

CHALLENGES OF WORKING FROM HOME IN SOFTWARE DEVELOPMENT DURING COVID-19 LOCKDOWNS

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The COVID-19 pandemic in 2020/2021/2022 and the resulting lockdowns forced many companies to switch to working from home, swiftly, on a large scale, and without preparation. This situation created unique challenges for software development, where individual software professionals had to shift instantly from working together at a physical venue to working remotely from home. Our research questions focus on the challenges of software professionals who work from home due to the COVID-19 pandemic, which we studied empirically at a German bank. We conducted a case study employing a mixed methods approach. We aimed to cover both the breadth of challenges via a quantitative survey, as well as a deeper understanding of these challenges via the follow-up qualitative analysis of fifteen semi-structured interviews. In this paper, we present the key impediments employees faced during the crisis, as well as their similarities and differences to the known challenges in distributed software development (DSD). We also analyze the employees' job satisfaction and how the identified challenges impact job satisfaction. In our study, we focus on challenges in communication, collaboration, tooling, and management. The findings of the study provide insights into this emerging topic of high industry relevance. At the same time, the study contributes to the existing academic research on work from home and on the COVID-19 pandemic aftermath.

CCS Concepts: • **Software and its engineering** → **Programming teams**; **Open source model**; *Agile software development*.

Additional Key Words and Phrases: Distributed Software Development, DSD, COVID-19, Coronavirus, Corona Crisis, Lockdown, Mixed Methods, Open Source, Work from Home, Remote Work

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1 INTRODUCTION

For decades, the management, development, and maintenance of software have been changing from being at a single location to a distributed network, also called Distributed Software Development (DSD), sometimes even globally

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53 distributed (GSD, GDSD) [16, 39, 69, 77]. However, many companies traditionally developed software from fixed places
54 of work, such as offices [28]. The COVID-19 pandemic and its countermeasures prompted a rapid shift to work from
55 home for many employees worldwide, including software professionals in non-tech companies, many of whom were
56 previously working from fixed offices [10, 26, 30, 61, 70]. In the study, we focus on this special case of DSD, characterized
57 by software professionals having to shift swiftly and unexpectedly from working together in a physical location to
58 working individually from home, without much preparation. We found this new form of DSD is not only quantitatively
59 larger (as the crisis and the changed working conditions involved hit everyone) but also different from traditional DSD.
60 DSD, caused by the COVID-19 pandemic, induced a row of specific organizational and engineering challenges [6, 13],
61 such as the perception of having too many meetings, feeling overworked, and experiencing negative impact on physical
62 and mental health as reported in a study at Microsoft in 2021 (after shifting to work from home during the pandemic).
63 Other challenges included reaching milestones and a perceived decrease in team productivity resulting from two surveys
64 with 2873 developer responses [61]. In our study, we confirmed these findings and identified deeper insights thanks to
65 our follow-up qualitative study. We echo the above-mentioned challenges and confirm communication challenges in
66 part resulting from excessive meetings, as well as employee satisfaction challenges. We also explore the novel challenges
67 to the forced shift to work from home, while drawing parallels with traditional DSD research. We recognized that many
68 of the solutions required to solve the challenges exist and are used in DSD companies. Some solutions from the recent
69 COVID-era literature include "No Meeting Friday" programs [13] and fostering peer support culture [61].

74 For this study, we defined our research scope to focus primarily on common challenges software professionals
75 faced due to the work from home during the pandemic and to compare and contrast them to known challenges in
76 DSD. In particular, we studied the corporate challenges regarding internal communication, collaboration, tooling, and
77 management, while also assessing the effects on employee satisfaction. Even if we hint at some potential solutions, the
78 focus on this paper is on the challenges of working from home in software development.

79 We started by reviewing related literature on DSD and work from home regarding challenges that arise due to the
80 geographical distribution of contributors or employees according to the methodology described by Webster and Watson
81 [99]. For our main analysis, we followed the sequential explanatory mixed methods approach by Creswell and Plano
82 Clark [20].

83 We chose a German bank as the subject of our case study. As a consequence of the COVID-19 lockdown in March
84 2020, the employees of the company under study were asked to change their workplace from the office to their homes.
85 In our survey we analyzed the situation of software professionals of this company while working from home and thus
86 experiencing a form of DSD. Afterwards we conducted fifteen in depth expert interviews. Therefore, we chose experts
87 from the company of our case study and from other companies. To compare and contrast derived challenges from the
88 case study to traditional DSD challenges, we chose experts from various countries with different levels of experience in
89 DSD.

90 Both data collection and analysis were conducted by an interdisciplinary team of researchers including experts from
91 software engineering, labor economics, and social sciences research institutes as well as from business. This investigator
92 triangulation led to wide knowledge in different research methods and generated a broad perspective for discussion
93 and analysis of this interdisciplinary topic [92].

94 The paper is structured as follows: In section 2, we present a review of related literature. In section 3, we explain our
95 research approach and methodology. In section 4, we present the research results. In section 5, we discuss the results as
96 well as the limitations of the study, including threats to internal and external validity. In section 6, we conclude the
97 paper.

2 RELATED WORK

Challenges in DSD are established research subtopics of software engineering literature. In this related work section we present some of the prominent literature on the topics of DSD and work from home. Our goal for this literature review was to identify the known challenges and challenge categories in DSD and work from home, as well as to find some proposed and tested best practices for dealing with these challenges. We used the findings of the literature review to design the rest of our study, namely the survey and interview questions we used to identify the specific challenges and perceived solutions of working from home among our study participants.

In this paper, we use the term DSD to encompass “global”, “distributed”, “multi-site” software development and define it as “the management, development, and maintenance of software being geographically distributed across the globe” [77]. While we found multiple definitions and nuances between each term, we decided to take this broad approach because our topic was sufficiently and equally distinct from the terms above. In our case, we focus on the special form of DSD where the management, development, and maintenance of corporate software was performed exclusively from home during the COVID-19 pandemic resulting from a forced and rapid transition to this work setup. We refer to this phenomenon under investigation as *work from home* throughout the paper. While similar in some practical aspects to DSD, work from home in this context had distinct challenges, such as collaboration issues due to the rapid and often little organized transition, communication gaps and problems due to the new and unfamiliar work setup, as well as tooling and management issues. The latter two had to be adapted swiftly and with little preparation due to the nature of the COVID-19 lockdowns starting in March 2020 in Germany.

Following the literature review methodology by Webster and Watson [99], we systematically searched for and identified the relevant literature on challenges in distributed software development in general and on work from home challenges of software professionals during the COVID-19 lockdown in particular. We recognized that the very discipline of global DSD has been transforming rapidly over the last two decades [38, 39]. This trend was accelerated by the COVID-19 pandemic, as well as the widespread adoption of remote work tools, such as Zoom, GitHub, GitLab, and many more. Our goal was to validate our research objective and refine our research design including the research questions, to get an overview of existing related literature in the context of the COVID-19 pandemic and to compare known challenges in DSD before the pandemic to those employees faced due to the work from home during the pandemic. We present our findings and the above-mentioned comparisons in the discussion section of this paper, where we compare and contrast our research results next to the literature findings.

One significant finding of our literature review was that while there is a lot of literature addressing DSD and work from home challenges in general, few authors focus on the enforced, unplanned transition to work from home for software professionals. Our study comes to bridge this gap and to provide insights on this highly relevant topic using German corporate context for the research. While recognizing the high relevance of this topic, we also focused on the rigor of our research methods and data collection, which ensures the overall quality of the paper, as well as its repeatability and data traceability.

This is an interdisciplinary study focusing on software engineering, work from home, and DSD, which was reflected in our literature search strategy and resulting search terms. We searched for related literature in software engineering, management, and psychology, as well as in information systems scholarship.

2.1 Work from Home Challenges due to COVID-19 and Effects on Job Satisfaction

Work from home is not a new reality for software development [79]. Though, the World Health Organization [100] declared the situation from 2020 onward a Public Health Emergency of International Concern and many countries declared states of emergency or lockdowns. As a consequence, many employees were asked to work from home [7]. Therefore, the situation under review is not a case of regular work from home but involuntary distributed work, enforced unexpectedly, during an unprecedented public health crisis [73]. Thus, the prevailing knowledge base of work from home may not apply and new challenges may arise [25, 73].

Communication was identified as one out of four key work from home challenges by Wang et al. next to work-home interference, procrastination, and loneliness [98]. Communication difficulties were also identified by other studies investigating the work from home challenges during the crisis [1, 34]. Further highlighted challenges included less defined work-life boundaries, higher need for self-discipline, reliance on private infrastructure, coordination and collaboration issues [1, 34]. This is in line with the results of two literature reviews regarding the challenges of software professionals during COVID-19 that both identified communication and collaboration issues as the main challenges during the forced work from home [64, 67]. We decided to focus our study on these two categories namely communication and collaboration where challenges may occur. We structured our paper according to them.

Using adequate tools set the basis for effective communication and collaboration in distributed teams [88]. Many companies had to swiftly adapt their tools to remote work due to the new situation evoked by COVID-19 [3]. Thus, we also analyzed tooling related challenges in this study.

Furthermore, we were interested in management challenges. According to Ferreira et al. [29], managerial issues are one of three main work from home challenge categories during the COVID-19 pandemic. As this is a very broad field, we have focused on some aspects of management such as authority and decision making, and on some aspects of the control process such as internal management and requirements change management.

Only a number of studies [13, 32, 43, 61, 73, 79, 82], focus explicitly on work from home challenges of software professionals during a pandemic of this magnitude because there has not been a pandemic of this scale since before the invention of the world wide web [73]. Before 2020, some researchers studied similar challenges on a smaller scale, such as the home-based teleworking in the aftermath of a natural disaster [25].

While Spataro et al. [82] analyzed the challenges of the new unplanned remote work setting due to COVID-19 for developers in general and proposed remote-friendly tools and processes, the other studies referenced above analyzed the shift to work from home regarding certain aspects: Forsgren [32] thereby focused the impact on the themes: productivity and activity, work cadence, and collaboration, Ralph et al. [73] emphasized productivity and wellbeing and Silveira et al. [79] analyzed the influence on daily activities.

The studies mentioned above mainly focus on large technology companies [32, 73, 82], such as Microsoft [13]. Behrens et al. [8] found that whether work from home has positive or negative consequences for software professionals depend on the interplay between the extent of work from home and the efficiency of information and communication technologies. We assume that large technology companies have more experience with distributed work and therefore necessary technologies are already established. In our study, we conducted a case study at a medium-sized non-tech company, where software professionals were not used to entirely distributed work.

Beyond the work from home challenges caused by COVID-19 pandemic, our study focused on job satisfaction. While job satisfaction is manifoldly defined in software engineering literature, in the context of our study, we refer to the definition of Locke [58] who described job satisfaction as "a pleasurable or positive emotional state resulting from the

209 appraisal of one's job or job experiences". We followed this definition, when designing the survey questions and the
210 interview questionnaire used in our study to assess the shifts in job satisfaction levels after the forced transition to
211 work from home.

212 According to our literature review, job satisfaction is one of the most important aspects of a company to stay
213 attractive as an employer [12, 18, 101]. Workers with high levels of job satisfaction are more likely to be committed
214 to the organization and demonstrate a decreased propensity to leave [18, 101]. While many of the already published
215 studies on challenges for software professionals due to the COVID-19 pandemic emphasized the impacts on productivity
216 [32, 73, 82] we decided to analyze effects on job satisfaction. This also refers to the findings of Silveira et al. [79] who
217 highlighted that the impact of the COVID-19 pandemic is not reduced on a shift of the employees' productivity but
218 rather on a spectrum of many aspects that, beside others, includes wellbeing.
219
220
221

222 2.2 Known Challenges in DSD

223 Some scholars predict that the pandemic will make certain jobs permanently remote [40, 87]. Thus, it is also practically
224 important to explore how to solve actual challenges in work from home [97]. In doing so, understanding differences
225 and similarities to existing practises could help to identify which of these may be applied or further developed. For
226 identifying similarities and differences, we analyzed literature in DSD before the COVID-19 pandemic. The challenges
227 in software development that arise due to the geographical distribution of contributors or employees are studied
228 broadly and there are plenty of valuable case studies and various literature reviews on this topic. Below we provide an
229 overview of known DSD challenges in our fields of study stemming from our literature review, namely in collaboration,
230 communication, tooling, management, and control process.
231
232
233

234 *2.2.1 Collaboration.* In the literature, distributed collaboration is seen as one of the main challenges of DSD [22, 46, 47,
235 66, 81, 85].

236 Thereby, asynchronous collaboration is identified as a main challenge as it slows down decision making, issues
237 clarification, and thus delays projects [46, 47]. On the other hand, synchronous collaboration in distributed projects is
238 often impossible because of different time zones in global distributed projects or, in our case, other factors like child
239 care, home schooling or several parallel meetings.
240
241

242 Also establishing or maintaining team spirit and group awareness is an often addressed challenge in the field
243 of collaboration [66, 85]. Former studies identified more human-centred, agile, and collaborative working modes as
244 beneficial for successful DSD [21, 37, 42]. This is in line with the findings of o'Leary et al. [65] who propose social
245 factors like leadership skills, empathy, and motivation as crucial for successful distributed collaboration.
246

247 However, contrary to former research that mainly addressed collaboration challenges between multiple sites of
248 a company [22, 81], in our study we focused on the collaboration of a highly distributed organisation where every
249 employee is working from a different location namely from home. According to Šmite et al. [81] there is a clear lack of
250 studies about this aspect of distributed collaboration.
251

252 *2.2.2 Communication.* Communication challenges are often addressed in the literature and therefore we also empha-
253 sized this topic in our study. Challenges in communication include finding the right balance between loosely and tightly
254 coupled work and between synchronous and asynchronous communication as well as the lack of personal contact and
255 trust [4, 11, 17, 62, 63, 81].
256
257

258 Missing personal contact is a frequently addressed impediment to proper communication in literature [6, 61]. As
259 mentioned in the introduction, respondents from the survey by Miller et al. [61], who were forced to shift to work
260

261 from home, reported communication issues, such as the limited ability to brainstorm with colleagues and decreased
262 satisfaction from interactions and virtual social activities. The latter negatively affected software development team's
263 productivity.
264

265 Further research revealed that "limited face-to-face meetings reduce informal contact and this can lead to reduction
266 of teamness, loss awareness of task, and decreased trust" [4]. In related studies, implications for practice often propose
267 common conferences and business trips to enable personal contact in distributed teams [62, 81, 84].
268

269 Also the frequency of communication (tightly vs. loosely coupled work) is discussed in literature [11, 63]. While
270 tightly coupled work necessitates frequent communication and is usually non-routine, loosely coupled work is typically
271 either routine or has fewer dependencies [63]. Another challenge often addressed is finding the right balance between
272 synchronous and asynchronous communication which could depend from task to task and from the frequency of
273 communication mentioned above [14].
274

275
276 2.2.3 *Tooling.* Šmite et al. [81] found that technical-oriented research about DSD challenges mainly focuses on
277 implementing effective infrastructure and providing tool support. In their literature review focusing on DSD challenges
278 da Silva et al. [21] take up the subject by providing a set of tools supporting DSD. Major challenges regarding tooling
279 are inappropriate selection of communication technologies as well as the lack of tool supported training and knowledge
280 sharing [48, 78, 102].
281

282 Due to the COVID-19 pandemic, employees were forced to use tools in new ways to perform their work and to
283 engage with their colleagues [96]. As many studies reported a rapid adoption of digital technologies and tools due to
284 the enforced work from home [2, 96], we also addressed this topic in our study.
285
286

287 2.2.4 *Management.* Also challenges related to management, coordination, and control are frequently analyzed [62,
288 76, 78]. The importance of management is strengthened by the literature review of Khan et al. [53] who stated that
289 management commitment is one of the most crucial factors for successful distributed software development. Saleem et
290 al. [76] found project and process management one of the main challenges in all three levels of operation: country,
291 company and team.
292

293 DSD research mentions the challenge of not knowing who is in charge of what due to different company sites and fast
294 changing environments and thus a slowdown in decision-making [62]. This is in line with the finding that centralized
295 authority has a negative influence on member satisfaction and team identification [63] which calls for adapting agile
296 practices including democratic decision-making.
297

298 In distributed agile development, as we also can find it in our case study, lack of management commitment as well
299 as lack of roles and responsibilities are main challenges identified in the literature review of Shameen et al. [78] and
300 hinder proper planning and prioritization.
301

302
303 2.2.5 *Control Process.* Another key challenge of distributed software development is the control process in the
304 context of the geographical distribution of software developers [49]. They define control processes to include internal
305 management and reporting of the software quality, budget, and standards. This is especially challenging for global
306 software development (GSD), be it in open source projects or companies operating across multiple countries and
307 time zones. Kahya and Seneler [49], among others [52, 75], recently conducted a case study at a global company to
308 uncover the GSD challenges resulting from the geographical distance between different parts of the company and their
309 employees working across different countries around the world.
310

313 They found that companies that switch to global software development face temporal, geographical, and socio-
314 cultural distance challenges [49, 75]. Moreover, they identified that to mitigate such challenges, companies introduce
315 agile software development methods, which, however, comes with its own challenges, as agile development requires
316 synchronous communication and control processes that are difficult to conduct across different times zones and cultures.
317

318 As a result of their empirical study with twelve participants at a Germany-based global company, Kahya and Seneler
319 suggest that switching to GSD work setup carries risks in communication, coordination, and control processes for
320 companies. Communication and coordination challenges are in line with our previous findings presented in subsections
321 above.
322

323 Other researchers also mention the challenge of control processes, for example in the context of requirements change
324 management in GSD setup [52]. In COVID-19 related literature about work from home the challenge of control processes
325 was not a major topic. We have therefore decided to include aspects such as requirements change management in the
326 management challenges sub-category and to no longer have the control process as a separate category.
327

328 2.3 Research Questions

329 After analyzing literature about challenges in work from home due to the COVID-19 pandemic and known challenges
330 in DSD, the encompassing research questions aiming to achieve the research objective and refined by reviewing related
331 literature are:
332

- 333 • **What are the main challenges of software professionals resulting from the switch to work from**
- 334 **home?**
- 335 • **How do these challenges impact job satisfaction of software professionals?**
- 336 • **Are the challenges similar to the prevailing knowledge base of DSD challenges?**
- 337
- 338
- 339

340 Our narrow focus on challenges of software professionals in a medium-sized, non-tech company and how these
341 challenges affect job satisfaction allows us to extensively study an important field. In the literature we found challenges
342 that we wanted to further analyze in this study in communication, collaboration, tooling, and management including
343 control process. For further analyzing we employed mixed methods research, which we cover in detail in the following
344 section.
345

346 3 RESEARCH METHOD

347 3.1 Mixed methods research

348
349
350 3.1.1 *Study design.* To develop a detailed understanding of the main challenges in work from home during the COVID-
351 19 lockdown we used a mixed methods approach [90]. Mixed methods research is characterized by integrating both
352 quantitative and qualitative data within a single study [19]. We chose a mixed methods approach to gain both breadth
353 of the study by gathering multiple participant perspectives as well as deep insights from selected expert interviews
354 [20]. Tashakkori and Creswell [89] distinguish four major types of mixed methods design: triangulation, embedded,
355 explanatory, and exploratory design. In this paper we applied the sequential explanatory approach which means that
356 qualitative data is used to explain and further elaborate quantitative results.
357

358 The quantitative data helped to identify the main challenges in work from home in general, as well as in commu-
359 nication, collaboration, management, and tooling in particular. The qualitative data from semi-structured interviews
360 enabled us to elaborate on results from the quantitative analysis that needed further explanation and to compare them
361 to known DSD challenges.
362
363
364

365 We connected the quantitative and qualitative phases when selecting participants for qualitative interviews and
366 developing the interview protocol based on the results from the statistical test of the quantitative approach [20]. Our
367 aim was to gain a deep understanding of challenges in work from home during the COVID-19 lockdown. The results of
368 both quantitative and qualitative phases were integrated in the discussion of outcomes [20].
369

370
371 *3.1.2 Target population and sampling.* Using the explanatory mixed methods design involves first collecting and
372 analyzing quantitative data and second using the results to inform the follow-up qualitative data collection. Thus,
373 sampling occurs in two phases: the quantitative and the qualitative phase.
374

375 Our subject company for the quantitative phase was a small to medium-sized non-tech company specialized in
376 consumer finance and liquidity management. We chose this company as neither DSD nor work from home was
377 commonplace for the employees there before the crisis and we had good access to it. The bank counts about one million
378 clients. Its business activities are carried out in Germany as well as in Austria by approximately 1,000 employees. The
379 processes of the bank are highly automated and digitization plays an important role in the business strategy.
380

381 Preceding the COVID-19 pandemic, all software professionals worked together in one physical venue, there are
382 no further development sites except one IT-service provider who worked off-site on Fridays; thus the employees had
383 limited or no experience in DSD. However, around one third of the software professionals worked from home regularly
384 (maximum once a week). Therefore, technologies like vpn or communication tools were in place and used for individuals
385 working from home rather than the whole team.
386

387 The tools mainly applied for communication before the lockdown were Skype (for video conferencing and meetings)
388 and Mattermost (for instant chatting). JIRA was used for collaboration and GitHub for development. A wiki, accessible
389 to all employees, was used for documentation and knowledge-sharing. Most of the development teams were interdis-
390 ciplinary and consisted of a Product Owner, a Scrum Master, Developers, Business Analysts and Testers. They mainly
391 used agile development processes (predominantly Scrum).
392

393 To compare the challenges in work from home during the lockdown to the impediments experienced in DSD, the
394 target population in this study were software professionals because their work was most comparable to people engaging
395 in distributed software development. Additionally, our sample focused on the teams that started working remotely at
396 full scale in the aftermath of the COVID-19 pandemic.
397

398 We chose only one company for the quantitative part of our study which allowed us to do an in-depth study on our
399 research topic. In future investigations the sample can be extended to companies from other sectors and sizes as well as
400 further types of organizations and different customer groups.
401

402 As recommended by Creswell and Plano Clark [20] for qualitative data collection, we took a smaller sample than for
403 the quantitative data collection by gathering enough qualitative information to develop meaningful themes. The data
404 was collected in fifteen in-depth semi-structured interviews. For sampling, we used the maximal variation sampling in
405 which diverse individuals are chosen who are expected to hold different perspectives on the phenomena under study
406 [20]. Six interviewees were selected from employees who had completed the online survey because the individuals who
407 can best explain the quantitative results are those who already participated in the quantitative part of the study [20]. In
408 the second interview iteration we selected five more interviewees, one from a company that also started DSD due to
409 the COVID-19 lockdown and four from companies that had experienced DSD before the COVID-19 crisis started. After
410 this iteration we added four more interviewees working in large open source software projects or foundations who are
411 used to work distributed all over the globe. Overall we interviewed fifteen people from ten companies in five different
412 countries. In each iteration we adapted the interview protocol regarding findings of the previous iteration.
413
414
415

Table 1. Data sources of the qualitative study

Company ID	Interview ID	Expert Role	Branch	Country	DSD Experience
X1	Y1	Developer	Finance	Germany	Since COVID-19
X1	Y2	IT Coordinator	Finance	Germany	Since COVID-19
X1	Y3	Technical Product Owner	Finance	Germany	Since COVID-19
X1	Y13	Developer	Finance	Germany	Since COVID-19
X1	Y14	Developer	Finance	Germany	Since COVID-19
X1	Y15	Developer	Finance	Germany	Since COVID-19
X2	Y4	Developer	Technology	US	Since COVID-19
X3	Y5	Developer (Co-Founder)	Technology	Spain	Many years
X4	Y6	Technical Consultant	Finance	Austria	Many years
X8	Y10	Developer	Education	Canada	Many years
X9	Y11	Developer	Technology	Germany	Many years
X5	Y7	Developer	Technology	US	Only DSD
X6	Y8	Developer	Technology	US	Only DSD
X7	Y9	Developer	Technology	Canada	Only DSD
X10	Y12	Developer	Technology	Germany	Only DSD

The sampling procedure was directed by the quantitative statistical results of the first phase and aimed at identifying individuals who can best explain the phenomenon of interest [20]. The data we collected is depicted in Table 1.

The participants in both the survey and the qualitative interviews took part on a voluntary basis.

3.2 Quantitative study

3.2.1 Quantitative data collection. The methodology used for data collection in the first, quantitative phase was a cross-sectional survey [60]. For developing our survey we followed the method outlined by Kallus [50]. To calibrate the survey length, design, and questions we used existing surveys in related fields [27, 91, 93].

We divided our survey into 6 parts. The first part included general questions about work from home. After that in part 2 till 5 we asked about particular challenges in the fields of communication, collaboration, management, and tooling derived from reviewing related literature in DSD (see chapter 2). In the last part of the survey we asked questions regarding main challenges and opportunities, about the actual working environment and job satisfaction.

To adequately consider possible confounding factors [36] such as having children [41] or living at a subsistence level (that can impact work from home) [9], further challenges were included in the questionnaire in both a drop-down choices and open text fields. We used Likert scales as well as open text fields and dropdowns. Control questions were included to ensure proper answering [72].

To assess the influence on job satisfaction, we considered proven approaches such as the michigan organizational assessment questionnaire (MOAQ) [57] or the job satisfaction survey (JSS) [83]. As our focus was to identify the change of job satisfaction due to the shift to work from home while known approaches rather emphasis on job satisfaction in general, we decided to directly ask the participants whether their job satisfaction has improved through working from home during the COVID-19 lockdown. The participants had the option to rate this using a five point Likert scale from 0 (= strongly disagree) to 4 (= strongly agree).

The survey instrument was pre-tested on 6 selected participants. Based on the pre-test we slightly revised some survey items, especially minimized answer options and added examples and instructions. The survey was administered

469 online and was accessed through a distributed URL. The data collection took place between May 12 and May 26, 2020.
 470 The survey was closed on May 30, 2020 (after four days without new incoming responses). To not be biased by the
 471 transition phase, because the survey took place only two month after the first lockdown, we sent the survey to the
 472 same target group again in August 2020. To not be biased by asking only one company, we additionally sent the survey
 473 to software professionals from other companies. The second data collection took place between August 24 and October
 474 26, 2020. The survey was closed again after four days without new incoming responses.
 475

476 Reliability and validity of the survey scales and items were established, analyzing frequency distributions and
 477 inter-item correlations (using the control questions for comparison) as well as internal consistency reliability indexes
 478 for each field of study namely communication, collaboration, management, and tooling [44, 86]. We used Cronbach's α
 479 as a reliability index. According to Streiner [86] it was calculated as shown in formula 1.
 480

$$481 \alpha = \frac{k}{k-1} * \left(1 - \frac{\sum \sigma_k^2}{\sigma_t^2}\right) \quad (1)$$

482 In the formula k stands for the number of items, $\sum \sigma_k^2$ = the sum of variances of all of the items and σ_t^2 = the variance of
 483 the total scores. The computation of Cronbach's α can be found in the supplementary material. The complete overview
 484 of survey questions and corresponding answer options is enclosed in the appendix.
 485

486 3.2.2 *Quantitative data analysis.* We used both univariate and multivariate statistical procedures to analyze the survey
 487 data. Demographic information was evaluated using frequency counts. We analyzed how different items correlated
 488 with each other using inter-item correlations. Thereby we focused on the question of how the experienced challenges
 489 correlated with job satisfaction.
 490

491 An ordered logit analysis was conducted to identify the predictive power certain explaining variables have on the
 492 dependent variables following the procedure outlined by Cameron and Trivedi [15]. Generally, ordered logit models
 493 estimate relationships between ordinal variables to be explained and (other) explaining variables. Our survey included
 494 questions on the situation during the crisis that we were primarily interested in and that we defined as variables to be
 495 explained. Other questions referred to the situation before the pandemic or to unchanged organizational or personal
 496 contexts. We interpret these variables as explaining variables. The probability of a given outcome for the ordered logit
 497 model is:
 498

$$500 \text{Prob}(a_i = j) = \text{Prob}(j-1 < b_0 + b_1 x_i + u_i \leq j) = \frac{1}{\exp(-\kappa_j + b_0 + b_1 X_i)} - \frac{1}{\exp(-\kappa_{j-1} + b_0 + b_1 X_i)} \quad (2)$$

501 The linear function: $b_0 + b_1 x_i + u_i$, consists of the constant term b_0 . The explaining variables are stacked together
 502 with further covariates in the column vector $x_i = (x_{i1} \ x_{i2} \ \dots \ x_{ik})'$. The corresponding coefficients are stacked in row
 503 vector $b_1 = (\beta_{11} \ \beta_{12} \ \dots \ \beta_{1k})$. The probability $\text{Prob}(a_i = j)$ of the outcome $j=1, \dots, l$ corresponds to the probability that
 504 the estimated linear function, plus the logistically distributed error term, u_i , is within the range of the cutpoints κ_1 ;
 505 $\kappa_2; \dots; \kappa_l - 1$. These are simultaneously estimated with the coefficients $b_0; \beta_{11}; \beta_{12}; \dots; \beta_{1k}$. In our analysis κ_0 goes to
 506 $-\infty$ and κ_l to ∞ .
 507

508 Due to the non-linearity in the logit model structure, the model is estimated based on maximum likelihood. We
 509 tested our specification with a link test, described by Pregibon [68]. The test was based on the assumption that if a
 510 regression was correctly specified, there should be no additional explaining variable that was significant except by
 511 chance. What the test does is to refit the model based on the predicted and the squared predicted values of the model of
 512

521 interest. In case of the significance of the squared predicted values the link test indicates that the model is not properly
522 specified. In case of the significance of the predicted values and the insignificance of the squared predicted values our
523 model would pass the link test. All ordered logit estimates can be found in the appendix.
524

525 Furthermore, we applied techniques of natural language processing to analyze the open text questions of the survey.
526 The technological basis of our analysis was primarily built by the Natural Language Toolkit for Python [95] and the
527 German-language Resource for Sentiment Analysis [74]. As part of our investigation we examined the frequencies
528 of unigrams (single words) as well as bigrams (paired words). We further analyzed the association of the bigrams by
529 calculating their pointwise mutual information [11, 46]. Finally, we performed a sentiment analysis using an algorithm
530 that counts positive words of an answer, subtracts the sum of negative unigrams and divides the outcome by the
531 word-count. As a result, we obtained a sentiment score between -1 and +1 for the observed answers.
532
533

534 3.3 Qualitative Study

535
536 3.3.1 *Qualitative data collection.* In the qualitative phase of the study, we conducted fifteen follow-up semi structured
537 interviews with experts from several companies and different countries aiming to reach internal and external validity
538 and some “company-unrelated” narratives for the results of the quantitative survey.
539

540 The content for the interview protocol was based on the quantitative results from the first phase. The goal of the
541 second, qualitative phase, was to explore and elaborate on the results from the statistical analysis that needed further
542 explanations [20, 45]. The interview protocol can be found in the appendix.
543
544

545 3.3.2 *Qualitative data analysis.* We audio recorded and verbatim transcribed each interview [19]. The German interviews
546 were translated. The transcripts were added to the QDA software for coding and exploration. For data analysis, we
547 followed the constant comparative method [59] developed for the use in the grounded theory method of Glaser and
548 Strauss [35]. Thus, we moved iteratively between codes and text to derive themes based on the concepts found from the
549 quantitative data analysis.
550

551 In terms of the number of participants, in the sequential explanatory mixed methods approach the aim of the
552 qualitative part is not to generalize from the sample (as in quantitative research) but to develop an in-depth understanding
553 of a few people [20]. According to Fusch et al. [33] data saturation is reached when the study is replicable, further
554 coding is no longer feasible and the ability to obtain additional new information has been attained. To ensure having
555 reached data saturation we suggest that our study can be replicated using the interview protocol, we coded all parts of
556 each interview and we conducted interviews until we did not identify any meaningful new themes from the answers.
557 However, we do not claim our qualitative study to be generalizable as the objective of this part is to gain in-depth
558 information about the central phenomenon.
559

560 The code system including definitions and number of codings per code can be found in the appendix.
561

562 After describing the data collection and approaches used for analyzing the data, in the following, we will explain our
563 results from both the quantitative and the qualitative analysis.
564
565

566 4 RESULTS

567 4.1 Quantitative analysis

568 4.1.1 *Demographic information.* The survey was sent to all employees who were listed in the IT and infrastructure
569 email distribution list of the company under study. This included 180 employees from four different departments namely
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572

573 data analytics and reporting, IT infrastructure and support, conception and strategy and software development. From
 574 180 potential participants, we got 64 complete answers (response rate of 35,6%).

575 The study participants were compared on the following demographic or general characteristics: role, division,
 576 proportion, and duration of work from home during and before the COVID-19 lockdown. Most of the respondents were
 577 employed in software development (50%) or in the data analytics and reporting division (27%). Participants worked
 578 mainly in the following roles: manager (34%), business analyst (19%), test and operation (15%), or developer (10%). All
 579 participants and their teams worked remotely at full scale during the COVID-19 lockdown starting in March 2020.
 580 Before the lockdown only 37% of the surveyed employees worked from home on a regular basis, which means once a
 581 week, 9% worked from home once a month, 36% irregularly, and 18% of the participants did not work from home at all.
 582

583
 584
 585 **4.1.2 Uni- and Multivariate Analysis.** We found that while missing personal contact was rated as the main challenge
 586 (see figure 1), it did not directly correlate with the overall job satisfaction during the crisis (see figure 2). In contrast,
 587 adherence to work-life-balance, and coordination problems had a slight negative correlation to the working satisfaction
 588 (also see figure 2). Even if this correlation was not statistically significant we found it interesting and wanted to further
 589 analyze it using the qualitative follow-up interviews.
 590
 591

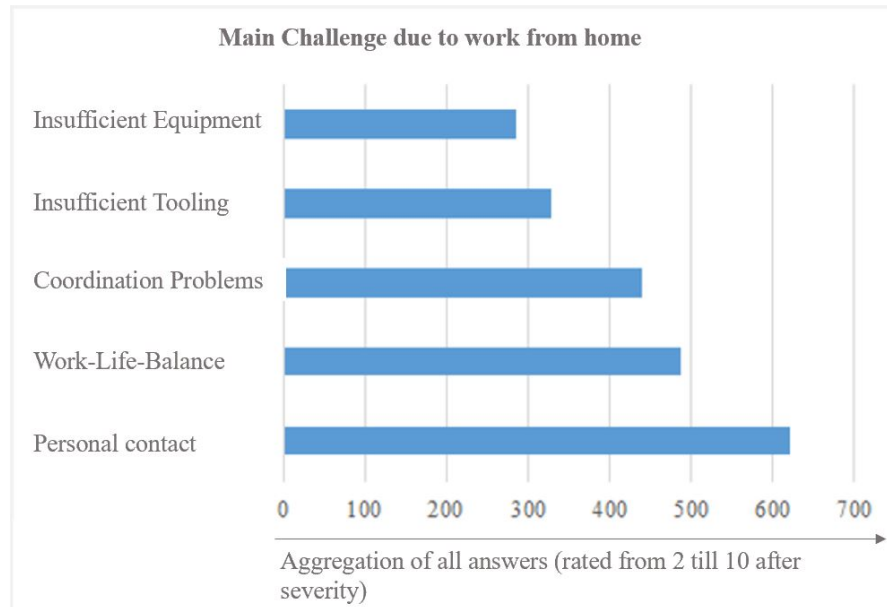


Fig. 1. Main Challenge due to work from home

617 We then analyzed selected responses with ordered logit models [15] and divided the results by their belonging to the
 618 four fields under study: communication, collaboration, management and tooling.
 619

620 **4.1.3 Communication.** The ordered logit analysis showed that employees from the division of software development
 621 did not agree that communication in remote work was challenging or lead to misunderstandings. Quite to the contrary,
 622 they rated the communication as good, just like employees who characterized their teams as agile. Employees who
 623

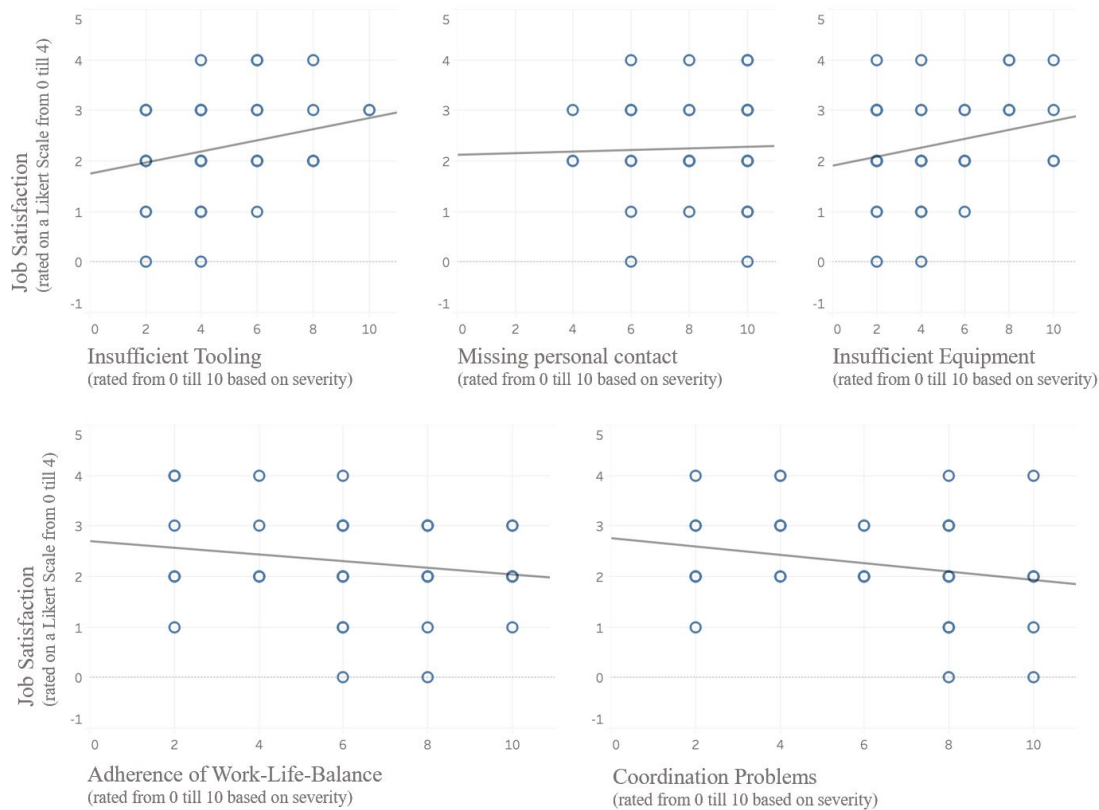


Fig. 2. Correlation of challenges (rated from 2 till 10 after severity) and Job Satisfaction (rated from 0 = not satisfied at all till 4 = more satisfied than before the crisis)

rated their team as process oriented did not agree that communication was exhausting while working from home. In contrast, employees from the conception and strategy division, who rated the communication as exhausting. Employees who classified their team as competitive and employees whose work strongly depended on others agreed at a higher rate that information was unequally distributed. Employees who classified their team as agile did not experience the issue of unequal distributed information.

4.1.4 Collaboration. Furthermore, we found that employees who classified their teams as collaborative agreed at a higher rate that effective work was possible while working from home and they were satisfied with the team collaboration. In contrast, employees whose work strongly depended on others were less satisfied with the collaboration in the team and tended to agree that effective work was not possible while working from home during the COVID-19 lockdown.

4.1.5 Management. In the ordered logit analysis we found that employees who classified their team as competitive agreed at a higher rate, that decision-making decelerated through the work from home during the crisis. Employees who characterized their team as agile and employees from teams, in which most of the members before the lockdown already worked from home on a regular basis did not feel an impact of the decision-making velocity. The latter and

Table 2. Most frequent unigrams (single words) mentioned as challenges in open-ended responses of the survey

R	German	English Translation	F
1	kommunikation	communication	13
2	person	personal	7
2	kontakt	contact	7
2	arbeit	work	7
2	abstimm	coordination	6

Table 3. Most frequent bigrams (paired words) mentioned as challenges in open-ended responses of the survey

R	German	English Translation	F	PMI
1	person, kontakt	personal, contact	5	4.22

members of teams classified as collaborative did not feel a negative impact on planning during their remote work. This is equally true for employees in the software development and conception and strategy divisions. In contrast, employees whose work strongly depend on others agreed at a higher rate that the remote work during the crisis impeded proper planning. Furthermore, we found that employees who classified their team as collaborative agreed that their overall working situation improved through the work from home during the COVID-19 lockdown.

4.1.6 Tooling. In the ordered logit analysis we found that employees in whose teams no new tools were introduced consented that communication is challenging. We also found that employees who characterized their team as competitive were significantly less satisfied with the provided tools than employees who classified their team as collaborative or process oriented. As we found this result very interesting, we wanted to further elaborate this through emphasizing it in the follow-up interviews.

4.1.7 Analysis of Open-Ended Responses. We asked the participants of the survey in an open question to describe their main challenge while working from home due to the COVID-19 lockdown to avoid neglecting confounding factors which means factors that are perceived as main challenges but that are not addressed in our survey. Furthermore, we invited participants to explain why their working satisfaction increased or decreased, to further elaborate the aspects that mainly influenced their job satisfaction.

In the open-ended responses to the question regarding the main challenge of remote work the most frequently mentioned unigrams (at least 5 occurrences) are listed in table 2.

The analysis of the unigrams gave a good impression of the problems that occurred with work from home in the bank, which primarily concerned social aspects such as communication, coordination, and personal contact. This is confirmed by the most frequently mentioned bigrams (at least 3 occurrences) in table 3.

Five participants mentioned that a lack of personal contact was the main challenge when working from home.

We finally asked the participants if their job satisfaction has improved through the shift to work from home during the crisis. In addition to this question we provided a free text field to explain their choice. Figure 3 shows the distribution of the calculated sentiment score for these given explanations.

The results of the sentiment analysis confirmed our previous findings. Overall, the score reflects a positive sentiment among the explanations (mean=0.08, median=0.023, standard deviation=0.14). The score is positive for 20, neutral for 13,

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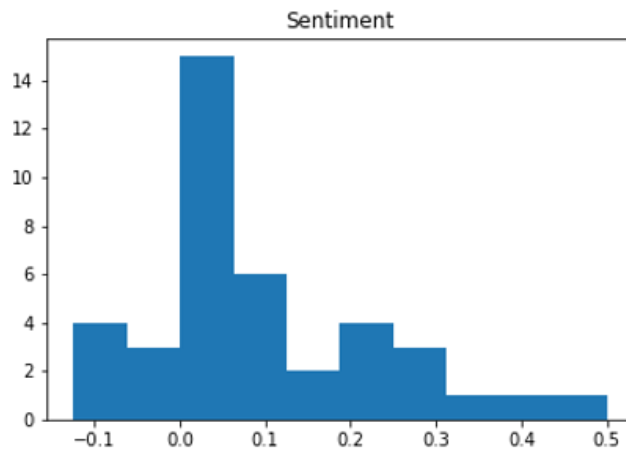


Fig. 3. Sentiment Analysis for the explanations of survey participants if their job satisfaction improved through the shift to work from home

Table 4. Most frequent unigrams (single words) mentioned as explanation why job satisfaction decreased / increased through the shift to work from home

R	German	English Translation	F
1	arbeit	work	29
2	mehr	more	17
3	arbeitsweg	commute to work	9
4	flexibel	flexible	8
5	moglich	possible	7
5	tag	day	7
6	zeit	time	5
6	arbeitszeit	working hours	5
6	termin	appointment	5
6	schwierig	difficult	5
6	konzentriert	concentrated	5
6	homeoffic	home office	5
6	kolleg	colleague	5

and negative for 7 answers. Some respondents did not explain their choices. The most frequently mentioned unigrams (at least 5 occurrences) are listed in table 4.

We found the terms “work” (29), “flexible” (8), and “concentrated” (5) in the explanations. In addition, the unigrams “commute to work” (9), “working hours” (5), “day” (5), “time” (5), and “colleague” (5) occur in several answers. These can be connected to the most frequently mentioned bigrams in table 5.

On one hand, due to the remote work, the participants could better concentrate on fulfilling their tasks. Furthermore, they had more time at their disposal, as they did not have to commute to their workplace and were more flexible in planning their tasks. On the other hand, they missed their colleagues and the social interaction.

Table 5. Most frequent bigrams (paired words) mentioned as explanation why job satisfaction decreased / increased through the shift to work from home

R	German	English Translation	F	PMI
1	konzentriert, arbeit	concentrated, work	5	4.20
2	mehr, zeit	more, time	4	4.65
3	kolleg, fehlt	colleague, missing	3	6.74

To not be biased neither by the transition phase nor by asking only one company, we sent the survey at a later time to a larger target group. There, we got 101 complete answers. Comparing the ordered logit models mainly confirmed the results drawn from the first survey. We found that the positive effect of working in collaborative teams are equal in the ordered logit models. Comparing the ordered logit models also confirmed the negative effects of working in a competitive team or having a very tightly coupled work e.g. in conception or strategy. Also the negative effects of depending from colleagues could be reassured. In contrast to the first ordered logit model, in the second one we did not find any negative effects because of the urge to work at certain core working hours. In contrast, we found that participants who feel the need to work at certain core working hours tend to rate the communication as good.

To sum it up, the sentiment analysis revealed that the participants were rather satisfied with their actual working situation. Missing personal contact turned out to be the main communication challenge derived from both the univariate analysis and the analysis of open ended answers. Furthermore, we identified that mainly employees working in the conception and strategy division perceived remote communication as exhausting. We also found that employees in competitive teams or those whose work strongly depend on others are mainly affected by the shift to work from home. The communication challenge of unequally distributed information was perceived by employees working in a competitive team or by employees highly depending on colleagues. The latter also were less satisfied with the inner team collaboration, general planning, and the work effectiveness. Employees in competitive teams agreed at a higher rate, that decision-making decelerated and they were less satisfied with provided tools.

Furthermore, it seemed like missing personal contact did not directly correlate with job satisfaction, while adherence to work-life-balance and coordination problems had a slight negative impact on job satisfaction. As described above, we wanted to further analyze some of the results in the follow-up interviews.

4.2 Qualitative Phase

The interviews were held with the aim to better understand and further elaborate results from the quantitative phase explained in the previous section. Data analysis of the qualitative follow-up interviews enabled us to identify, codify, and categorize the key challenges employees had to face through the (newly introduced) work from home and their impact on job satisfaction. Through the interviews with employees who had worked distributed before the COVID-19 pandemic, we could compare and contrast the identified challenges. The final codebook included 12 code categories and 57 codes. In summary, we derived more than 500 coding segments, some of which we present in this section. The complete codebook can be found in the appendix.

From the quantitative analysis we derived remote communication especially missing personal contact as the main challenge. Moreover, employees who highly depend on colleagues tended to be less satisfied with remote collaboration. To further elaborate on this, in the interviews, we asked for main challenges of working from home, detailed explanations, and examples.

833 From the univariate analysis, we found that missing personal contact did not correlate with job satisfaction. On the
834 other hand, adherence to work-life-balance and coordination problems led to decreased employee satisfaction. Thus,
835 we asked interviewees which challenges mainly affect their job satisfaction.
836

837 From the multivariate analysis we found that employees from teams characterized as competitive were less satisfied
838 with the decision-making processes, with tools, and with communication in their teams while working from home
839 during the COVID-19 lockdown. As opposed to employees working in teams characterized as collaborative who were
840 rather satisfied with their tools and who even tended to rate their job satisfaction during the COVID-19 lockdown
841 as higher than before the crisis. To gain a broader understanding on this topic we asked the interviewees how team
842 characteristics and collaboration modes impact their working satisfaction. In the following we present the results from
843 the interviews.
844
845
846

847 *4.2.1 Main challenges while working from home.* We divided the challenges mentioned during the interviews into
848 challenges related to communication, collaboration, management, tooling, and others. With 85 code segments, challenges
849 in communication were referred to most often. The most frequently mentioned communication challenges were
850 missing personal contact (35 coding segments), accessibility and finding the right balance between synchronous and
851 asynchronous communication (18 coding segments) as well as technical issues (10 coding segments).
852

853 Communication was referred to as main challenge while working from home from one of the interviewees who also
854 took part in the quantitative survey as follows:
855
856

857 *“The biggest challenges... well, I think we work in teams overall, so I don’t think there’s anybody in the bank who’s really*
858 *working on his own. And when you work together with someone, communication is naturally part of it, no. So communica-*
859 *tion has to work. If it doesn’t work, then you can’t do your work, or at least for me, I can’t do my work properly.”* [Interview Y3]
860
861

862 Within the communication part, interviewees often addressed the challenge of missing personal contact and direct
863 interaction especially within their teams:
864
865

866 *“The biggest challenge related to work. Let’s think for a second, [...] When you see people, you meet people. I think*
867 *that’s what people miss at home. I can imagine that through the absence of social contacts you get in a depressive mood.”*
868 [Interview Y13]
869
870

871 or *“Because it’s just fun to talk, or just to have a coffee, or just to exchange what happened this week. And that’s what I*
872 *think, you can not do it [...] for example via Skype or something like that, it just doesn’t really work.”* [Interview Y1]
873
874

875 Also participants who are used to work from home stated the importance of personal contact:
876

877 *“[...] it’s still very important that you’ve actually meet your colleagues in person because you really get an idea of a*
878 *personality much better like that. You can then use that knowledge online.”* [Interview Y9]
879
880

881 An interesting fact about missing personal contact was that this was especially addressed as the main challenge by
882 software professionals who had to shift to work from home because of the COVID-19 pandemic. Some of the more
883
884

885 experienced distributed workers did not mention missing personal contact as a challenge neither before nor during the
886 pandemic.

887 Possible reasons for this could be that they are used to work distributed or found adequate substitutes for personal
888 contact. Directly asked if and how they replace personal contact we received a wide range of answers from measures
889 like installing remote coffee breaks and organizing virtual conferences up to interviewees stating that they do not need
890 intense personal contact. For that we found two reasons, first was that colleagues (also asynchronously) communicated
891 about their mental wellbeing:
892
893

894
895 *“I find seeing each other helps, of course, but I find, actually, it’s more important for me to know where the other person*
896 *is mentally.”* [Interview Y8]
897

898
899 and second, more frequently addressed, reason was that the software professionals took their sense of belonging
900 from other aspects like the company culture or from working towards a shared vision like stated in the following answers:
901

902 *“We have this philosophy that we act as a family. It’s like a circle of friends. There’s actually this feeling and that’s also*
903 *required of everybody, that everybody belongs. And that everyone is part of [...] the family and also of the group and is*
904 *treated accordingly.”* [Interview Y7]
905
906

907 or *“I think it’s because the identification with what we do is very high. [...] That’s where everybody kind of takes pride in*
908 *working for the team and feels comfortable with the team and feels that the product, the open source product, is great and*
909 *everyone is proud to be a part of that.”* [Interview Y11]
910
911

912 This is an interesting finding as it seems like personal contact becomes less important over time and if the company
913 installs a familiar culture including a shared vision in which employees could exchange about their mental wellbeing.
914 This could also happen asynchronously. Nevertheless, also more experienced DSD workers mentioned the challenge of
915 missing personal contact, especially when it comes to networking and integration:
916
917

918 *“Especially as a remote worker, it’s difficult or important also to make new contacts in just a big company. And of course*
919 *that’s hard to do when I’m in such a remote meeting. So even if it’s a larger meeting, I’m only a small window on the screen.*
920 *[...] so without personal contact I have not yet found a good way to get it right.”* [Interview Y7]
921
922

923 Remote Meetings are a good starting point to discuss the second most addressed challenge within communication,
924 namely "how to find the right balance between synchronous and asynchronous communication?" Asynchronous
925 communication is a best practice often referred to in the interviews to not depend on reaching colleagues or being
926 reachable all time. However, the interviewees who also took part in the quantitative survey did not significantly increase
927 their proportion of asynchronous communication and also some of the interviewees who already gained some years of
928 experience in work from home stated that this is not the solution for everything:
929
930

931
932 *“Of course, this asynchronous teamwork is very important. So that must be emphasized tremendously, because otherwise*
933 *it’s useless if I just sit at the screen and talk on the phone all day. [...] So it was an adjustment for me then when I went into*
934 *this remote work from 2013. And in fact, I have also noticed over the years that this asynchronous communication does not*
935
936

937 *work perfectly with everyone...* [Interview Y7]
938
939

940 Also another interviewee who already worked in a distributed team before the COVID-19 pandemic explained that
941 in his team synchronous is preferred over asynchronous communication:
942

943 *"[...] We don't have core working hours. So I maintain we have a very modern approach. If you want to sleep in today*
944 *because you don't feel well. Then just work longer in the evening. I don't care. Actually, so if it's not every day now. But of*
945 *course it makes it easier and it is basically expected that you are more or less available. In a core working time that is not*
946 *defined [...]."* [Interview Y6]
947
948

949 Thus, it seems like the urge to be reachable, at least between certain periods, to enable synchronous communication
950 is also present in companies that are more experienced in DSD. Nevertheless, interviewees explained that they intro-
951 duced measures to avoid having meetings and having to talk on the phone all day, which is a threat of synchronous
952 communication. One interviewee for example described the concept of *"no interruption Thursdays.."* [Interview Y7]
953 which means they don't have any meetings at all on Thursdays.
954

955 Communication is closely linked with collaboration. We assigned 38 Code segments to challenges related to collabo-
956 ration which makes the second largest part after communication. Challenges related to management were mentioned 15
957 times, and 14 code segments were assigned to challenges related to tooling. Regarding challenges that are not assigned
958 to one of the four categories the challenges that are referred to the most often were adherence of work-life balance (16
959 coding segments) and missing office and equipment (12 coding segments).
960
961

962
963
964 **4.2.2 Impacts of challenges on work satisfaction.** When we asked which challenge had the greatest negative impact on
965 job satisfaction the challenges most often referred to were technical issues (9 coding segments) and missing personal
966 contact (7 coding segments).
967

968 Technical issues were mentioned as impediments to productive work and also resulted in a decrease of job satisfaction.
969 We derived this from comments like:
970

971 *"[...] I always have a loss of productivity when communication is disturbed, i.e. when the software is disturbed..."* [Inter-
972 view Y3]
973

974
975 or *"If for example systems or something like that failed, [...] of course you got upset for a short time because you just*
976 *wanted to continue with your topics."* [Interview Y1]
977

978
979 *"It is difficult when things don't work. I was relatively new at the bank and then there were problems with the general*
980 *access and then you have to find out if it's just me or if no one can get in..."* [Interview Y14]
981

982
983 *"I don't remember exactly what it was, but every now and then I had to go there with the device and have them fix it. Of*
984 *course, that's rather inconvenient. [...] That is just annoying of course because afterwards you have to make up for the lost*
985 *time."* [Interview Y15]
986

989 Despite the quantitative result, we found that missing personal contact had a negative impact on job satisfaction as
990 expressed e.g. in the following statement:
991

992 *“Then, I think, not only for me but also for others there was a certain low point, if you want to call it like that, a kind*
993 *of camp fever. You don’t see your colleagues anymore, [...] you don’t meet at the coffee machine any more, sometimes in*
994 *between, that’s just what was missing, of course.” [Interview Y3]*
995
996

997 or *“So from my point of view what I’m missing are the specific human encounters in real life. And I miss the inspiration*
998 *and the energy that you get from that.” [Interview Y12]*
999
1000

1001 Other aspects that were mentioned as a reply to the question which challenges impact the work satisfaction the most
1002 were challenges regarding the level of dependence on colleagues and missing work-life balance (both with 4 coding
1003 segments). As expected, more experienced DSD workers did not emphasize technical issues. Instead, they referred to a
1004 general uneasiness or anxiety because of the pandemic or to challenges like home schooling and child care:
1005
1006

1007 *“We also had people very early on who could no longer cope at all, especially with childcare.” [Interview Y6]*
1008
1009

1010 In contrast to the quantitative results none of the interviewees mentioned coordination problems as reason for
1011 decreased satisfaction.
1012

1013 We also found that not only work from home challenges but also team characteristics and working modes influenced
1014 the satisfaction of employees and thus will further explain this in the following paragraph.
1015

1016 **4.2.3 Impacts of team characteristics on job satisfaction.** We analyzed why employees from collaborative and competi-
1017 tive teams experienced different impacts on their job satisfaction through changing to work from home. Therefore, we
1018 tried to find out how team characteristics and collaboration modes impacted the work satisfaction of the interviewees.
1019 None of the interviewees described their own work setting as competitive. Many interviewees explicitly mentioned
1020 their gratitude working in a collaborative team:
1021

1022 *“[...] you really work together, you actually see the team concept, the team spirit, the cooperation works well and you*
1023 *don’t try to work against each other [...].” [Interview Y3]*
1024
1025
1026

1027 or *“if you have a problem, to support the other person remotely.” and that “if you have to go away for a moment or to the*
1028 *doctor, and the other person says: Yes, that’s no problem. So if something happens, then he’s definitely there too.” [Interview*
1029 *Y1]*
1030
1031

1032 To further investigate this topic, we asked interviewees who are experienced in distributed work which team
1033 characteristics or working modes are most important for work from home. From the answers we derived that working
1034 modes (e.g. following certain processes or using an agile development approach) are less important for work satisfaction
1035 in distributed teams than having a high level of trust and a common goal (12 code segments) and the ability to act self
1036 responsible (10 code segments). The experienced DSD workers for example explained:
1037
1038

1041 “So right at the top is trust [...] And that’s really top down in every area of work. That’s so with every decision that every
1042 developer makes, that’s always in the back of their mind. [...] And the basis for that is really trust. The moment I can no longer
1043 trust my boss or I can no longer trust my colleagues, then the situation probably wouldn’t be the way it is now.” [Interview Y7]
1044

1045
1046 or “Having a common goal, feeling that the other person is competent and is also trying their best towards that goal. It
1047 definitely makes you feel connected. Like, you know, I do research collaborations with people in other countries, some of
1048 whom I’ve never met in person and I feel connected because we have this common interest and I trust that they are doing
1049 their work. And I’m doing mine and. Seeing them every day would just add nothing for me.” [Interview Y10]
1050

1051
1052 or “I don’t necessarily have the feeling that I’ve lost so much personal contact. And that’s one of the experiences I’ve had
1053 in the open source communities is that I can work excellently with people, for years, without even knowing what they look
1054 like and build an excellent relationship. [...] That is perhaps because in the open source community most people are there
1055 out of personal motivation, because from the beginning there was such a common community feeling or common values
1056 also such a common spirit was there.” [Interview Y12]
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1059 Trust builds on self-responsibility of employees, which was addressed as follows:
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1061
1062 “So you have to take a lot of responsibility for yourself.” [Interview Y8]
1063

1064 or: “[...] the developers are very independent at our company.” [Interview Y7]
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1067 This shows that even if an agile development approach is beneficial for work from home, there are team characteristics
1068 that seem to be more important like trust, a common goal, and self-responsibility.
1069

1070 To sum it up, we could generate a better causal understanding from the qualitative research after identifying
1071 quantitative correlations. With this in-depth knowledge, some results of the quantitative analysis could be reinforced,
1072 others could not be confirmed. The qualitative data confirmed the main challenges found in the quantitative data
1073 namely communication issues (personal and technical) and missing personal contact among software professionals.
1074 On the contrary, more experienced DSD workers did not mention missing personal contact, at least not as the main
1075 challenge. Also finding the right balance between synchronous and asynchronous communication was addressed as a
1076 challenge frequently.
1077

1078 In contrast to the quantitative data analysis that revealed coordination problems as having a negative impact on
1079 work satisfaction, the aspects mentioned to this question most often included missing personal contact, technical
1080 issues and depending on colleagues. The negative impact from missing work-life-balance on work satisfaction was
1081 confirmed by the follow-up interviews. The qualitative data could not reaffirm dissatisfaction in competitive teams
1082 but confirmed that employees working in collaborative teams are rather satisfied with the work from home situation.
1083 Furthermore, employees experienced in distributed work recommended to let employees act self-responsible and to
1084 build up a community of trust.
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1088 5 DISCUSSION 1089

1090 The goal of this study was to identify the key challenges software professionals experienced throughout the rapid and
1091 unexpected change to work from home during the COVID-19 lockdown and how these challenges impacted their work
1092

1093 satisfaction. Furthermore, we wanted to compare and contrast the challenges to known challenges in DSD. In both our
1094 quantitative and the qualitative analyses we found that there was a broad acceptance of work from home at the case
1095 company under study and in the surveyed companies. After systematically surveying DSD literature in the context of
1096 our research questions we found that challenges mainly can be categorized in the following categories: communication
1097 [1, 29, 62, 63, 94, 98], collaboration [34, 71, 94], management [24, 29, 54], and tooling [5, 31, 103]. As follows, we discuss
1098 each category in detail, discussing the implications of our findings, as well as drawing parallels with the recent DSD and
1099 COVID-19-related literature. Broadly this discussion will serve as the basis for a future study, where we plan to address
1100 the identified work from home challenges through industry best practices observed in hands-on case studies to follow.
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1104 5.1 Communication

1106 A challenge in communication is finding the right balance between synchronous and asynchronous communication. We
1107 found that employees in the company under study depended on synchronous communication. Also more experienced
1108 remote workers still partly preferred synchronous communication, while existing literature recommends fostering
1109 asynchronous communication. We also found that the conception and strategy division was the only division that rated
1110 distributed communication as exhausting. Hence, we assume that employees working on tightly coupled and complex
1111 non routine tasks which necessitates frequent, mainly synchronous communication are less satisfied with distributed
1112 communication. Thus, synchronous communication while working from home seems to be necessary and exhausting
1113 at the same time.
1114
1115

1116 In addition, people faced challenges in remote communication of both personal and technical nature which led
1117 to decreased work satisfaction. In general, the topic of personal communication challenges is broadly addressed in
1118 DSD and we think that many best practices generated there (focus on public, easily accessible communication, using
1119 appropriate communication tools, etc.) can be applied to improve remote communication for software professionals
1120 who had to switch to work from home due to COVID-19. Despite the known personal communication challenges and
1121 best practices in DSD, our novel finding was the emergence of technical issues. This was mainly caused by the lacking
1122 employee knowledge and technical infrastructure that needed to be adapted.
1123
1124

1125 Furthermore, we found that missing personal contact, as an aspect of communication, is one of the main challenges
1126 perceived by the participants and also led to a decrease in work satisfaction. This is in line with the finding that virtual
1127 communication has its limitations, is a hindrance relative to face-to-face interaction and increases work stress [23, 98].
1128 Frequently discussed recommendations in DSD literature to overcome this challenge indicate a necessity of investments
1129 in travelling and socialization because it seems like real personal contact is not replaceable by any virtual measure [62].
1130 However, in the qualitative interviews we found that personal contact seems to become less important if the company
1131 has a common culture, employees are working together on one shared vision, and can talk about their mental state
1132 with their colleagues (even if this happens asynchronously). As this is an interesting finding this topic should be further
1133 analyzed.
1134
1135

1136 In sum, there are some new challenges in the field of communication (missing personal contact, higher impact of
1137 technical communication issues and finding the right balance between synchronous vs. asynchronous communication).
1138 These results matter because they directly impact work satisfaction and thus need to be addressed in order to generate
1139 positive workplace outcomes. In our study, we did not find an adequate substitute for personal contact but it seems
1140 like the negative impact on work satisfaction could be reduced by taking the right measures regarding the company's
1141 culture and vision.
1142
1143

1145 Thus, for research we recommend to further analyze how to adequately replace personal contact, as this situation
1146 might take some more time and missing personal contact seems to be one of the main challenges due to the enforced
1147 work from home. Also finding the right balance between synchronous vs asynchronous communication needs to be
1148 further studied.
1149

1150 In practice we recommend companies to offer training in remote communication and to set up a technical support
1151 hotline to overcome technical communication issues. Regarding missing personal contact, possible improvements might
1152 be e.g., having virtual coffee breaks or discussion rounds using video calls to give employees the possibility to see each
1153 other and a space to talk about private matters. Furthermore, the negative impact of missing personal contact on work
1154 satisfaction could be reduced by taking the right long-term measures such as focusing on a culture of trust and creating
1155 a common vision.
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1158

1159 5.2 Collaboration

1160 In the field of collaboration we identified *depending on colleagues* as well as *the urge to be reachable between core working*
1161 *times* as main challenges. We also found that working in a competitive team negatively impacts the work satisfaction
1162 in general and the satisfaction with team collaboration in particular. This supported findings from former studies
1163 that identified agile and collaborative working modes as beneficial for successful DSD [37, 42]. Also Krzywdzinski
1164 et al. [56] found in their study based on an online survey of 1,516 individuals who worked from home during the
1165 COVID-19 pandemic that the quality of team collaboration and team productivity slightly increased in agile teams.
1166 From the qualitative interviews we found that the most important team characteristics in distributed teams are trust
1167 and self-responsibility.
1168

1169 The collaboration challenges found in the study (urge to be reachable, depending on colleagues and negative impact
1170 of competitive working mode) is studied in recent research. Nevertheless, results matter because right now we have a
1171 different type of distributed collaboration. We do not have collaboration between multi sites of a company (as often
1172 addressed in former DSD research) and neither single employees who are working from home (which was the usual
1173 case in work from home studies). Instead, we have entirely distributed collaboration where everyone is working from a
1174 different place namely from home. Thus, it was important to reassess the challenges under this situation of distributed
1175 collaboration.
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1178

1179 A limitation is, that we cannot foresee if and how the challenges will change, when it comes to a more hybrid type
1180 of collaboration when some employees return to the office and some remain at home, as could be a possible future
1181 scenario.
1182

1183 As challenges identified in this study are known and thus extensively studied in existing literature. In practice we
1184 recommend applying existing best practices as, e.g., to focus on agile and collaborative working modes with defined
1185 and clear processes that foster on asynchronous collaboration. Furthermore, we recommend fostering a culture of trust
1186 and self-responsibility.
1187
1188

1189 5.3 Management

1190 In our study we found that depending on certain decision-makers has a negative impact on planning and that working
1191 in a competitive environment seems to slow down the decision-making process. This means that management should
1192 foster collaborative team settings, transfer responsibility and decision-making power to the teams, and set up an
1193 environment of trust. This point of view was supported by experienced DSD workers as well as by recent work from
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1196

home literature. For example Wang et al. [98] found that employees with higher levels of job autonomy have higher levels of performance and well-being during the period of work from home.

The working mode described above is well established in larger open source projects and foundations thanks to clearly defined and efficient governance structures [55]. While one important goal of open source project governance is to ensure continuity and to integrate the competing forks [51, 55], we found that companies do not have to deal with this issue because of the often top-down management, which dictates what software needs to be developed. However, we found that companies can learn from the other DSD best practices of open source communities, especially when it comes to the management in order to foster collaboration and asynchronous decision-making.

In the category of management we focused on decision-making, planning, and team setting. This narrow scope was by design, as we didn't want to gather general data on the large topic of DSD management, instead we predefined the focus based on our preliminary literature review. At the same time, this can be seen as a limitation of the study, as DSD management is a broad field in which many other aspects could be addressed and analyzed.

While our research supported some findings by peer researchers as presented above, we also identified some dissimilarities between our findings and related literature. Namely, when it comes to global software development, a key challenge is associated with software process improvement [24, 54]. We recognized this challenge from the literature, however, in our study we didn't systematically identify software process improvement as a key challenges our study participants addressed. One reason for this could be the specific context of our study focused on the COVID-19 pandemic period during which the focus was generally less on process improvements across the board, but more on keeping things running and managing the forced transition to work from home. In a future study, we will consider asking about this topic especially to software developer interviewees in order to validate this suggestion from the literature, as well as to potentially identify some best practices that emerged to address software process improvement in the context of DSD.

5.4 Tooling

Our findings suggest that employing the right tools in companies that were forced to work remotely due to COVID-19 foster intraorganizational collaboration, knowledge transfer, development, and communication. However, we also found that choosing and implementing such tools can be a challenge for companies as seen in our data. This topic is addressed in DSD literature broadly [5] and also mentioned in other literature in the specific context of the COVID-19 pandemic [103]. Interestingly, our study found that tooling was a major challenge for companies forced to work from home during the COVID-19 pandemic, even though some other researchers found tooling, especially collaboration tooling to be less of a challenge in a similar transition [31]. In particular in their recent 2021 TOSEM article on software developers working from home during the COVID-19 pandemic, Ford et al. find that friction with collaboration tools was rated by their study participants as the least frequently mentioned major challenge (selected by only 22% of their study participants). In our study, on the contrary, we identify both collaboration and tooling as two major areas that our study participants struggled with during the sudden transition to work from home. This is supported by Ferreira et al. [29] who also identified finding the best work from home tools among the top 5 challenges within their interviews.

While tooling was considered essential by most employees, we also found that participants who rated their team as competitive were less satisfied with provided tools. In our study, we could not find out why this is the case. The question why and how competitive working modes influence the satisfaction with provided tools should be further analyzed. In our follow-up studies, we plan to expand on this insight and search for corporate best practices that emerged in

1249 competitive teams to address the issue of inadequate tooling software developers and other employees used while
1250 working from home.

1251 Finally, we want to echo the proposition of Smite et al. that the forced work from home, while challenging, can actually
1252 result in a widely accepted work from anywhere in the long-run [80]. Such an approach to telework coupled with the
1253 acknowledgment and resolution of key challenges presented in this paper can result in more scalable organizations that
1254 are able to seize the benefits of DSD environments to a higher extent. Further studies on these long-term effects remain
1255 within our research outlook.
1256
1257

1258 6 LIMITATIONS

1259 6.1 External validity

1262 A limitation of this study is the sample size of one company and fifteen qualitative interviews though analyzed in depth.
1263 The company was carefully selected and the focus on one company enabled applying the mixed methods approach via
1264 both survey and qualitative interviews soon after the first COVID-19 lockdown. Nevertheless, we do not claim results
1265 of this study as generalizable to other companies and further research on this is required.
1266

1267 Furthermore, our response rate did not cover all software professionals of the selected company. Thus, our results
1268 could be biased because only certain employees answered (e.g. employees who have a positive attitude towards working
1269 from home). Even so, we assess the participants to be a good representation of the company as we got results from all
1270 four departments including different roles and a wide variance in responses.
1271

1272 Several respondents have already experienced work from home, and there are certain tools/procedures established
1273 to at least partially assist such work practice in the company under study. Thus, one could claim that this population
1274 does not represent a proper population for studying forced shift to work from home. Nevertheless, the COVID-19 crisis
1275 poses new challenges because of the enforced, unplanned work from home of all employees. This is a novel situation
1276 for every software professional in the company under study but might become the new norm.
1277

1278 The quantitative survey was conducted in May and in August 2020 during the first COVID-19 lockdown. As the
1279 situation is changing fast and the further development of the crisis can not be foreseen, answers might change over
1280 time and need to be re-recorded in further studies at a later time.
1281

1282 6.2 Internal validity

1285 To infer causality, we must demonstrate correlation, precedence and the absence of third variable explanations. Other
1286 confounding variables influencing the satisfaction with the actual work from home situation might include individual
1287 differences (e.g. personality), having children, and many others. It is very difficult to exclude all other factors. Thus, we
1288 decided to offer open questions where participants had the option to describe challenges that were not emphasized in
1289 the questionnaire and analyzed these via natural language processing. Therefore, we also received answers including
1290 challenges like homeschooling or inappropriate working conditions at home but as a whole open answers supported
1291 the results drawn from the ordered logit model. Nevertheless, further challenges can be used to extend our model in
1292 subsequent research.
1293
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1295

1296 6.3 Conclusion validity

1297 Confirmability, the degree to which the authors are neutral towards the inquiry and their potential bias effect on
1298 the findings, is another potential limitation. Qualitative data research realized by only one researcher has inherent
1299

1301 subjectivity and bias. In our case we were an interdisciplinary team from different fields of research and industry. This
1302 helped to incorporate different points of view in our study. Moreover, the measurement instruments were tested to
1303 ensure reliable measurements.
1304

1305 1306 **7 CONCLUSION** 1307

1308 In this study, we analyzed challenges of the unplanned switch from working in companies to working from home for
1309 software professionals in a medium-sized non-tech company. We also compared and contrasted these challenges to
1310 already documented ones in DSD and work from home literature to find where existing practices can be applied and for
1311 which fields further research is required.
1312

1313 In our study, we found that the identified work from home challenges can be mainly categorized into the following
1314 topical groups: communication, collaboration, management, and tooling.
1315

1316 In the field of communication, we found some challenges that differ from those identified in existing research. These
1317 are missing personal contact, higher impact of technical communication issues and finding the right balance between
1318 synchronous vs. asynchronous communication. Previous DSD research recommends fostering real personal meetings
1319 to overcome the challenge of missing regular personal contact. This is not possible in the current situation and thus
1320 adequate substitutes need to be found. A possible measure could be fostering a common culture and a shared vision
1321 which seems to reduce the negative effects of missing personal contact. Technical communication issues can be mainly
1322 derived from work from home as a new situation for both employees and companies. Thus, we recommend providing
1323 a help-hotline and focus on adequate infrastructure. DSD research and most experienced remote workers mainly
1324 recommend asynchronous communication, while at the company under study synchronous communication is seen
1325 as necessary on the one hand but also as exhausting on the other hand, especially at fulfilling tightly coupled work
1326 including highly complex, non-routine tasks. Thus finding the right balance between synchronous and asynchronous
1327 communication still needs to be analyzed.
1328

1329 In the field of collaboration, we identified the dependence on colleagues as well as the urge to be reachable between
1330 core working times as main challenges. We also found that working in a competitive team negatively impacts the
1331 satisfaction with team collaboration. We found that most experienced remote workers recommend to emphasize on
1332 trust and self-responsibility in teams. That agile working modes are beneficial for DSD is addressed in existing literature
1333 but needs to be reassessed for the actual situation in which everyone is working from a different place namely from
1334 home.
1335

1336 In the field of management, the challenge of decelerated decision-making processes due to working from home
1337 was only perceived by employees who rated their team as competitive. Participants who highly depend on others
1338 rather agreed that no proper planning was possible due to the enforced work from home. This is in line with the
1339 recommendation of DSD experts who recommend that management should foster collaborative team settings, transfer
1340 responsibility and decision-making power to the teams, and set up an environment of trust. In contrast to existing DSD
1341 literature, software process improvement was not identified as key challenge in our study.
1342

1343 The main challenge regarding the usage of tools was finding appropriate tools supporting collaboration and knowledge
1344 transfer. We further found that employees working in a competitive team are significantly less satisfied with provided
1345 tools. The question why and how competitive working modes influence the satisfaction with provided tools should be
1346 further analyzed. Even though some other researchers found tooling, especially collaboration tooling to be less of a
1347 challenge, in our study we identify both collaboration and tooling as two major challenges.
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When trying to improve the quality of work from home, one should address the negative aspects. Thus, further research on this topic can focus on how to best deal with the missing personal contact and how to improve remote communication, especially finding the right balance between synchronous and asynchronous communication. Moreover, the aspect of competitive vs. collaborative teams and whether collaborative teams deal better with unforeseen situations like the COVID-19 lockdowns should be addressed in further research.

Potential remedies for companies being forced to switch to work from home are to offer appropriate training and technical support. Beyond that, we advise to focus on compensation for missing personal contact by providing social offers like open virtual coffee breaks or discussion rounds and to foster this through appropriate tooling. Moreover, agile, collaborative working modes seem to be beneficial as well as having a common culture and working on a shared vision. However, no single action appears appropriate to everyone, hence organizations should steadily communicate with their employees to keep their job satisfaction as high as possible and the needs of employees should be reassessed over time, as the situation is steadily changing.

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A APPENDICES

A.1 Survey questions and answer options

Remote work after the Corona Lockdown - your opinion is needed!

Due to the current situation, triggered by the corona pandemic, an above-average number of people work from home (remote work). Remote work is perceived very differently. This survey is about your personal experiences with remote work.

There are no prizes to be won for answering, but we donate € 1 for each survey answered to a selected Corona aid project.

Of course, your data will be treated confidentially and only processed for scientific purposes. No personal data is collected in the survey.

We would be happy to inform you about the evaluation of the survey. To do this, you can enter your email address at the end or contact us directly.

*It takes about 15 minutes to complete.
Thanks for your support!*

First a few general questions about remote work

Q1. How often do you currently work remotely (i.e. from home)?

Answer Options

- not at all
- irregular
- 1-2 times a week
- 3-4 times a week
- I only work remotely
- Other (please specify)

Q2. Does your entire team work remotely for the most part (more than 2 days a week)?

Answer Options

- yes
- no
- Other (please specify)

Q3. How often did you work remotely before the Corona crisis?

Answer Options

- not at all
- irregular
- monthly
- weekly
- every day

Q4. Please sort the following challenges that arise due to remote work according to your personal weighting.

To do this, drag the options with the mouse to the appropriate place, starting with the greatest challenge (1 = very stressful, 6 = not very stressful).

Answer Options

- Coordination difficulties in the team
- Balance between work and private life
- Lack of personal contact with colleagues
- Insufficient tools (e.g. for video telephony)
- Inadequate equipment (e.g. screen, microphone)
- Technical problems (e.g. when establishing a connection or when using tools and communication media)

Q5. How much do you agree with the statement: The current remote work prevents effective work in my team.

Answer Options

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

Next, some questions about the decision-making process in your team

Q6. How are decisions currently predominantly made in your team? Please choose one option.

Answer Options

- Democratic in the team
- The boss decides
- By coordinating with stakeholders
- Guidelines from the company
- According to company vision and mission
- No decisions are made in the team
- Other (please specify)

Q7. How much do you agree with the statement: Because of the remote work, decisions are postponed.

Answer Options

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

Q8. If decisions are postponed: What kind of decisions are postponed due to the crisis?

You can choose several options.

Answer Options

- strategic (e.g. alignment, new projects)
- operational (e.g. prioritization of topics)
- personnel (e.g. salary increases)
- no decisions are postponed
- Other (please specify)

Q9. How much do you agree with the statement: The decision-making process has slowed down due to the remote work.

Answer Options

- strongly disagree
- disagree
- neutral
- agree
- strongly agree

Q10. How much do you agree with the statement: Remote work impairs stable planning and prioritization of topics within the team.

Answer Options

Part 1 : General Questions regarding work from home

Part 2: Management

strongly disagree
disagree
neutral
agree
strongly agree

And here are a few more questions about cooperation within your team or your department
Q11. How would you characterize your team or your department?

Answer Options

collaborative
competitive
agile
flexible
process-oriented
result-oriented

Answer Options for each characteristic

strongly disagree
disagree
neutral
agree
strongly agree

Q12. How much do you agree with the statement: In my team or in my department there is competition between colleagues.

Answer Options

strongly disagree
disagree
neutral
agree
strongly agree

Q13. How much do you agree with the statement: I have the feeling that I have to prove myself to my boss.

Answer Options

strongly disagree
disagree
neutral
agree
strongly agree

Q14. How much do you agree with the statement: I am expected to be available during core working hours (between 9 a.m. and 3 p.m.).

Answer Options

strongly disagree
disagree
neutral
agree
strongly agree

Q15. How much do you agree with the statement: The progress of my work depends to a large extent on direct coordination with colleagues.

Answer Options

strongly disagree
disagree
neutral
agree
strongly agree

Q16. How satisfied are you currently with the cooperation in the team or in the department?

Answer Options

not satisfied at all
rather not satisfied
neutral
rather satisfied
extremely satisfied

Next, a few questions about communication within your team or department

Q17. How often do you speak to one or more colleagues on average per day?

Answer Options

not at all
1 - 2 times
3 - 5 times
more than 5 times

Q18. Did you talk to your colleagues more or less often before starting remote work?

Answer Options

more often
equally often
rarer

Q19. How much do you agree with the statements: I perceive remote communication as ...

... Challenging
... Stressfull
... Good
... Danger for misunderstandings
... Risk for unequal distribution of information

Answer Options for each characteristic

strongly disagree
disagree
neutral
agree
strongly agree

And now some questions about the tools you use

Q20. Were new tools introduced for remote work during the crisis (e.g. Skype, Zoom, Miro ...)?

Answer Options

yes
no
If so, which tools have been introduced?

Part 3: Collaboration

Part 4: Communication

Part 5: Tooling

Q21. How satisfied are you with the tools currently in use?

Answer Options

- not satisfied at all
- rather not satisfied
- neutral
- rather satisfied
- extremely satisfied

And finally, questions about you and your work environment

Q22. Which of the following best describes your role?

Answer Options

- Analyst
- Developer / DevOps
- Product / UX - Designer
- Project Manager / Produkt Owner
- Expert for Quality / Test
- Scrum Master
- Architect
- Other (please specify)

Q23. In which department are you working?

Answer Options

- IT- / Software Development
- Data Analytics / Reporting
- IT Infrastrukture / Support
- Conception / Strategy
- Other (please specify)

Q24. Please write down what, in your opinion, is the greatest challenge and the greatest opportunity of remote work.

Answer Options

- Challenge (Text field for open answer)
- Opportunity (Text field for open answer)

Q25. How much do you agree with the statement: Working remotely has improved my job satisfaction.

Answer Options

- strongly disagree
- disagree
- neutral
- agree
- strongly agree
- Please briefly describe why your situation has improved / worsened:
(Text field for open answer)

Q26. Yes, I would like to receive the results of the survey at the following email address.

Answer Options

- Email address (optional):

Q27. Which Corona aid project should be donated to?

Answer Options

- Aktionsbündnis Katastrophenhilfe (Action Alliance for Disaster Relief)
- Ärzte der Welt (Doctors of the world)
- SOS-Kinderdörfer (SOS Children's Villages)

Part 6: Personal questions and working environment

1561 A.2 Questions of qualitative interviews

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Manuscript submitted to ACM

Questions for semi structured interviews

General Situation / Employee satisfaction

1. How did the COVID-19 pandemic affect your work?
2. How satisfied are / were you with your working situation during the crisis?
 - a. What were the reasons?
 - b. What else affected you during this time?
3. Did your working situation improve or get worse while working remote during the crisis?
 - a. Please explain why.
 - b. Do you expect future changes, either perceived as positive or negative?
4. How satisfied is / was your time during this pandemic?
5. How satisfied are you with the inner team collaboration while working entirely remote?
6. Would you classify your team rather as collaborative or as competitive?
 - a. Please explain what collaborative and competitive means to you.
 - b. Could you give an example why you classify your team as collaborative, competitive?
7. *Experienced DSD workers: What is the most important team characteristic / the best working mode for working from home?*
8. *Experienced DSD workers: Please mention the most important best practice/s regarding work from home.*

Main Challenges

9. What are / were your main challenges in remote work during the corona crisis?
Experienced DSD workers: Did the main challenge change because of the pandemic? And if yes, what are / were your main challenges in remote work before the corona crisis?
 - a. Directly related to your work?
 - b. Other challenges?
8. How did those main challenges impact your work?
9. Can you give an example for the challenges mentioned?
10. Did you do anything to face these challenges?
11. What are / were your team's / colleagues' main challenges in remote work during the corona crisis?
12. How did you cope with the situation where personal contact is missing?
13. Did you substitute personal contact (e.g. with having virtual coffee breaks...)?
14. Did you have any problems with missing equipment (f.e. mouse, monitor) or with insufficient tools (f.e. tools for video conferences)?
 - a. If yes, how did you cope with that?
15. Does your work depend on other colleagues?
 - a. If yes, did this affect your remote work?

Correlation between employee satisfaction and main challenges

16. Which challenges affected your job satisfaction the most?
 - a. How?
17. What was your worst job-related experience during working remote in the corona crisis?
18. Which chances do you see in the crisis?

General Questions

- In which department are you working?
- In which role are you working?
- Are you still working entirely remotely?
- Is your team still working entirely remotely?

1613 **A.3 Ordered logit analysis**

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Ordered logit models

- Coefficients are reported as odds ratios, where the null effect is 1 (values smaller than 1 indicate a negative effect; values greater than 1 indicate a positive effect)
- References [xx] are described at the end of the table

		Decision-making			Collaboration		Communication
ID	VARIABLES	(2) Approval decision postponement	(3) Approval decision deceleration	(4) Approval negative impact on planning	(5) Approval satisfied with collaboration	(1) Approval no effective work possible	(6) Frequency team communication (how often per day)
Collaboration	Approval: <i>My team is...</i>						
	collaborative	0.910 (0.188)	0.963 (0.200)	0.650** [10]	1.533* [7] (0.349)	0.570** [7] (0.128)	1.048 (0.238)
	competitive	1.164 (0.176)	1.481** [9] (0.232)	1.251 (0.191)	0.799 (0.135)	0.994 (0.163)	0.782 (0.128)
	agile	1.023 (0.246)	0.592** [9] (0.147)	0.971 (0.239)	1.417 (0.383)	1.279 (0.340)	1.672* (0.453)
	flexible	0.646 (0.174)	1.431 (0.377)	0.691 (0.190)	1.153 (0.330)	1.366 (0.381)	0.676 (0.188)
	Process oriented	0.887 (0.199)	0.766 (0.173)	1.097 (0.243)	1.441 (0.358)	1.312 (0.311)	1.131 (0.256)
	Result oriented	1.145 (0.289)	0.876 (0.224)	1.097 (0.288)	1.177 (0.335)	0.639 (0.178)	1.254 (0.342)
	Approval need to be reachable at core times	1.321* (0.213)	1.338* (0.206)	1.114 (0.171)	0.965 (0.162)	1.169 (0.188)	1.031 (0.160)
	Approval depend on other colleagues	1.140 (0.211)	1.048 (0.192)	1.552** [11] (0.299)	0.609** [8] (0.127)	2.379*** [8] (0.534)	1.082 (0.215)
	Communication	Communication frequency before crisis (more often or less)	0.724 (0.197)	1.292 (0.334)	0.934 (0.244)	1.061 (0.305)	1.429 (0.394)
Familiarity with remote work		Remote work before crisis (individual)	0.771 (0.134)	1.163 (0.197)	0.916 (0.158)	0.983 (0.191)	0.795 (0.146)
	Remote work in the team (how many worked remote on a regular basis)	0.755** (0.100)	0.750** [9] (0.098)	0.804* [10] (0.105)	1.097 (0.159)	0.928 (0.125)	0.895 (0.121)
Division	<i>Division (Reference: Data Analytics/Reporting)</i>						
	IT infrastructure/support	0.395 (0.303)	1.084 (0.717)	0.627 (0.413)	0.767 (0.537)	3.827* (2.639)	2.454 (1.620)
	Conception/strategy	0.926 (0.653)	1.325 (0.934)	0.125** [10] (0.105)	0.634 (0.507)	2.883 (2.201)	3.246 (2.590)
	Software development	1.088 (0.480)	0.432* (0.193)	0.393** [10] (0.175)	1.263 (0.619)	1.037 (0.495)	3.037** (1.464)
Communication	<i>Communication before crisis (Reference: Chat Confluence /Wiki)</i>						
	Confluence /Wiki	1.185 (1.066)	3.046 (2.717)	1.189 (1.123)	0.387 (0.398)	8.351** (7.930)	0.279 (0.269)
	Email	1.396 (0.590)	0.911 (0.391)	1.439 (0.623)	1.355 (0.640)	1.043 (0.460)	0.486* (0.208)
	Others	0.714 (0.624)	8.394** (7.195)	2.375 (2.030)	5.180 (5.289)	8.242** (7.625)	1.308 (1.082)
	Phone	0.493 (0.288)	0.819 (0.456)	1.566 (0.881)	1.610 (1.035)	0.619 (0.379)	1.337 (0.776)

<i>Tools</i>							
	<i>No new tools to support crisis (Reference: yes)</i>	0.859 (0.424)	0.279** (0.142)	0.744 (0.374)	1.181 (0.641)	0.386* (0.202)	3.447** (1.920)
Observations		64	64	64	64	64	64
Pseudo R-squared		0.170	0.199	0.216	0.228	0.315	0.204
Linktest (Significance, - = not sign.)							
Pred		-	*	*	-	***	***
Pred ²		-	-	-	-	**	-

Standard errors in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

		Communi- cation				Tools	Satis- faction	
VARIABLES		(8) Approval communicatio n is challenging	(9) Approval misunder standings in communi cation	(10) Approval communi cation is exhaustin g	(11) Approval communi cation is good	(12) Approval unequal distributi on of informati on	(13) Satisfied with usage of tools	(14) Approval improve ment of working situation through remote work
Collabo- ration	Approval: <i>My team is...</i>							
	collaborative	0.909 (0.186)	0.862 (0.178)	0.908 (0.175)	1.288 (0.291)	0.733 (0.146)	1.767** [14]	1.535** [12]
	competitive	1.227 (0.185)	1.130 (0.177)	1.112 (0.155)	0.816 (0.137)	1.809*** [5]	0.597*** [14]	1.094 (0.159)
	agile	0.676 (0.164)	0.683 (0.172)	0.998 (0.223)	2.021** [2]	0.519*** [6]	0.689 (0.187)	1.294 (0.304)
	flexible	0.833 (0.219)	1.108 (0.295)	1.015 (0.254)	0.729 (0.215)	1.566* (0.405)	1.796* (0.548)	0.766 (0.198)
	Process oriented	1.026 (0.224)	0.927 (0.206)	0.620** [3]	1.188 (0.287)	0.758 (0.162)	1.849** [14]	1.081 (0.231)
	Result oriented	0.838 (0.213)	0.988 (0.255)	1.002 (0.243)	1.144 (0.314)	1.014 (0.248)	0.798 (0.232)	0.791 (0.199)
	Approval need to be reachable at core times	0.923 (0.239)	1.461 (0.390)	1.450 (0.350)	0.808 (0.225)	1.160 (0.292)	1.590 (0.515)	0.708 (0.178)
	Approval depend on	1.064 (0.185)	1.274 (0.230)	1.250 (0.197)	0.769 (0.150)	1.344* [5]	0.832 (0.163)	1.257 (0.209)
Communi- cation	other colleagues							
	Communication before crisis	0.899 (0.113)	1.000 (0.129)	1.042 (0.123)	1.007 (0.141)	0.890 (0.110)	0.972 (0.142)	1.001 (0.120)
Familiarity with remote work	Remote work before crisis	0.923 (0.239)	1.461 (0.390)	1.450 (0.350)	0.808 (0.225)	1.160 (0.292)	1.590 (0.515)	0.708 (0.178)
	Remote work in the team	1.064 (0.185)	1.274 (0.230)	1.250 (0.197)	0.769 (0.150)	1.344* (0.222)	0.832 (0.163)	1.257 (0.209)
Division	<i>Division (Reference: Data Analytics/Reporting)</i>							
	IT infrastructure/support	0.556 (0.364)	0.427 (0.295)	1.977 (1.207)	1.037 (0.738)	0.429 (0.272)	1.743 (1.254)	0.290* (0.189)
	Conception/strategy	0.974 (0.677)	0.524 (0.380)	4.073** [4]	2.918 (2.891)	1.278 (2.318)	2.763 (2.270)	0.646 (0.455)
	Software development	0.258*** [1]	0.352** [1]	0.809 (2.891)	3.032** [2]	0.789 (0.873)	0.703 (2.270)	0.843 (0.455)
	Communication before crisis (Reference: Chat)							
Communi- cation	Confluence /Wiki	1.051 (0.960)	3.079 (2.808)	1.692 (1.420)	1.148 (1.238)	1.474 (1.295)	1.121 (1.223)	0.724 (0.669)
	E-mail	0.385** (0.167)	0.890 (0.390)	1.810 (0.717)	1.410 (0.674)	1.166 (0.475)	0.474 (0.230)	1.543 (0.639)
	Others	0.196* (0.173)	0.622 (0.584)	0.804 (0.637)	2.831 (2.854)	3.444 (2.772)	0.830 (0.805)	0.381 (0.322)
	Phone	0.230** (0.133)	0.522 (0.310)	2.126 (1.108)	2.227 (1.379)	0.566 (0.310)	0.577 (0.376)	2.015 (1.110)
Tools	<i>No new tools to support crisis (Reference: yes)</i>	0.196*** [13] (0.101)	0.402* (0.213)	0.458* (0.212)	1.558 (0.842)	1.241 (0.592)	0.852 (0.468)	2.033 (0.984)
	Observations	64	64	64	64	64	64	64
	Pseudo R-squared	0.226	0.193	0.177	0.217	0.194	0.343	0.163
	<i>Linktest (Significance)</i>							
	Pred	**	***	*	***	***	***	***
	Pred ²	-	-	-	-	-	-	-

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Description of Findings

- [1] Employees from the division of software development did not agree that communication in remote work was challenging or lead to misunderstandings.
- [2] Employees from the division of software development rated the communication as good, just like employees who characterized their teams as agile.
- [3] Employees who rated their team as process oriented did not agree that communication was exhausting while working from home.
- [4] Employees from the conception and strategy division rated the communication as exhausting.
- [5] Employees who classified their team as competitive agreed at a higher rate that information was unequally distributed as well as employees whose work strongly depended on others.
- [6] Employees who classified their team as agile or as flexible did not experience the issue of unequal distributed information.
- [7] Employees who classified their teams as collaborative agreed on a higher rate that effective work was possible while working from home and they were satisfied with the team collaboration.
- [8] Employees whose work strongly depended on others were less satisfied with the collaboration in the team and tended to agree that effective work was not possible while working from home during the COVID-19 lockdown.
- [9] Employees who classified their team as competitive agreed on a higher rate, that decision-making decelerated through the work from home during the crisis. Employees who characterized their team as agile and employees from teams, in which most of the members before the lockdown already worked from home on a regular basis did not feel an impact of the decision-making velocity.
- [10] The latter and members of teams classified as collaborative did not feel a negative impact on planning during their remote work. This is equally true for employees in the software development and conception and strategy divisions.
- [11] In contrast, employees whose work strongly depended on others agreed on a higher rate that the remote work during the crisis impeded proper planning.
- [12] Employees who classified their team as collaborative agreed at a higher rate that their overall working situation improved through the work from home during the COVID-19 lockdown.
- [13] Employees in whose teams no new tools were introduced due to the remote work, agreed on a higher rate, that communication is challenging.
- [14] Employees who characterized their team as competitive were significantly less satisfied with the provided tools than employees who classified their team as collaborative or process oriented.

1665 A.4 Code book including code definitions

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Manuscript submitted to ACM

List of codes	Definition	Frequency
Sum of code segments		504
Challenges	Challenges regarding changed working situation.	
Challenges (entire remote work)	Main challenges in entire remote work during the corona shutdown.	
Challenges related to Tooling	Challenges because of insufficient or inappropriate tools.	14
Challenges related to Mangement	Challenges because long and hierarchical decision-making processes.	15
Challenges related to Collaboration	Challenges because of ineffective collaboration.	0
Decreasing motivation	Challenges regarding depending on experts or "bottle necks".	1
Depending on colleagues	Challenges because of missing innovation and creativity.	7
Missing innovation / creativity	Challenges because of missing team spirit.	1
Missing Team Building	Challenges because of the feeling that information ist not equally distributed.	1
Unequal distributed information	Challenges because of missing collaboration with other teams / colleagues.	5
Missing Collaboration across teams	Challenges because of problems in synchronisation or coordination.	1
Synchronisationissues	Challenges regarding know-how transfer and documentation.	6
Lack of / or contradictory Explicit Knowledge	Challenges because new projects or topics are more difficult to arrange / start by working remotely.	6
Starting new Projects	Challenges in incorporating new colleagues.	2
Integrating new Colleagues	Challenges because of problems in communication.	8
Challenges related to Communication	Challenges because of missing communication skills.	1
Many Meetings / Conversations	Challenges because of inadequate or missing communication tools.	7
Wrong way of communication	Challenges because of missing personal contact with colleagues.	4
Wrong / Missing Communication Tools	Challenges because of technical issues / connection problems that hinder proper communication.	1
Missing Personal Contact / Estrangement	Challenges because of missing nonverbal communication such as posture, gesture and facial expressions.	35
Technical Issues	Challenges because of missing office grapevine or smalltalk.	10
Missing Nonverbal Communication	Challenges because colleagues are not accessible or reachable when they are needed.	4
Missing Office Grapevine	Challenges because of missing office grapevine or smalltalk.	5
Lack of Accessibility / Urge to be reachable / synchronous com	Challenges because colleagues are not accessible or reachable when they are needed.	18
Other challenges	Challenges not directly related to decision-making, collaboration, communication or usage of tools.	0
Support from company (equipment, ...)	Challenges because of missing support from the company f.e. providing appropriate equipment.	1
Legal affaires	Challenges regarding legal affaires.	1
Different time zones	Challenges because of global distribution and different time zones.	10
Internal Technical Issues	Challenges because of internal technical issues, like problems with connection, software updates or data access.	3
External Technical Issues	Challenges because of external technical issues (outside of the company) e.g. network collapse, bad internet connection, etc.	1
IT-Security	Challenges in ensuring IT-Security.	5
Home Schooling or other Distractions	Challenges because of various distractions while working from home.	6
Lack / Change of Daily Routine	Challenges because of missing daily routines.	8
Missing Office and Equipment	Challenges in setting up a fully equipped working space at home and ensuring IT-security.	12
Adherence of Work-Life Balance	Challenges because of difficulties in separating work and private life, working more than before the crisis or facing personal challenges because of children at home.	16
Challenges (hybrid work)	Hybrid work means some people are on site and some people work remotely. This is a situation many companies currently have because of the partly relaxation of the corona situation. Through hybrid work, new challenges arise.	11
Measures / Learnings / Best Practices	Measures which were taken already to face the existing challenges while working remotely or in a hybride mode during the corona crisis.	81
Team Characteristics	Characteristics of the team the respondent belongs to or personal opinions about certain team characteristics.	
Identification with product and culture / Pride	High level of identification with rather the developed products or the company culture resulting in pride in working at the team or the company	8

Toxic people	Characteristic assigned to a person who works against the team or does not add any value intentionally.	1
Having the same goal	High level of connection with colleagues through working together on a shared goal	6
Assume responsibility / Decision making power	High level of self responsibility and commitment of team members.	10
Trust	High level of trust from the company / from the management.	6
Hierarchy and Control	Level of control and layers of hierarchy within the team / within the company.	4
Agile	Characteristic assigned to an agile working team.	5
Competitive	Characteristic assigned to a rather competitive team.	5
Collaborative	Characteristic assigned to a rather collaborative team.	13
Employee (Dis-)satisfaction	Satisfaction or dissatisfaction with the remote working situation during the corona shutdown and the respective causes for the satisfaction / dissatisfaction.	
Employee Satisfaction	Employee satisfaction in general during the corona shutdown.	
More / more efficient online meetings / conferences	Employee satisfaction regarding more efficient online meetings and more meetings and conferences that could be attended online in general	3
Introvert vs Extrovert	Employee satisfactions as they categorize themselves as an introvert person and thus are satisfied with working alone at home	2
Company / Management Support	Employee satisfaction with the company strategy as well as with the support from the management.	1
Satisfaction with actual Working Situation	Employee satisfaction with the working situation in general during the corona shutdown.	18
Improvement of Work-Life Balance	Employee satisfaction with the work-life balance during the corona shutdown.	8
Increase in Productivity	Employee satisfaction regarding the productivity of their team or of the whole company during the corona shutdown.	15
Increase of Satisfaction	Increase of employee satisfaction due to the remote work because of the corona crisis.	15
Hybrid Work Approaches	Employee satisfaction with the hybrid mode of work that was set up after the shutdown and allows to partly go back to company for work.	2
Employee Dissatisfaction	Employee dissatisfaction in general during the corona shutdown.	
Decrease in productivity	Perceived decrease in productivity because of dissatisfaction with the working situation.	0
Uneasiness / Discomfort / Pandemic	Employee dissatisfaction because of general uneasiness and discomfort triggered by the COVID-19 pandemic.	3
Missing Work-Life Balance	Employee dissatisfaction because of missing work-life balance or family-related reasons e.g. children who could not go to school.	4
Work Overload	Employee dissatisfaction because of work overload, over hours or working during evening / night caused by the remote work during the corona crisis.	1
Missing Personal Contact	Employee dissatisfaction because of missing personal contact including also missing private conversations with colleagues.	7
Dependencies	Employee dissatisfaction because of depending on other colleagues who are more difficult to reach while working remote and not together in one office.	4
Technical Issues	Employee dissatisfaction because of technical issues like e.g. connection problems, systems shutdown or bad internet connection.	9
Future impacts of the corona crisis	Possible short and long term impacts of the corona crisis regarding work and professional life and chances seen in the crisis for society in general and for work and professional life in particular.	
Chances / Positive impacts	Chances seen in the crisis for society in general and for work and professional life in particular.	32
Short Term Impacts	Possible short term impacts of the corona crisis regarding work and professional life.	2
Long Term Impacts	Possible long term impacts of the corona crisis regarding work and professional life.	8