA were impacted and ‘recovered’ from the initial shock of the pandemic to a similar extent. |
| The Future of Work will be diverse.                                    | When the company preferred employees to work from the office, developers who preferred working remotely were more likely to intent to change jobs. |

Results when looking at between-country mean differences. Our conclusions are reproducible since we made the anonymized raw data and R analysis code openly available on Zenodo. Moreover, some of our conclusions are based on general measures. For example, while we found that the quality of social contacts correlated positively with well-being and improved between wave 1 and 6, it is unclear which social contacts were mostly responsible for this. Thus, future research could directly ask for the quality of contact for various social relationships (e.g., with partner, family, friends, colleagues) and correlate the outcomes with well-being to get a better understanding of which social contact contribute most to developers well-being.

Internal validity. Our study relies on self-reported measures, limiting the validity due to potential response biases. Although our informants have been initially identified in other work [83], we applied several quality checks also after each time point. Additionally, we searched for inaccurate or unlikely responses (of which we found none, which ensures data quality). The attrition rate across the six waves is comparable to other longitudinal studies across a similar timespan [3, 31].
Due to the evolving nature of the pandemic, data collection has been performed based on the information available by that point in time. As a consequence, the time spans are not homogeneous but represent moments of the pandemic where data collection seemed to be representative of the pandemic trend. This might have affected the variability of our data.

External validity. The primary aim of our longitudinal analysis was to maximize internal validity by finding significant effects. Thus, we did not look to work with a representative sample of the software engineering population (e.g., such as Russo & Stol did with \( N \approx 500 \) to generalize their findings [83]). However, we acknowledge, we only included software developers who were working for at least 20h/week, which limits the generalizability of our findings to software developers who are at least working part-time. There might have been an unknown number of developers whose work-related productivity substantially declined because of health issues or caring responsibilities, for example.

6 CONCLUSION

In this investigation, we performed a six-wave longitudinal study over 24 months from the start of the COVID-19 pandemic in April 2020 to April 2022, involving 192 software developers. We analyzed how well-being and productivity of software engineers and 15 related social and psychological variables changed over time. Additionally, we compared developers based in the USA to those based in the UK.

We found that well-being, quality of social contacts, and self-blame increased over time while emotional loneliness decreased. Also, people living in the UK and USA did not differ for any of the variables we measured across all six data collection waves. Further, we found in wave 6 that preference for working from home was not associated with productivity, well-being, solidarity towards the company, and job satisfaction, indicating that developers who prefer working from home are as productive, solidary, and satisfied with their job than those who prefer more working from the office. Job satisfaction and solidarity with the company were both negatively associated with the intention to change jobs, boredom, and loneliness but positively with well-being and needs. Interestingly, neither job satisfaction nor solidarity with the company was associated with productivity.

The significance of our conclusions lies in the extensiveness of our investigation (i.e., over two years) during the COVID-19 pandemic. We carefully selected our informants after an a priori power analysis to ensure the trustworthiness of our results and adjusted our alpha level to reduce the risk of false-positive results and misleading recommendations. So far, this is the most comprehensive longitudinal analysis involving software engineers to understand the effects of the COVID-19 pandemic on their well-being and productivity. Moreover, while our results are especially relevant in another disastrous event, they also help the software engineering community provide better-informed recommendations for future Working from Home policies after the pandemic. Similarly, this paper offers an outlook into the future of work and how the software profession might change after the pandemic.

Future works will therefore need to focus on a prolonged assessment of software engineers’ working conditions and work arrangements. In particular, new investigations are needed to understand how software professionals’ well-being and productivity will be affected by more flexible working arrangements and how this will eventually affect software projects.

SUPPLEMENTARY MATERIALS

The complete replication package is openly available under a CC BY 4.0 license on Zenodo, DOI: https://doi.org/10.5281/zenodo.7391051.
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REFERENCES

[1] Amanda J Anderson, Seth A Kaplan, and Ronald P Vega. 2015. The impact of telework on emotional experience: When, and for whom, does telework improve daily affective well-being? European Journal of Work and Organizational Psychology 24, 6 (2015), 882–897. https://doi.org/10.1080/1359432X.2014.966086

[2] YaMei Bai, Chao-Cheng Lin, Chih-Yuan Lin, Jen-Yeu Chen, Ching-Mo Chue, and Pesus Chou. 2004. Survey of stress reactions among health care workers involved with the SARS outbreak. Psychiatric Services 55, 9 (2004), 1055–1057. https://doi.org/10.1176/appi.ps.55.9.1055

[3] Anat Bardi, Kathryn E Buchanan, Robin Goodwin, Letitia Slabu, and Mark Robinson. 2014. Value stability and change during self-chosen life transitions: Self-selection versus socialization effects. Journal of Personality and Social Psychology 106, 1 (2014), 131–147. https://doi.org/10.1037/a0034818

[4] Jose Maria Barrero, Nicholas Bloom, and Steven J Davis. 2021. Why working from home will stick. Technical Report. National Bureau of Economic Research.

[5] Yehuda Baruch. 2000. Teleworking: benefits and pitfalls as perceived by professionals and managers. New Technology, Work and Employment 15, 1 (2000), 34–49.

[6] Kira S Birditt and Toni C Antonucci. 2007. Relationship quality profiles and well-being among married adults. Journal of Family Psychology 21, 4 (2007), 595–604. https://doi.org/10.1037/0893-3200.21.4.595

[7] Nicholas Bloom, James Liang, John Roberts, and Zhichun Jenny Ying. 2015. Does working from home work? Evidence from a Chinese experiment. The Quarterly Journal of Economics 130, 1 (2015), 165–218. https://doi.org/10.1093/qje/qju032

[8] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. Qualitative Research in Psychology 3, 2 (2006), 77–101.

[9] Virginia Braun and Victoria Clarke. 2019. Reflecting on reflexive thematic analysis. Qualitative Research in Sport, Exercise and Health 11, 4 (2019), 589–597.

[10] Virginia Braun and Victoria Clarke. 2021. One size fits all? What counts as quality practice in (reflexive) thematic analysis? Qualitative Research in Psychology 18, 3 (2021), 328–352.

[11] Samantha K Brooks, Rebecca K Webster, Louise E Smith, Lisa Woodward, Simon Wessely, Neil Greenberg, and Gideon James Rubin. 2020. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. The Lancet 395 (2020). https://doi.org/10.1016/S0140-6736(20)30460-8

[12] Jenna Butler and Sonia Jaffe. 2021. Challenges and gratitude: A diary study of software engineers working from home during covid-19 pandemic. In International Conference on Software Engineering. IEEE, 362–363.

[13] Bernardo Caldarola and Steve Sorrell. 2022. Do teleworkers travel less? Evidence from the English National Travel Survey. Transportation Research Part A: Policy and Practice 159 (2022), 282–303. https://doi.org/10.1016/j.tra.2022.03.026

[14] Grazia Caleo, Jennifer Duncombe, Freya Jephcott, Kamalini Lokuge, Clair Mills, Evita Looijen, Fivi Theoharaki, Ronald Kremer, Karline Kleijer, James Squire, et al. 2018. The factors affecting household transmission dynamics and community compliance with Ebola control measures: a mixed-methods study in a rural village in Sierra Leone. BMC Public Health 18, 248 (2018). https://doi.org/10.1186/s12889-018-5158-6

[15] Katarzyna Cantarero, Wijnand AP van Tilburg, and Ewelina Smoktunowicz. 2021. Affirming basic psychological needs promotes mental well-being during the COVID-19 outbreak. Social Psychological and Personality Science 12, 5 (2021), 821–828. https://doi.org/10.1177/1948550620947208

[16] Charles S Carver. 1997. You Want to Measure Coping But Your Protocol’s Too Long: Consider the Brief COPE. International Journal of Behavioral Medicine 4, 1 (1997), 92.

[17] Charles S Carver, Michael F Scheier, and Jagdish K Weintraub. 1989. Assessing coping strategies: a theoretically based approach. Journal of Personality and Social Psychology 56, 2 (1989), 267–283. https://doi.org/10.1037/0022-3514.56.2.267

[18] Wayne F Cascio. 2000. Managing a virtual workplace. Academy of Management Perspectives 14, 3 (2000), 81–90.

[19] Ho Fai Chan, Jordan W Moon, David A Savage, Ahmed Skali, Benno Torgler, and Stephen Whyte. 2021. Can psychological traits explain mobility behavior during the COVID-19 pandemic? Social Psychological and Personality Science 12, 6 (2021), 1018–1029. https://doi.org/10.1177/1948550620952572

[20] CIPD. 2020. Getting the most from remote working. https://www.cipd.co.uk/knowledge/fundamentals/relations/ flexible-working/remote-working-top-tips.

[21] Sheldon Cohen, Tom Kamarck, and Robin Mermelstein. 1983. A global measure of perceived stress. Journal of health and social behavior (1983), 385–396. https://doi.org/10.2307/2136404

ACM Trans. Softw. Eng. Methodol., Vol. 37, No. 4, Article 111. Publication date: November 2022.
[22] Adrian-Alexandru Cucolas and Daniel Russo. 2022. The Impact of Working From Home on the Success of Scrum Projects: A Multi-Method Study. *Journal of Software and Systems* (2022).

[23] Danish Health Authority. 2020. Questions and answers on novel coronavirus. https://www.sst.dk/da/Viden/Smitsomme-sygdomme/Smitsomme-sygdomme-A-AA/Coronavirus/Spoergsmaal-og-svar/Questions-and-answers.

[24] Reinout E. de Vries. 2013. The 24-item Brief HEXACO Inventory (BHI). *Journal of Research in Personality* 47, 6 (2013), 871–880. https://doi.org/10.1016/j.jrp.2013.09.003

[25] Sumit S Deole, Max Deter, and Yue Huang. 2021. Home Sweet Home: Working from home and employee performance during the COVID-19 pandemic in the UK. Technical Report.

[26] Ed Diener, Robert A Emmons, Randy J Larsen, and Sharon Griffin. 1985. The satisfaction with life scale. *Journal of Personality Assessment* 49, 1 (1985), 71–75.

[27] Ed Diener, Richard E Lucas, and Christie Napa Scollon. 2009. Beyond the hedonic treadmill: Revising the adaptation theory of well-being. In *The science of well-being*. Springer, 103–118.

[28] Noelle Donnelly and Sarah B Proctor-Thomson. 2015. Disrupted work: home-based teleworking (HbTW) in the aftermath of a natural disaster. *New Technology, Work and Employment* 30, 1 (2015), 47–61.

[29] Richard Farmer and Norman D Sundberg. 1986. Boredom proneness—the development and correlates of a new scale. *Journal of Personality Assessment* 50, 1 (1986), 4–17. https://doi.org/10.1207/s15327752ja5001_2

[30] Franz Faul, Edgar Erdfelder, Axel Buchner, and Albert-Georg Lang. 2009. Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods* 41, 4 (2009), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

[31] Matthew Feinberg, Chloe Kovacheff, Rimma Teper, and Yoel Inbar. 2019. Understanding the process of moralization: How eating meat becomes a moral issue. *Journal of Personality and Social Psychology* 117, 1 (2019), 50. https://doi.org/10.1037/pspa0000149

[32] Colin MG Foad, Lorraine Whitmarsh, Paul HP Hanel, and Geoffrey Haddock. 2021. The limitations of polling data in understanding public support for COVID-19 lockdown policies. *Royal Society Open Science* 8, 7 (2021), 210678. https://doi.org/10.1098/rsos.210678

[33] Denae Ford, Reed Miliewicz, and Alexander Serebrenik. 2019. How remote work can foster a more inclusive environment for transgender developers. In *Proceedings of the International Workshop on Gender Equality in Software Engineering*. IEEE, 9–12.

[34] Denae Ford, Margaret-Anne Storey, Thomas Zimmermann, Christian Bird, Sonia Jaffe, Chandra Maddila, Jenna L Butler, Brian Houck, and Nachiappan Nagappan. 2020. A Tale of Two Cities: Software Developers Working from Home During the COVID-19 Pandemic. *arXiv preprint arXiv:2008.11147* (2020).

[35] Marylène Gagné and Edward L Deci. 2005. Self-determination theory and work motivation. *Journal of Organizational behavior* 26, 4 (2005), 331–362. https://doi.org/10.1002/job.322

[36] Gallup. 2020. Is Working Remotely Effective? Gallup Research Says Yes. (2020). https://www.gallup.com/workplace/283985/working-remotely-effective-gallup-research-says-yes.aspx

[37] Michael Gibbs, Friederike Mengel, and Christoph Siemroth. 2021. *Work from Home & Productivity: Evidence from IT Professionals*. Technical Report 2021-56. University of Chicago, Becker Friedman Institute for Economics.

[38] Jenny De Jong Gierveld and Theo Van Tilburg. 2006. A 6-item scale for overall, emotional, and social loneliness: Confirmatory tests on survey data. *Research on Aging* 28, 5 (2006), 582–598. https://doi.org/10.1177/0164027506289723

[39] Hong Guo. 2001. Special requirements for software process improvement applied in teleworking environments. In *Proceedings of the Second Asia-Pacific Conference on Quality Software*. IEEE, 331–340.

[40] Eva Gutierrez-Sigut, Veronica M Lamarche, Katherine Rowley, Emilio Ferreiro Lago, María Jesús Pardo-Guijarro, Ixone Saenz, Berta Frigola, Santiago Frigola, Delfina Aliaga, and Laura Goldberg. 2022. How do face masks impact communication amongst deaf/HoH people? *Cognitive Research: Principles and Implications* 7, 1 (2022), 1–23. https://doi.org/10.1186/s41235-022-00431-4

[41] Joseph F Hair, William C Black, Barry J Babin, Rolph E Anderson, Ronald L Tatham, et al. 2013. *Multivariate data analysis*. Vol. 7th ed. Pearson Education.

[42] Paul H P Hanel, Gregory R Maio, and Antony SR Manstead. 2019. A new way to look at the data: Similarities between groups of people are large and important. *Journal of Personality and Social Psychology* 116, 4 (2019), 541–562. https://doi.org/10.1037/pspi0000154

[43] Ixone Saenz, Berta Frigola, Santiago Frigola, Delfina Aliaga, and Laura Goldberg. 2022. How do face masks impact communication amongst deaf/HoH people? *Cognitive Research: Principles and Implications* 7, 1 (2022), 1–23. https://doi.org/10.1186/s41235-022-00431-4

[44] Frederick Herzberg, Bernard Mausner, and B. B. Snyderman. 2017. *Motivation to work*. Transaction Publishers, London.
[69] General Assembly of the World Medical Association et al. 2014. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. The Journal of the American College of Dentists 81, 3 (2014), 14.

[70] Ilan Oshri, Julia Kotlarsky, and Leslie P Willcocks. 2007. Global software development: Exploring socialization and face-to-face meetings in distributed strategic projects. The Journal of Strategic Information Systems 16, 1 (2007), 25–49.

[71] Andrew J Oswald and Nattavudh Powdthavee. 2008. Does happiness adapt? A longitudinal study of disability with implications for economists and judges. Journal of Public Economics 92, 5-6 (2008), 1061–1077. https://doi.org/10.1016/j.jpubeco.2008.01.002

[72] Andrew J Oswald, Eugenio Proto, and Daniel Sgroi. 2015. Happiness and productivity. Journal of labor economics 33, 4 (2015), 789–822. https://doi.org/10.1086/681096

[73] Owl Labs. 2019. State of Remote Work 2019. Report (2019). https://www.owllabs.com/state-of-remote-work/2019

[74] Stefan Palan and Christian Schitter. 2018. Prolific.ac—A subject pool for online experiments. Journal of Behavioral and Experimental Finance 17 (2018), 22–27.

[75] Chris Pounder. 1998. Homeworking: No longer an easier option? Computers & Security 17, 1 (1998), 27–30.

[76] Gabriele Prati, Luca Pietrantoni, and Bruna Zani. 2011. A social-cognitive model of pandemic influenza H1N1 risk perception and recommended behaviors in Italy. Risk Analysis: An International Journal 31, 4 (2011), 645–656.

[77] Paul Ralph et al. 2020. Empirical standards for software engineering research. arXiv preprint arXiv:2010.03525 (2020).

[78] Paul Ralph et al. 2020. Pandemic Programming: How COVID-19 affects software developers and how their organizations can help. Empirical Software Engineering (2020). https://doi.org/10.1007/s10664-020-09875-y

[79] Diane L Reynolds, JR Garay, SL Deamond, Maura K Moran, W Gold, and R Styra. 2008. Understanding, compliance and psychological impact of the SARS quarantine experience. Epidemiology & Infection 136, 7 (2008), 997–1007. https://doi.org/10.1017/S0950268807009156

[80] Daniel Russo, Paul H P Hanel, Seraphina Altnickel, and Niels van Berkel. 2021. The daily life of software engineers during the covid-19 pandemic. In International Conference on Software Engineering. IEEE, 364–373.

[81] Daniel Russo, Paul H P Hanel, Seraphina Altnickel, and Niels van Berkel. 2021. Developers Activity Satisfaction and Performance during the COVID-19 Pandemic. arXiv preprint arXiv:2107.07944 (2021).

[82] Daniel Russo, Paul H P Hanel, Seraphina Altnickel, and Niels van Berkel. 2021. Predictors of Well-being and Productivity among Software Professionals during the COVID-19 Pandemic–A Longitudinal Study. Empirical Software Engineering 26, 62 (2021), 1–64. https://doi.org/10.1007/s10664-021-09945-9

[83] Daniel Russo and Klaas-Jan Stol. 2020. Gender Differences in Personality Traits of Software Engineers. IEEE Transactions on Software Engineering 48, 3 (2020), 16.

[84] Richard M Ryan and Edward L Deci. 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist 55, 1 (2000), 68–78.

[85] Gillian M Sandstrom and Elizabeth W Dunn. 2014. Social interactions and well-being: The surprising power of weak ties. Personality and Social Psychology Bulletin 40, 7 (2014), 910–922. https://doi.org/10.1177/0146167214529799

[86] Kennon M Sheldon and Jonathan C Hilpert. 2012. The balanced measure of psychological needs (BMPN) scale: An alternative domain general measure of need satisfaction. Motivation and Emotion 36, 4 (2012), 439–451. https://doi.org/10.1007/s11031-012-9279-4

[87] Darja Smite, Anastasiia Tkлич, Nils Brede Moe, Efi Papatheocharous, Eriks Klotins, and Marte Pettersen Buvik. 2022. Changes in perceived productivity of software engineers during COVID-19 pandemic: The voice of evidence. Journal of Systems and Software 186 (2022), 11197.

[88] Bruce W Smith, Jeanne Dalen, Kathryn Wiggins, Erin Tooley, Paulette Christopher, and Jennifer Bernard. 2008. The brief resilience scale: assessing the ability to bounce back. International Journal of Behavioral Medicine 15, 3 (2008), 194–200. https://doi.org/10.1007/s10734-007-9081-z

[89] Robert L Spitzer, Kurt Kroenke, Janet BW Williams, and Bernd Löwe. 2006. A brief measure for assessing generalized anxiety disorder: the GAD-7. Archives of Internal Medicine 166, 10 (2006), 1092–1097.

[90] Ginny Sprang and Miriam Silman. 2013. Posttraumatic stress disorder in parents and youth after health-related disasters. Disaster medicine and public health preparedness 7, 1 (2013), 105–110. https://doi.org/10.1017/dmp.2013.22

[91] Andyri A Struk, Jonathan SA Carriere, J Allan Cheyne, and James Danckert. 2017. A short boredom proneness scale: Development and psychometric properties. Assessment 24, 3 (2017), 346–359. https://doi.org/10.1177/1073191115609996

[92] Yohtaro Takano and Eiko Osaka. 2018. Comparing Japan and the United States on individualism/collectivism: A follow-up review. Asian Journal of Social Psychology 21, 4 (2018), 301–316. https://doi.org/10.1111/ajsp.12322

[93] Gabriele Prati, Luca Pietrantoni, and Bruna Zani. 2011. A social-cognitive model of pandemic influenza H1N1 risk perception and recommended behaviors in Italy. Risk Analysis: An International Journal 31, 4 (2011), 645–656.

[94] Richard M Ryan and Edward L Deci. 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist 55, 1 (2000), 68–78.

[95] Gillian M Sandstrom and Elizabeth W Dunn. 2014. Social interactions and well-being: The surprising power of weak ties. Personality and Social Psychology Bulletin 40, 7 (2014), 910–922. https://doi.org/10.1177/0146167214529799

[96] Kennon M Sheldon and Jonathan C Hilpert. 2012. The balanced measure of psychological needs (BMPN) scale: An alternative domain general measure of need satisfaction. Motivation and Emotion 36, 4 (2012), 439–451. https://doi.org/10.1007/s11031-012-9279-4

[97] Darja Smite, Emily L. Christensen, Paolo Tell, and Daniel Russo. 2023. The Future Workplace: Characterizing the Spectrum of Hybrid Work Arrangements for Software Teams. IEEE Software (2023).

[98] Darja Smite, Anastasiia Tklich, Nils Brede Moe, Efi Papatheocharous, Eriks Klotins, and Marte Pettersen Buvik. 2022. Changes in perceived productivity of software engineers during COVID-19 pandemic: The voice of evidence. Journal of Systems and Software 186 (2022), 11197.

[99] Bruce W Smith, Jeanne Dalen, Kathryn Wiggins, Erin Tooley, Paulette Christopher, and Jennifer Bernard. 2008. The brief resilience scale: assessing the ability to bounce back. International Journal of Behavioral Medicine 15, 3 (2008), 194–200. https://doi.org/10.1007/s10734-007-9081-z

[100] Robert L Spitzer, Kurt Kroenke, Janet BW Williams, and Bernd Löwe. 2006. A brief measure for assessing generalized anxiety disorder: the GAD-7. Archives of Internal Medicine 166, 10 (2006), 1092–1097.

[101] Ginny Sprang and Miriam Silman. 2013. Posttraumatic stress disorder in parents and youth after health-related disasters. Disaster medicine and public health preparedness 7, 1 (2013), 105–110. https://doi.org/10.1017/dmp.2013.22

[102] Andyri A Struk, Jonathan SA Carriere, J Allan Cheyne, and James Danckert. 2017. A short boredom proneness scale: Development and psychometric properties. Assessment 24, 3 (2017), 346–359. https://doi.org/10.1177/1073191115609996

[103] Yohtaro Takano and Eiko Osaka. 2018. Comparing Japan and the United States on individualism/collectivism: A follow-up review. Asian Journal of Social Psychology 21, 4 (2018), 301–316. https://doi.org/10.1111/ajsp.12322

[104] Gabriele Prati, Luca Pietrantoni, and Bruna Zani. 2011. A social-cognitive model of pandemic influenza H1N1 risk perception and recommended behaviors in Italy. Risk Analysis: An International Journal 31, 4 (2011), 645–656.
[95] Ronald P Vega, Amanda J Anderson, and Seth A Kaplan. 2015. A within-person examination of the effects of telework. *Journal of Business and Psychology* 30, 2 (2015), 313–323. https://doi.org/10.1007/s10869-014-9359-4
[96] Christiaan Verwijs and Daniel Russo. 2021. A Theory of Scrum Team Effectiveness. *arXiv preprint arXiv:2105.12439* (2021).
[97] VV.AA. 2020. The 2020 State of Remote Work. https://lp.buffer.com/state-of-remote-work-2020
[98] Stefan Wagner and Melanie Ruhe. 2018. A systematic review of productivity factors in software development. *arXiv preprint arXiv:1801.06475* (2018).
[99] Sara Walton, Paula O’Kane, and Diane Ruwhiu. 2020. *New Zealanders’ attitudes towards working from home*. Technical Report. University of Otago.
[100] Netta Weinstein and Richard M Ryan. 2011. A self-determination theory approach to understanding stress incursion and responses. *Stress and Health* 27, 1 (2011), 4–17. https://doi.org/10.1002/sm.1368
[101] Jason A Wilken, Paran Pordell, Brant Goode, Rachel Jarteh, Zayzay Miller, Benjamin G Saygar, Leroy Maximore, Watta M Borbor, Moses Carmue, Gregory W Walker, et al. 2017. Knowledge, attitudes, and practices among members of households actively monitored or quarantined to prevent transmission of Ebola Virus Disease — Margibi County, Liberia: February–March 2015. *Prehospital and Disaster Medicine* 32, 6 (2017), 673–678. https://doi.org/10.1017/S1049023X17006720
[102] Fabienne Wöhner. 2022. Work flexibly, travel less? The impact of telework and flextime on mobility behavior in Switzerland. *Journal of transport geography* 102 (2022), 103390. https://doi.org/10.1016/j.jtrangeo.2022.103390
A QUESTIONNAIRE INSTRUMENTS

Appendix A reports all the questionnaires used in all six waves.

A.1 Well-being – Satisfaction with Life Scale [26] – Waves 1-6

Below are five statements that you may agree or disagree with. Please be open and honest in your responding. [7-point response scale ranging from Strongly disagree – Strongly agree]

• I was satisfied with my life in the past week.
• The conditions of my life in the past week were excellent.
• If I could live the past week over again, I would change almost nothing.
• In the past week, I have gotten the important things I want.
• In most ways, my life in the past week has been close to my ideal.

A.2 Productivity – Self-developed scale – Waves 1-6

Please answer the following questions about your work. Remember that all answers are anonymous.

• How many hours have you been working approximately in the past week? [0–80 hours]
• How many hours were you expecting to work over the past week assuming there would be no global pandemic and lockdown? [0–80 hours]
• How many tasks that you were supposed to complete last week did you effectively manage to complete? [0–100%]
• If you rate your productivity (i.e., outcome) per hour, has it been more or less over the past week as compared to a normal week? [100% less productive – 100% or more productive]

A.3 Boredom – Boredom Proneness Scale [29, 92] – Waves 1-6

Please indicate to what extent you agree with the following statements. [7-point response scale ranging from Strongly disagree – Strongly agree]

• In most situations, it is hard for me to find something to do or see to keep me interested.
• Much of the time, I just sit around doing nothing.
• It takes more stimulation to get me going than most people.
• I often find myself at “loose ends,” not knowing what to do.
• I don’t feel motivated by most things that I do.
• Many things I have to do are repetitive and monotonous.
• Unless I am doing something exciting, even dangerous, I feel half-dead and dull.
• I find it hard to entertain myself.

A.4 Self-blame and behavioral disengagement – Subscales of the Brief COPE scale [16] – Waves 1-6

These items deal with ways you’ve been coping with the stress in your life in the past week. There are many ways to try to deal with problems. Obviously, different people deal with things in different ways, but we are interested in how you’ve tried to deal with it. Use these response choices. Try to rate each item separately in your mind from the others. Make your answers as true FOR YOU as you can. [5-point response scale ranging from I’ve not been doing this at all – I’ve been doing this a lot]

• I’ve been giving up trying to deal with it. [Behavioral disengagement]
• I’ve been criticizing myself. [Self-blame]
• I’ve been giving up the attempt to cope. [Behavioral disengagement]
• I’ve been blaming myself for things that happened. [Self-blame]
A.5 Autonomy, competence, and relatedness – Psychological needs scale [86] – Waves 1-6

Please read each of the following statements carefully, thinking about how true it was for you in the past week. [5-point response scale ranging from No agreement – Much agreement]

- I took on and mastered hard challenges.
- I experienced some kind of failure, or was unable to do well at something.
- There were people telling me what I had to do.
- I had a lot of pressures I could do without.
- I felt a strong sense of intimacy with the people I spent time with.
- I felt unappreciated by one or more important people.
- I was free to do things my own way.
- I was successfully completing difficult tasks and projects.
- I had to do things against my will.
- I did something stupid, that made me feel incompetent.
- I had disagreements or conflicts with people I usually get along with.
- I felt close and connected with other people who are important to me.
- I felt a sense of contact with people who care for me, and whom I care for.
- I was really doing what interests me.
- I was lonely.
- I struggled doing something I should be good at.
- I did well even at the hard things.

A.6 Quality and quantity of communication with colleagues and line managers – Self-developed scale – Waves 1-6

The following questions refer to communication with colleagues and line managers. If you don’t have any colleagues or line managers, please skip the following three items. [6-point response scale ranging from Strongly disagree – Strongly agree]

- I feel that my colleagues and line manager believed in me over the past week.
- I feel that my colleagues and line manager have been supporting me over the past week.
- Overall, I am happy with the interactions with my colleagues and line managers over the past week.

A.7 Stress – Perceived Stress Scale [21] – Waves 1-6

The questions in this scale ask you about your feelings and thoughts during the last week. [5-point response scale ranging from Never – Very often]

- In the last week, how often have you felt that you were unable to control the important things in your life?
- In the last week, how often have you felt confident about your ability to handle your personal problems?
- In the last week, how often have you felt difficulties were piling up so high that you could not overcome them?
- In the last week, how often have you felt that things were going your way?

A.8 Extraversion – Subscale of the Brief HEXACO Inventory [24] – Waves 1-6

Please indicate to what extent you agree with the following statements. [5-point response scale ranging from Strongly disagree – Strongly agree]

- I like to talk with others.
• I easily approach strangers.
• Nobody likes talking with me.
• I am seldom cheerful.

A.9 Distractions at home – Self-developed scale – Waves 1-6
Distractions at home [5-point response scale ranging from Not at all – Very often]
• I am often distracted from my work (e.g., noisy neighbors, children who need my attention)
• I am able to focus on my work for longer time periods

A.10 Generalized anxiety – adapted version of the 7-item Generalized Anxiety Disorder scale [90] – Waves 1-6
Over the last week, how often have you been bothered by the following problems? [5-point response scale ranging from Not at all – Every day]
• Feeling nervous, anxious or on edge.
• Not being able to stop or control worrying.
• Worrying too much about different things.
• Trouble relaxing.
• Being so restless that it is hard to sit still.
• Becoming easily annoyed or irritable.
• Feeling afraid as if something awful might happen.

A.11 Pandemic concerns – Self-developed scale – Wave 1-6
Over the last week, have you been concerned about the following problem? [5 steps, Not at all concerned – Extremely concerned]
• How concerned do you feel about COVID-19?
• How concerned do you feel about future pandemics?

A.12 Emotional and social loneliness – De Jong Gierveld Loneliness Scale [38] – Waves 1-6
Over the last week, how much do the following statements apply to you? [5-point response scale ranging from Not at all – Every day]
• I experience a general sense of emptiness.
• I often feel rejected.
• I miss having people around.
• There are plenty of people I can rely on when I have problems.
• There are enough people I feel close to.
• There are many people I can trust completely.

A.13 Quality of social contacts – Two items adapted from the social relationship quality scale [6] and one self-developed item – Waves 1-6
The following questions refer to your social contacts outside of work. [5-point response scale ranging from Strongly disagree – Strongly agree]
• I feel that the people with whom I have been in contact over the past week support me.
• I feel that the people with whom I have been in contact over the past week believe in me.
• I am happy with the amount of social contact I had in the past week.
A.14 Demographics

Demographics and debriefing You almost made it! Now some questions about yourself.

What is your gender? [single-selection]
- Woman
- Man
- Non-binary
- Prefer not to disclose
- Prefer to self-describe [...]

In which country are you currently based? [single-selection]
- United Kingdom
- United States
- Other [...]

In which state do you currently reside? [dropdown]

Is there still a lockdown where you are living (i.e., are still all schools and non-essential shops closed)? [single-selection]
- Yes
- Unsure
- No

How old are you? [in years, input field]

My living situation at the moment: [single-selection]
- Living alone
- Living with other people

How many of the people you're living with at the moment are: [input boxes]
- Babies / Infants (0–1 years old)
- Toddlers (1–3 years old)
- Children (4–11 years old)
- Teenagers (12–17 years old)
- Adults (18+ years old)

What type of organization do you work for?
- Public
- Private
- Other
- Unsure

What was your approximate yearly household income before taxes in US-Dollar in 2019?
- <20,000
- 20,000-40,000
- 40,001-60,000
- 60,001-80,000
- 80,001-100,000
- >100,000

What percentage of your time have you been working remotely (i.e., not physically in your office) over the past 12 months? [input field]

Thank you for participating in the first wave of this longitudinal study. We will contact you again in approximately one week and in two weeks and ask you to complete a shorter survey. It is important for us that you participate in all three waves.
Do you have any comments so far? [freexte input]

B QUESTIONNAIRE INSTRUMENTS – WAVE 6
Appendix B reports the additional questionnaire used exclusively in wave 6.

B.1 Preference for working from home – Self-developed scale – Wave 6
Additional questions

• Do you prefer working from home or from the office in the subsequent years? \[0–100\] ranging from Want to go to the office to Want to continue working from home
• If I could choose myself, I would work \[0–100\] ranging from In my office full-time to From anywhere full-time
• My company allows me to: \[0–100\] ranging from Go back to the office fulltime to Working from anywhere full-time, with option ’No clear policy from my company yet on this regard’
• I expect to: \[0–100\] ranging from Go back to the office fulltime to Working from anywhere full-time, with option ‘No clear policy from my company yet on this regard’

B.2 Resilience – Brief Resilience scale \[89\] – Wave 6
Please indicate the extent to which you agree with each of the following statements \[5-point response scale ranging from Strongly disagree to Strongly agree\]

• I tend to bounce back quickly after hard times
• I usually come through difficult times with little trouble
• It is hard for me to snap back when something bad happens
• I tend to take a long time to get over set-backs in my life
• It does not take me long to recover from a stressful event
• I have a hard time making it through stressful events
• I confirm that I pay attention and select disagree

B.3 Solidarity with the company – 3-item Solidarity subscale of the In-group Identification Scale \[56\] – Wave 6
Below are a few questions about how you feel towards your company \[5-point response scale ranging from Strongly disagree to Strongly agree\]

• I feel a bond with my company
• I feel solidarity with my company
• I feel committed to my company

B.4 Job satisfaction– 4 highest loading items of the Generic Job Satisfaction Scale \[61\] – Wave 6
Below are a few questions about how you feel towards your company \[5-point response scale ranging from Strongly disagree to Strongly agree\]

• I feel good about my job
• I receive recognition for a job well done
• I feel secure about my job
• I feel good about working at this company

B.5 Commuting experience – Self-developed scale – Wave 6

• I find commuting to work effortful
• What I like about working from home is that I do not have to commute
B.6 Intention to change jobs – Self-developed scale – Wave 6
Please respond to the following statements [7-point response scale ranging from Not at all – Very]

• I am likely to change jobs within the next year
• I am considering changing jobs soon

B.7 Changed jobs – Self-developed scale – Wave 6
Have you changed jobs since March 2020?

• No
• Yes, once
• Yes, twice
• Yes, more than twice
• I became unemployed

My decision to change jobs was affected by my company’s work from home policy.

• No, this did not play a role.
• Yes, I wanted to work more from home than my company allowed.
• Yes, I wanted to work more at the office than my company allowed

C CHANGES ALONG COVID-19 PANDEMIC
Appendix C reports additional figures of our within-subjects ANOVAs (changes across the two years).

Fig. 3. Self-blame across time. The red line displays the trend over time, whereas the box at each time point shows the range in which the middle 50% of the data falls. Responses were given on a 5-point scale, with 1 being the lowest possible score and 5 being the highest possible score.
Fig. 4. Behavioral disengagement across time. The red line displays the trend over time, whereas the box at each time point shows the range in which the middle 50% of the data falls. Responses were given on a 5-point scale, with 1 being the lowest possible score and 5 being the highest possible score.

Fig. 5. Generalized anxiety across time. The red line displays the trend over time, whereas the box at each time point shows the range in which the middle 50% of the data falls. Responses were given on a 5-point scale, with 1 being the lowest possible score and 5 being the highest possible score.
Fig. 6. Emotional loneliness across time. The red line displays the trend over time, whereas the box at each time point shows the range in which the middle 50% of the data falls. Responses were given on a 5-point scale, with 1 being the lowest possible score and 5 being the highest possible score.

Fig. 7. Social loneliness across time. The red line displays the trend over time, whereas the box at each time point shows the range in which the middle 50% of the data falls. Responses were given on a 5-point scale, with 1 being the lowest possible score and 5 being the highest possible score.
Fig. 8. Distractions at home across time. The red line displays the trend over time, whereas the box at each time point shows the range in which the middle 50% of the data falls. Responses were given on a 5-point scale, with 1 being the lowest possible score and 5 being the highest possible score.

Fig. 9. Quality of social contacts across time. The red line displays the trend over time, whereas the box at each time point shows the range in which the middle 50% of the data falls. Responses were given on a 6-point scale, with 1 being the lowest possible score and 5 being the highest possible score.