



Remote Persons Are Closer Than They Appear: Home, Team and a Lockdown

Mirjam Augstein

mirjam.augstein@fh-hagenberg.at
University of Applied Sciences Upper Austria
Hagenberg, Austria

Thomas Neumayr

thomas.neumayr@fh-hagenberg.at
University of Applied Sciences Upper Austria
Hagenberg, Austria
Johannes Kepler University
Linz, Austria

Johannes Schönböck

johannes.schoenboeck@fh-hagenberg.at
University of Applied Sciences Upper Austria
Hagenberg, Austria

Carrie Kovacs

carrie.kovacs@fh-hagenberg.at
University of Applied Sciences Upper Austria
Hagenberg, Austria

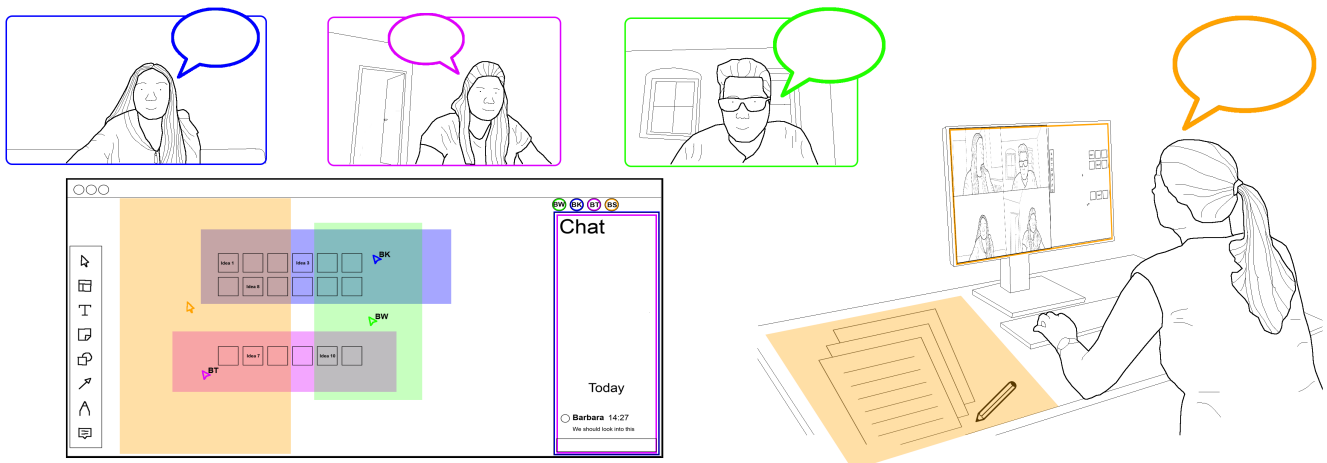


Figure 1: Remote collaboration of four participants connected via audio- and video stream, chat and shared whiteboard. The colored areas show the individuals' foci of activity (e.g., on the shared whiteboard but also on the desk in the non-virtual space).

ABSTRACT

Since 2020, worldwide COVID-19-related lockdowns have led to a rapid increase of remote collaboration, particularly in the domain of knowledge work. This has undoubtedly brought challenges (e.g., work-life boundary management, social isolation), but also opportunities. Practices that have proven successful (e.g., through increased task performance, efficiency or satisfaction) are worth retaining in future. In this qualitative empirical study, we analyzed four teams' (14 participants in total) mandatory remote collaboration over a period of several days to several months during a nationally imposed lockdown. We report results derived from questionnaires, logbooks, group interviews, and meeting recordings. We identify possible

factors influencing quality of task outcome as well as subjective aspects like satisfaction, motivation, and team atmosphere. As a basis for our conclusions, we provide a scheme for categorizing effects of remote collaboration based on an exhaustive literature review on pandemic-induced mandatory remote work and collaboration.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in collaborative and social computing.**

KEYWORDS

remote collaboration, mandatory remote collaboration, mandatory remote work, work from home



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1 INTRODUCTION

The restrictions and uncertainties during the COVID-19 pandemic clearly had a negative impact on many individuals' work environments, which is confirmed by the terminology used in recent related literature, including *Enforced Work* [85] or *Working From Home* [60, 87], *Enforced Remote Work* [92] or *Working* [7, 71, 78], *Forced Work From Home* [91], *Mandatory Remote Work* [70], *Required Work From Home* [61] or even *Emergency Remote Teaching* or *Learning*, respectively [38]. All of these designations imply an *involuntariness* on the participants' side, which usually has a negative connotation. However, there are also positive associations with remote work and collaboration (including involuntary conditions), such as increased flexibility [2, 16, 79, 92], autonomy [2, 56, 77] or efficiency [2]. While regular work from home (WFH) is fundamentally different to mandatory WFH [64], the pandemic provided us with a unique opportunity to learn from changes in work processes and better prepare for comparable situations in the future, but also to identify practices to improve future work and collaboration processes regardless of pandemic-related requirements.

Before describing our original work focusing on mandatory remote collaboration, we present the results of an exhaustive, targeted literature review we conducted in July 2022, providing a systematic overview of research related to remote work and collaboration during the pandemic. For the review, we used Google Scholar as a comprehensive database and searched for keywords such as “mandatory remote work”, “mandatory remote collaboration” (including synonyms such as “mandatory work from home” or “forced remote collaboration”). Additionally, we conducted a more general search for “remote collaboration” and “remote work” (again including synonyms) and limited the results to the years 2020 to 2022. In reviewing the results, we focused on scientific contributions (targeting journal articles but also including papers in conference proceedings and pre-prints, as many research papers were only recently submitted or accepted). Thereby, related work (see Section 2) can be roughly categorized into work that focuses on the effects of mandatory remote work or collaboration on the individual (see Section 2.1) or on the collaboration itself (see Section 2.2), work describing the collaboration surroundings (see Section 2.3), including physical and virtual spaces, and work containing earlier overview studies [9, 56, 86, 87]¹, e.g., literature reviews. Further, the literature we considered contains a collection of research related to the new future of work by Microsoft Research [83], which was published online. The review studies were additionally used for an adjunct literature analysis: tracing the search results on Google Scholar with reference to each review paper, and checking the references included in the review papers. In total, we reviewed several hundred items for their relevance, arriving at 62 journal articles, conference papers and pre-prints, as well as three tech-reports. With the exception of five earlier publications (which, however, also describe mandatory remote work or collaboration), all of these resources were published between 2020 and 2022 and relate directly to COVID-19-induced WFH situations. From these resources, we extracted and categorized the most important keywords in an iterative collaborative process involving three researchers, resulting in the classification visualized in Figure 2 and described in Section 2.

¹[87] contains a review but also describes an original study.

Our discussion of related work shows that most existing studies focus on a small subset of the relevant aspects which characterize mandatory WFH (e.g., individual or collaborative aspects, personal aspects related to wellbeing, or professional ones related to performance). Further, our literature analysis reveals that for many of the effects that have been studied so far (e.g., motivation, engagement, isolation, or work-life balance), findings are sparse or inconsistent (also see Table 1 and Section 2.4), suggesting that there might be unexplored factors moderating the effects of WFH and that further research is needed. Thus, though informed by this related work, our original research attempts to draw a more holistic picture of a mandatory remote collaboration situation, focusing on the domain of knowledge work [80] in a university setting. We chose a complex methodology for our qualitative study, including a wide range of analytical lenses, based on rich data collected via group interviews, individual questionnaires, audio-visual meeting recordings, chat protocols, and logbooks (see Section 3). Our study reports on the subjective experiences and behavior of 14 individuals in four teams in an academic context during times when WFH was mandatory due to a national lockdown. We analyzed teams' coping strategies in their respective professional settings, aiming to cover all of the aspects extracted from related work and more. Since ten of our 14 participants had basic educational training in Computer Supported Collaborative Work (CSCW), we discussed advanced concepts in our group interviews, such as the shaping of roles and responsibilities [13, 68], territoriality [75, 84], Bill Buxton's media spaces [17, 18, 81], and the perceived closeness [34, 43, 65] in remote collaboration. These concepts are not only relevant for (mandatory remote) collaboration, they also relate to effects where there is either inconsistent or insufficient evidence in existing research (see Table 1 and Section 2.4).

Our analysis e.g., shows that most teams increased their meeting frequency during WFH. Participants reported higher perceived availability of collaboration partners, “shorter paths”, but at the same time they experienced challenges related to boundary management, work satisfaction, and sociality (see Sections 4 to 5). We identified several work practices that could be retained for the future, off the context of mandatory WFH, and that have the potential to improve the overall quality of work and collaboration (see Section 6). In Section 7, we discuss and summarize contributions, impact and limitations of our work before we point out future research directions and extract key take-away messages in Section 8.

2 RELATED WORK

We present related research on (pandemic-induced) mandatory WFH and collaboration, based on the comprehensive literature review outlined in Section 1 (cf. Table 1).

2.1 Individual Aspects – Being by Yourself

According to related literature, a mandatory WFH or collaboration situation might have positive and negative effects on individuals, including personal aspects, e.g., wellbeing (cf. Personal Matters in Table 1), and those related to a person's work situation (cf. Professional Matters in Table 1).

2.1.1 Wellbeing. Numerous researchers have recently investigated how mandatory WFH impacts individuals' *wellbeing* and/or *health*

Table 1: Effects of mandatory remote work and collaboration, an overview of related literature. Pre-pandemic resources^a and such containing earlier systematic reviews^b are listed separately. All other literature dates 2020-2022 and describes work/collaboration during pandemic-induced WFH. Column “Result” indicates whether literature revealed an effect in either direction (“+” or “-”) of the mandatory WFH situation, whether existing results are inconsistent (“±”) or whether existing evidence is insufficient (“?”).

General	Concrete	Detail	References	Result
Individual Being by Yourself Personal Matters	Wellbeing	Stress	[8, 28, 42, 43, 60, 78] [86, 87] ^a	+
		Fatigue		
		Exhaustion		
		Frustration		
		Isolation	[49, 76] [56] ^a	+, ?
		Motivation	[8, 43, 54, 55, 59, 71, 89] [9, 87] ^a	±
		Engagement		
		Satisfaction		
		Happiness		
		Wellbeing	[1, 42, 49, 69, 72, 78, 92] [86] ^a [24] ^b	-
		Health		
	Boundaries	Boundary Management	[3, 6, 7, 27, 42, 51, 72, 89, 92] [9, 86] ^a [27, 51] ^b	±
		Work-Life Balance		
Professional Matters	Performance	Productivity	[1, 43, 47, 64, 88, 92, 93] [86] ^a	±
		Effectiveness	[5, 44, 55][48] ^b	±
		Efficiency	[2, 8]	±, ?
		Creativity	[35, 58]	-, ?
	Work Conditions	Flexibility	[2, 16, 79, 92][48] ^b	+
		Autonomy	[2] [56] ^a [77] ^b	+, ?
		Control		
		Roles	[11, 93] [56] ^a	?
		Relationships		
		Working Habits	[23, 26][9] ^a	?
		Workload	[3, 4, 21, 42, 88] [48] ^b	+
		Distraction	[21, 57] [56] ^a	+
		Interruption		
Collaboration Being Together	Interaction	Communication	[19, 22, 29, 61, 64, 70, 90, 93] [87] ^a	±
		Coordination	[30, 54]	?
		Team Organization		
		Collaboration	[21, 29, 43, 64, 90, 91] [87] ^a	±, ?
		Collaboration Readiness		
	Closeness	Connectedness	[21, 90, 92]	±, ?
		Presence	[50]	?
		Social Space	[11, 29, 36, 43, 64, 92] [77] ^b	-
		Territoriality		
	Sharing	Knowledge Sharing	[47, 66, 85, 87] [86] ^a	±
		Knowledge Exchange		
Surroundings Being There	Virtual Space	Supporting Technology	[8, 11, 20, 28, 36, 44, 50, 54, 57, 74, 79, 92] [9, 90] ^a	+, ?
		Technology Use		
	Physical Space	Task-Technology Fit	[1, 32]	?
		Work Environment	[3, 7] [51] ^b	±, ?
		Home		

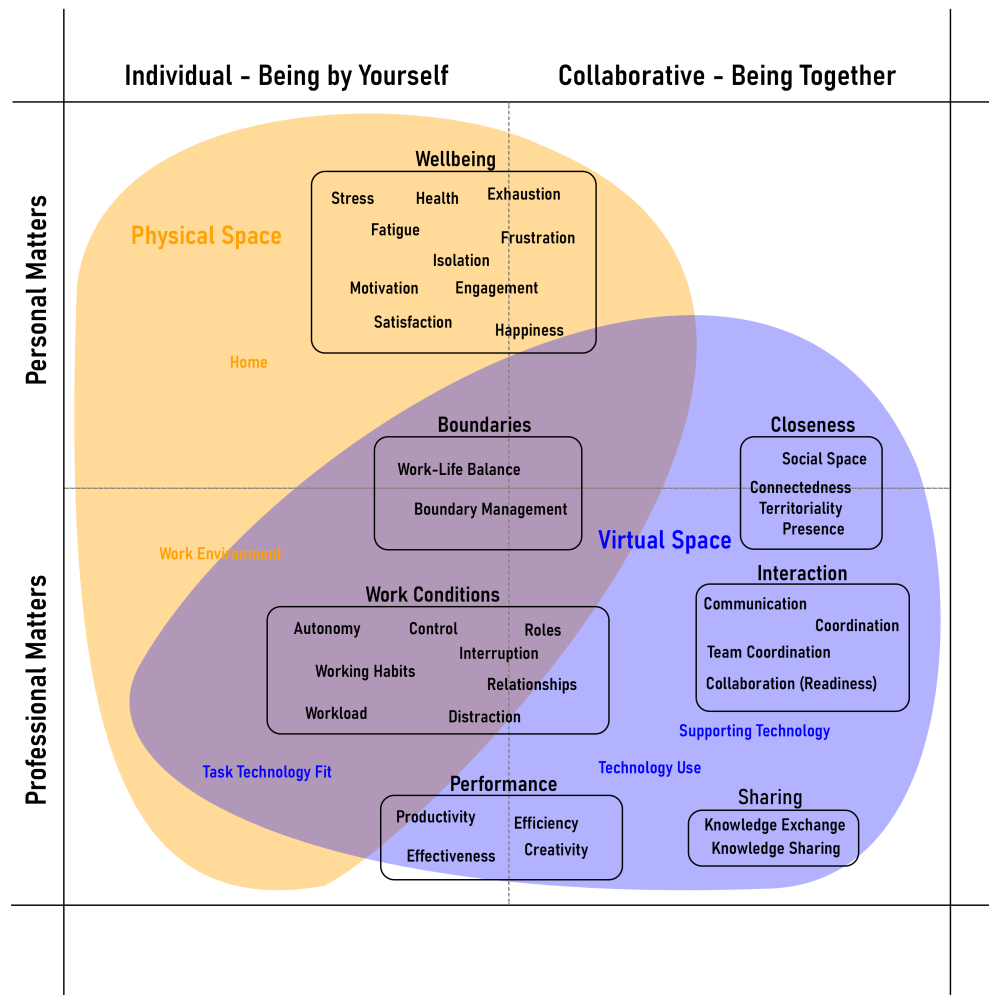


Figure 2: Categorization of possible effects of mandatory remote work and collaboration, based on a targeted literature review.

[1, 24, 42, 49, 69, 72, 78, 86, 92]. A prominent concern is *stress* stemming from extensive ICT use, which leads to detachment and communication overload [60], and was coined “technostress” [8, 24, 42, 78]. Interestingly, while ICT use increased due to WFH, ICT use for personal purposes also increased, resulting in even more technology *exhaustion* [52], a decrease in *wellbeing* [78], and greater *fatigue* [8, 28]. As most communication abruptly switched to technologically-mediated forms, this fatigue was often expressed towards video conferencing (VC), e.g., as “VC Fatigue”, or “Zoom Fatigue” [8, 28, 44]. Infringements on the *work-life boundary* (cf. Section 2.1.2) further led to increased *emotional exhaustion* and decreased *happiness* [72]. Consequently, work results and *productivity* might be at risk [59]. Counter-measures taken by organizations to keep employees’ *engagement* high include increasing individual autonomy and involving employees in discussions about future corporate strategy [71].

Other research reports negative effects on mental health without looking closely at their causes, including: stress, dwindling *motivation*, depression and feelings of *isolation*, a lack of social

interaction [69], and feelings of anxiety, anger, annoyance, tolerance, frustration, or uncertainty [86]. Fear of isolation, both socially and professionally, was mentioned as a factor hindering the voluntary adoption of WFH [56]. Besides psychological outcomes, *physical health* (e.g., sitting long hours, physical pain) was also considered [69, 72, 86]. E.g., a lack of ergonomic furniture in home-working environments increased “musculoskeletal disorders” [86], and changes in lifestyle (e.g., sleep, exercise, and nutrition)—both negative and positive—were described [72]. Further positive effects, such as individuals’ *positive emotions*, or increases in *job satisfaction* and *organizational commitment* levels [24] or better time management [69] were also reported. A systematic review [86] came to similar conclusions around *motivation* (also see [55]), enhanced perceived autonomy, and improved work-family-life balance.

2.1.2 Boundaries. Both voluntary and mandatory WFH presented challenges for *boundary management* and *work-life balance* [3, 6, 7, 12, 27, 42, 51, 72, 82, 86, 89, 92]. Foremost, abrupt transfer of workplaces to workers’ homes blurred work-non-work boundaries [6].

Pandemic-induced school closings further forced parents to put extra effort into care and/or education during traditional working hours [92]. “[W]omen, and mothers in particular” were most restricted in their boundary management autonomy [7]. Employees’ strategies to compensate for lost productivity included working in the evening or weekends, further blurring boundaries and contributing to negative psychological consequences [3, 12, 72, 82, 86] (also cf. wellbeing, Section 2.1.1). Besides personal circumstances, individual preferences for either *segmentation* or *integration* of work-non-work spheres also plays a role in how WFH is perceived [3, 6, 27]. While physical separation of workplace and home traditionally allowed for simple segmentation, this was largely lost through mandatory WFH. Besides well-known strategies (based on [53]), e.g., declaring certain rooms in the home a dedicated home office or keeping strict work hours, new approaches for re-establishing segmentation were identified [6], e.g.: “emulating office routine” (e.g., dressing the same way as when going to work), “purposefully disconnecting” (i.e., being intentionally unreachable after working hours), and “reducing work and home role overlap” (i.e., working when others are gone or asleep [3, 6]).

Beneficial outcomes of (usually voluntary) WFH have also been reported, e.g., connected to employees’ perceived *autonomy*, *freedom*, and gratitude for the chance to *self-organize* their work arrangements [7] (also cf. *work conditions*, Section 2.1.4). “Workplace flexibility, environmental conditions of home offices and organizational supports are positively associated with productivity, satisfaction with working from home and work-life balance” [89]. However, these beneficial outcomes might be lacking when WFH is mandatory [7].

2.1.3 Performance. Mandatory WFH and remote collaboration might also affect work performance. Related effects include productivity [1, 43, 54, 64, 86, 88, 92, 93], effectiveness [5, 44, 48, 55], efficiency [2, 8] and creativity [35, 58]. There seems to be a lot of evidence that (mandatory) WFH can lead to a decrease of *productivity* at work [43, 55, 64, 88], e.g., due to a low task-technology fit (TTF) [1] (i.e., how well technology is suited for the current tasks, considering abilities [37]), general technical issues [88], specific technical issues (e.g., caused by background noise [44]), motivational aspects [43] and current life events (e.g., health and childcare responsibilities [64]). Additionally, problems of traditional meetings such as the behaviour of participants (late arrival) or the organisation of meetings (too long, lack of agenda) also have a negative impact on *effectiveness* in WFH situations [44]. Further, an analysis of remote teams’ *creativity* suggests that they are “less likely to integrate existing knowledge and produce new, disruptive ideas” [58].

However, literature indicates that a more differentiated view is necessary. The *efficiency* of WFH seems to depend on the nature of tasks, e.g., researchers were less efficient in sharing thoughts, staying in touch with the team or collecting data, but more efficient in analyzing data, working on manuscripts, or reading literature [2]. Further, *creativity* of virtual teams can be improved by creative and adaptive virtual environments [35], and a greater TTF facilitates enhanced *performance* (and reduced feelings of loneliness, cf. wellbeing) [1]. One study additionally suggests differences between agile and traditional teams [54]: while the overall quality of team collaboration and *productivity* increased in agile teams, it decreased

in traditional ones. There is also evidence for explicitly positive effects of WFH on *productivity* or *effectiveness*, e.g., due to increased inclusiveness and empathy for teammates, team bonding or flexibility [64], use of more knowledge and skills, and multi-tasking [55]. With a clearly defined and well-organised workspace that provides easy access to resources [93], remote work is seen as conducive to productivity [92]. Additionally, a pre-pandemic study on flexible work found that remote workers often did more when they worked from home (“intensification of work” [48]). From companies’ perspective, the *productivity* and *international competitiveness* could increase, as remote working would make it easier for employees to work in different time zones and thus 24 hours per day [86].

2.1.4 Work Conditions. Existing studies agree that the pandemic has drastically changed how and under what conditions organizations and employees work [2, 11, 16, 21, 57, 78, 79, 88, 92]. A generally positive development is greater *flexibility* [2, 7, 70, 92], often accompanied by increased *autonomy* and *control* over the organization of one’s work [2, 56, 71]. Work conditions in a collaborative setting are further strongly impacted by *relationships* and *roles* within a team. Relationships have been reported to be of utmost importance during mandatory WFH [11, 56, 93] e.g., “[t]he pre-pandemic relationships of colleagues [...] serve to ameliorate or exacerbate the challenges of such [social talk] conversations” [11]. Further, they are described as the “common glue to determine the opportunities and etiquette around social talk in remote work” [11]. Positive relationships with colleagues can be a “motivational factor for boosting productivity, and decreasing the probability of voluntary turnover” [56] and “socialization is one essential component of teamwork that virtual teams may often miss out on, which can result in a lack of team spirit and cohesion” [93]. This is not only true for colleagues that have not known each other prior to mandatory WFH; existing relationships might also be more difficult to retain [93]. Many negative effects of mandatory WFH are related to *workload* and *distraction* or *interruptions*. Most related literature agrees that the *workload* increased during mandatory WFH [3, 4, 21, 42, 88] (also supported by pre-pandemic WFH research [48]). Distractions and interruptions might be directly imposed by the home environment (e.g., by family members or pets, arrival of parcels, incoming phone calls [21, 56, 57]) but also might come from coworkers reaching out more often [21]. In addition to the work conditions, mandatory WFH has been shown to also affect individuals’ *working habits*, e.g., increasing the frequency and scope of their communications (an effect that might continue into the weeks after lockdown) [26]. Further, *multitasking behavior* seems to have changed during remote work and, according to [23], depends on meeting characteristics (e.g., size, length, time and type). While multi-tasking can help boost *productivity*, it also leads to *loss of attention/engagement* and greater *mental fatigue*, and can be seen as disrespectful [23].

Importantly, literature on work conditions suggests a discrepancy between voluntary flexible work [48, 77] and mandatory WFH [16, 70, 71]. A pre-pandemic study found that job satisfaction and organizational commitment were higher and stress levels slightly lower for flexible (remote) employees than for traditional ones, although the flexible workers also experienced “work intensification” [48] (cf. also performance, Section 2.1.3). Intra-pandemic research,

on the other hand, reports *stress* as a negative result of mandatory WFH [3, 8, 21, 60, 78] (also cf. wellbeing, Section 2.1.1), with a (perceived) increase in *autonomy* or *control* on the positive side. However, a pre-pandemic study interestingly came to the conclusion that perceptions of autonomy had actually been undermined for remote working employees [77] through the need to be permanently available to colleagues (and probably also reinforced by a lack of social legitimacy of telework at that time). These discrepancies suggest that the evolvement of work conditions through the pandemic has had a lasting impact on the perception of WFH. While we expect a strong mitigation of the negative factors directly induced by the pandemic (e.g., stress through home schooling responsibilities) in a post-pandemic world, positive ones will probably remain (e.g., increased flexibility). This also specifically motivated us to identify work and collaboration practices worth being retained in the future (cf. Section 6).

2.2 Collaborative Aspects – Being Together

In this section, we describe effects that the mandatory WFH setting might have on collaboration among users.

2.2.1 Interaction. Much research on collaborative interaction during WFH found changes in *communication* behavior [19, 22, 29, 61, 64, 70, 90, 93]. Naturally, face-to-face communication significantly decreased during WFH while VC and chat significantly increased [61, 64]. Meetings got shorter but were held more frequently [70] (a possible main contributor to meeting fatigue and technostress, see wellbeing, Section 2.1.1). At the same time, email, text messaging, and phone usage did not significantly change [61]. Studies indicate a general increase in collaboration [90] but also a strong shift towards asynchronous communication [19, 90] (or decentralized work [43]) and an overall decrease in communication, e.g., resulting from less initiative to proactively seek remote communication [19]. These observations are partly contradicted by research on preconditions for successful remote *collaboration* during mandatory WFH [21], based on Olson and Olson’s distance framework [67]. The related findings suggest that, first, the *collaboration readiness* of technology and involved persons has to be high, and actors need to achieve common ground, but second, while previously, loosely coupled work was deemed preferable for remote collaboration [67], other forms of coupling (e.g., tight coupling in synchronous meetings) have also proved beneficial recently [21]. We thus expect that, fostered by technological improvements, tightly coupled work will ultimately be co-favored.

Further research suggests that employees adopted *new communication strategies*, improved their *communication skills*, learned how to *use new technologies*, diversified their *communication channels*, and generally had to learn to *collaborate more effectively* [19]. They had to accept that they could not interact with others as easily as before [64] (e.g., with customers in on-site visits [19], or simply with colleagues [19] and classmates [22]), and had to “rely more on [their] independence” [19]. *Informal communication* was found to be beneficial [22], but it was often hard to establish because social events were perceived as causing role conflict, issues with boundary management, and meeting fatigue [61, 87]. Consequently, many teams were unsuccessful in replacing the spontaneity and

informality of face-to-face meetings with computer-mediated communication. This led to detrimental effects on rapport [61] and individuals missing social interactions [64]. At the same time, fostering synchronous participation in meetings and a certain amount of accountability for individual contributions was identified as a motivating factor [29].

Regarding *coordination* and *organization* of work and knowledge in virtual teams, it was found that digital artefacts play a decisive role and serve as vehicles for the transfer (i.e., mere sharing of artefacts without changes), translation (i.e., adding to artefacts while preserving their original state), transformation (i.e., fundamentally changing artefacts), and holding (i.e., restricting others’ access to artefacts) of knowledge [30].

2.2.2 Closeness. Pre-pandemic research on *social space* already revealed that norms associated with traditional workplaces, e.g., visibility, presence, trust, and availability, have to be rethought for teleworking [77]. During the pandemic, intra-organizational networks became more “static” and “siloes” (fewer new contacts were established, old ones were discarded, and less time was spent with newly acquired ones [90]). Fewer connections and interactions between groups were observed, and the awareness of what was going on in other groups decreased [90]. However, on the positive side, remote connections that already existed pre-pandemic were intensified, e.g., remote young scholars’ career opportunities improved through “expanded and enriched professional and social relationships” [29].

Also related to *closeness*, a public sentiment study identified a strong need for social interaction [92]. One way through which sociability can be established is small talk [11], which usually has a considerable share of overall speech (in adults up to one third) and can help to “transition[...] between roles and activities throughout [our] workday” [62], but is also important for collegiality and productivity [36]. During WFH, a substantial decrease in informal talk was reported [64] (cf. Section 2.2.1), resulting in “less socio-emotional interaction” and consequently less motivation [43]. To counteract this, researchers suggested a tool that allows online meeting participants to engage in small talk during the initial and concluding minutes of a scheduled meeting (and also throughout the meeting) [36].

Issues with *connectedness* were not only reported among coworkers, but also for friends and family. Social distancing led to fewer contacts and attempts to compensate for productivity losses (also see Section 2.1.2) limited quality time with loved ones.

2.2.3 Sharing. *Knowledge sharing* or *exchange* are of utmost importance in collaborative work and might be decisive for the quality of outcomes. Both are affected by mandatory WFH [47, 66, 85], by motivational (e.g., information value, ease of use, organizational and technical support) as well as barrier factors (e.g., low content quality, loss of knowledge, i.e., intellectual property, emotional anxiety, lack of time, or insufficient organizational support) [47]. Similarly, implications of the pandemic for *knowledge exchange* might be positive (e.g., reduced barriers for participation, opportunities to assemble larger and more diverse groups) or negative (e.g., absence of face-to-face interactions might hinder building personal relationships and trust) [66]. Additionally, research on *digital knowledge sharing* during WFH indicates that internal and external digital knowledge

sharing is a significant predictor for a team’s creative performance and that the latter can be increased by use of digital platforms [85]. These findings show that organizations can promote knowledge sharing in virtual teams via personnel development (e.g., improving user engagement by training and education), but also by *optimizing* the (virtual) collaboration *environments* (cf. Section 2.3).

2.3 Surroundings – Being There

Here, we present literature describing the (virtual and physical) surroundings in which mandatory WFH takes place.

2.3.1 Virtual Space. While numerous tools and platforms support remote work and collaboration, having too many different ones to use and integrate hinders productive collaborative work [20, 78]. In summary, VC seems to be the most important supporting technology in virtual collaboration environments. VC is used across different work domains and tasks, and supports communication and collaboration. While existing research on *technology use* in the context of WFH agrees on the importance and value of VC, it also reveals numerous related challenges, e.g., general technical issues [44, 57] or (lack of) socializing [1, 11, 20, 36, 74, 79], small talk [36] and emotional expression [20], lack of perceived proximity and tele-presence (“distance effect” [50]), lack of surveillance [20], lack of spontaneity [20], blurring between on- and off-hours [8, 20], privacy issues [11, 44, 57, 79] (e.g., videos of home environments [11, 57] or while eating [44]), and lack of specific functionalities such as idea generation [20] or collaborative sketching support [32]. Additionally, research has addressed the phenomenon of VC fatigue [8, 28] (cf. wellbeing, Section 2.1.1). Such effects can be triggered or intensified by personal (e.g., socio-demographic variables, cognitive traits, a user’s social network), organizational (e.g., number and duration of VC sessions, timing, anticipated outcome of VC, activity during VC), technological (e.g., camera type, lighting conditions, video resolution, background noise) or environmental factors (e.g., work context at home, distractions) [28]. Further, rapid changes in VC systems or use complexity—or platforms forcing users to change their behavioral patterns—can induce VC fatigue [8]. Some challenges can be relatively easily overcome, e.g., by using external tools if functionality is missing, or background effects for privacy. The number and complexity of different technologies a user has to work with should be minimized [78], and a *high TTF* should be ensured [1, 32]. Other challenges are more difficult to tackle (e.g., lack of socialization, permanent availability). Here, some tailored solution approaches already exist, e.g., a “virtual commute” feature preventing a user from being contacted outside working hours [63], or a “conversational transition space” that enables social time [36]. However, many existing approaches are not yet available for the broad public.

2.3.2 Physical Space. As users’ physical work environments during mandatory WFH are usually their private homes, strong overlap exists with the *boundary management* aspect [3, 7, 51, 57] (cf. Section 2.1.2) and is kept brief here. Related research describes physical components contributing to a user’s work environment at home while at the same time functioning as “boundary objects” (“material ‘things’ [...] constitutive of interactions in a particular social domain [...] particularly visible when two communities of practice negotiate

relations as their boundaries” [51]), especially technology such as a laptop or phone (enabling WFH [51]) and (ergonomic) furniture such as a sofa, desk or chair (accommodating WFH [51, 56, 89]). During the pandemic, many remote workers’ physical environments functioned as office and home for several people (accompanied by pets) [57], which again relates to distraction and interruptions [21, 56, 57] (cf. Section 2.1.4). Establishing a suitable workplace at home is a crucial factor [56], e.g., comprising a dedicated room that allows for work-non-work separation [3, 56, 60, 89], and infrastructure such as a high-speed internet connection [21, 32, 42, 56, 89].

2.4 Academic Gaps and Need for Further Research

While there is quite a lot of research on mandatory work from home, particularly related to the COVID-19 period, as indicated by the previous sections, many unanswered questions remain. As can be seen in Table 1, many results are inconsistent between studies, suggesting that unexplored factors may moderate the effects of WFH and that more research is necessary. For instance, in the category Wellbeing, there is evidence for both increased as well as decreased motivation, engagement, satisfaction or happiness. Similar is true for Boundaries, Performance, and Interaction and Sharing. For other effects, existing evidence is still rare. For instance, there are only two studies ([35, 58]) that suggest a negative effect on creativity (in partly very specific settings, which affects generalizability). Similarly, for efficiency, there is only little targeted research [2, 8], and that existing evidence suggests potential effects in both directions. In other cases, literature discusses potential effects without identifying reliable evidence (e.g., this is true for roles and relationships, territoriality, presence, and task-technology fit). Further, for Supporting Technology and Technology Use there seems to be a lot of recent literature. The vast majority of these sources of evidence focuses on VC as supporting technology and/or on use of this technology, revealing e.g., a lot of consistent findings on VC fatigue (“+” in Table 1). However, there is insufficient evidence for other effects that are directly related to the supporting technology (exceeding the scope of VC). Similarly, although there are several studies on collaboration, most of them are looking at collaboration in general (suggesting different effects, in different directions, thus marked as inconsistent evidence in the table), without specifically considering collaboration readiness (i.e., insufficient evidence).

In addition to the research gaps described above, there is also evidence for a discrepancy between WFH before and during the COVID-19 pandemic (see e.g., [87]). For instance, more negative effects on wellbeing were found during than before the pandemic. This could relate to the different motivations behind the WFH scenarios (e.g., fewer distractions, increased autonomy, etc. vs. “comply with governmental or organizational restrictions” [87]) or be driven by other aspects of the COVID-19 situation that changed how remote collaboration was practiced and perceived. Comparing later data to phenomena observed during the pandemic may allow us to untangle these results and identify effects of factors that would not normally have shown variation without the “natural experiment” provided by COVID-19 lockdowns. Yet, such a comparison presupposes in-depth knowledge of what occurred during the pandemic.

Finally, in [87], a number of open research questions is listed, among them such that are not exclusively tailored to the Post-COVID-19 era, e.g.: “How does the style, frequency and length of online communication affect the efficiency and effectiveness of team collaboration through COVID-19?”, “How has COVID-19 impacted communication effectiveness and team decision-making through digital collaboration platforms?”, “How does the merger of working and living space during COVID-19 affect productivity and wellbeing of employees?”, “How will digital collaboration platforms lead to new practices of knowledge sharing in hybrid or virtual teams?”, “If and how has work productivity and efficiency been affected during lockdown with the use of digital collaboration platforms?” Thus, in addition to giving a review of the evidence on mandatory remote collaboration published within the first two years following outbreak of the pandemic, the current work aims to make a modest contribution to answering these questions by presenting further data gathered during this unusual time. Our contribution, therefore, lies in a synopsis of the current state of research on mandatory remote collaboration—including identification of those factors whose relationship with remote collaboration remains unclear—as well as a qualitative study that attempts to explore all those factors among a structurally heterogeneous—though small—group of teams engaged in academic knowledge work.

3 USER STUDY

Here we describe design, methodology and participants of the original qualitative user study we conducted to gain in-depth insights into users’ collaboration behavior, practices and attitudes during a COVID-19-induced lockdown and mandatory WFH. Most studies described in Section 2 focus on a subset of the aspects listed in Table 1, limited either to individual or collaborative matters, or on the virtual and physical surroundings, often relying on a small number of data sources (e.g., an online questionnaire or individual interviews). Since this might be responsible for at least part of the inconsistencies we identified in our review (see the discussion in Section 2.4 and column “Results” in Table 1), our study takes a more *holistic view* of mandatory remote collaboration in a university setting. This is attempted, firstly, by covering all of the factors we identified as important through our literature review (under all three categories Collaboration, Individual, and Surroundings) and providing new insights into practices that can be retained in the post-pandemic world of work and collaboration. Secondly, a number of different data sources are considered in combination, as detailed throughout this section, further contributing to an in-depth probe into different naturalistic tasks of knowledge work.

3.1 Recruitment Process, Participants & Tasks

We recruited four teams with 14 participants in total (nine female, five male). Their mean age was 25.7 years ($SD=4.6$, $min=21$, $max=37$). Six had a university degree (one professor, four research associates and one graduate student), and eight were undergraduate students. Each team’s members knew each other well beforehand. We selected and recruited participants based on the nature of their tasks and their team constellations, aiming at diversity. The recruitment process can shortly be described as follows. We sent out a call for

participation via email in a targeted way, aiming at reaching different groups we wanted to address (students working in teams, master students working on their thesis, as well as research associates working on a research project in a cross-campus team). We used the university’s mailing list to reach the students and additionally forwarded the invitation to a small number of individuals we wanted to reach that were not included in the mailing list we used. All participants we eventually recruited volunteered to participate (about 33% of the persons invited volunteered in total, and about 27% of the invited students) and responded to the call on their own initiative. They were neither required to participate, e.g., in order to earn course credit (students), nor were they in any way obliged to cooperate with the research team (research associates). The participating students received a 20€ Amazon vouchers as a small acknowledgement for their participation. Since some of the students attended a class taught by one of the authors, 1) the interviews and questionnaires concluding the study (see Section 3.2) were held after grades for that class had been finalized and 2) the affected author did not receive access to the collected data (including the group processes) before the end of the semester in order to avoid a potential conflict of interest. Because these students participated in the final year of their studies, the end of the semester effectively ended the classroom relationship. In the case of Team D (thesis supervision), the possible conflict of interest was additionally addressed via a two-way signed agreement between advisor and student that excluded the affected author from access to the raw data. Additionally, all study participants signed an informed consent form which was in accordance with the GDPR and explicitly allowed them to opt out of the study at any point in time without stating reasons (which however, none of the participants chose to do).

The teams worked on natural academic tasks (i.e., not specifically provided by us) in a university context and the participants were free to choose their collaboration tools, while the university provided basic software infrastructure.

- **Team A, Student Group Work I:** Team A consisted of bachelor students (names changed for anonymity): Abigail (female, 24 years), Alice (f, 23), Amy (f, 21), and Arnold (male, 27). Their task (assigned by an instructor in their degree program) was due two weeks after assignment. It comprised research, brainstorming, creation of a low-fidelity prototype, and preparation of a final presentation.
- **Team B, Student Group Work II:** Team B (Barbara, Beatrice, Bella, and Brooke, all bachelor students, f, 22) worked on the same task as Team A.
- **Team C, Research Project:** Team C consisted of research associates from a university’s R&D department at two different campuses: Cameron (m, 25), Carl (m, 26), Chris (m, 31), and Craig (m, 33). Cameron mainly worked together with Carl on frontend (e.g., visualization) tasks, Chris worked with Craig on the backend (e.g., mechanical algorithms). This also reflects their in-office situation prior to mandatory WFH. For the course of our investigation, the team worked on a subtask of their overall research project for the duration of several weeks.

- **Team D, Thesis Supervision:** Team D consisted of a master student (Daisy, f, 25) and her supervisor (Dora, f, 37). The study took place during the main writing phase of Daisy's thesis but also included some research.

Regarding existing roles and hierarchies, these teams were highly diverse. In Team A and B, there were no pre-existing roles and hierarchies at all (prior to the task). In Team C, the structure can best be described as a small-scale SCRUM team with one of the members acting in the role of a product owner (Chris), while in Team D there was a clear pre-defined hierarchy of advisor and student. The picture became even more multi-faceted as functional roles seemed to emerge in Teams A and B (e.g., through responsibilities for parts of the task, e.g., design, conceptualization, preparing the presentation, or prototyping), as well as process-related roles (e.g., facilitator), as described in further detail in Section 5.2.4.

3.2 Study Design and Apparatus

The study was designed with an initial briefing where each team received information on how they should capture their activities over the study period and provided voluntary informed consent. Participants were asked to keep a logbook of their meeting- and task-related activities, record their meetings with audio and/or video, and provide us additional sources of information, e.g., chat messages or task results. After task completion, we conducted one group interview with each team (between 46 and 67 minutes) and asked participants to complete a questionnaire individually.

3.2.1 Logbooks. Each team was asked to enter a protocol of their meeting and task activities into a spreadsheet in a standardized format comprising start and end times, activity type (e.g., discussion or brainstorming) and description, people involved, tools used to communicate and to work on the task, and an optional comment. The teams recorded between 11 (Team A) and 262² (Team D) logs, which gave us an initial overview of how the teams worked, the frequency and duration of their meetings, and their typical division of labor for tasks [65]. Please note that self-reports may have some drawbacks in terms of data quality, e.g., due to differences in the resolution of data points (some teams reported exact minutes while others rounded to the nearest 5 or 10 minutes). We tried to minimize such issues via clarifying discussions in the group interviews. Furthermore, the additional effort of log keeping during meetings in order to reduce a-posteriori reconstruction was deemed acceptable by the participants for the limited study period (e.g., the additional effort for Team C was rather low, since employees were already contractually obliged to keep records of their working schedule and this could be used as a basis for the manageable amount of extra information required in the logbooks). For reporting purposes, we rely on data provided by participants and report it as is (e.g., in Table 2 and Figure 3 through Figure 6).

3.2.2 Group Interviews. Two co-interviewers (identical for all teams) conducted semi-structured interviews, speaking to each team as soon as possible after completion of the observed task. We

took inspiration from contextual inquiries [39], interviewing participants in their “natural environment”, i.e., the same collaboration environment the task-related meetings were held in, establishing a good rapport and equitable conversational situations, using one interviewer as the main interlocutor while the other was responsible for the protocol (but could intervene in the discussion if needed), and trying to refer to concrete past situations to avoid too general answers. Ten participants had attended an introductory course in CSCW and were familiar with related terms, concepts and frameworks, which allowed us to have deeper discussions about their perceptions of what was happening and made these situations more comparable to expert interviews. We included questions around each team's general impression of the collaboration (what worked well, problems that occurred, tools that were used or needed, how work was organized), territoriality [75, 84] (whether and how different territories, i.e., personal, group and storage territory, were used), Buxton's media spaces [17, 18, 81] (how important the person, task and reference space were and whether available tools were sufficient in this context), roles and responsibilities [13, 68] (whether certain roles established implicitly or explicitly), closeness [34, 43, 65] (whether the setting had an effect on the team's closeness), effort (whether the setting affected the effort involved with the task), and retention of practices (whether the team's experiences might lead to changes in future work and collaboration for comparable tasks). For participants not sufficiently familiar with the CSCW models and frameworks we addressed, we provided a brief introduction prior to their group interview. All interviews were held after several months of mandatory WFH (for the student teams towards the end of the semester) and we encouraged participants to bring in perspectives from outside the scope of the observed task to complement their accounts (e.g., by relating to experiences from other projects). This was particularly helpful in capturing some effects of mandatory WFH that may take longer to develop, such as challenges for well-being or boundary management.

3.2.3 Questionnaire. After the group interviews, we asked participants to complete a questionnaire. This let respondents give an individual account of their perceptions and thus allowed for more critical answers that might have been hindered by the group setting or personal disclosure preferences. The questionnaire comprised self-developed items about participants' demographic background and their perception of collaboration, including their overall satisfaction with the task result and positive or negative consequences they felt accrued to the distributed setting. Additionally, participants completed the 24-item “Questionnaire on Working in Teams” (German: “Fragebogen zur Arbeit im Team”; F-A-T [45, 46]), which measured four dimensions of the team's quality of collaboration (see Section 5.2.4).

3.2.4 Meeting Recordings. We received 13 meeting recordings with an overall duration of 14 hours (mean=1:04, SD=0:32, min=0:17, max=2:17). Each team provided us material lasting between 3:17 (Team A) and 3:45 (Team B) hours. Participants were not required to activate their camera—however, except for Team C, where less than one third of the participants per meeting turned on their camera, all others had high shares of activated cameras, usually above 75%. Additionally, Teams A and B provided us with 10-20 chat messages taken from the VC software. The meeting recordings

²Note that Daisy logged the activities (start and end times, type of activity) of authoring her master thesis in a more fine-grained manner (using the time tracking tool Timeular), compared to the other participants, who, however, provided more details as required by the logbooks.

were selectively skimmed to find situations that either supported or contradicted what was captured through the other sources (i.e., group interviews, questionnaires, and logbooks).

4 RESULTS FROM THE LOGBOOKS

Based on participants' logbooks, we visualized individual groups' activities over time (cf. Figures 3 to 6). For an initial estimate of activities' scope, duration and team fragmentation, we calculated several metrics (cf. Table 2). Besides the number of team members (column **Team Size**), column **# of Activities** states the number of reported activities in the logbooks. In column **Activity Time (AT)**, the summed duration of all separate (and potentially parallel) activities is given (cf. Equation 1) where n is the number of activities and $t_{end}(a_i) - t_{start}(a_i)$ is an activity's duration. Column **Mean Duration** shows a team's average activity duration. Column **Person Hours (PH)** displays the sum of all activities' duration multiplied by the number of persons involved, expressed through $numPers(a_i)$ in Equation 2.

$$AT = \sum_{i=1}^n t_{end}(a_i) - t_{start}(a_i) \quad (1)$$

$$PH = \sum_{i=1}^n (t_{end}(a_i) - t_{start}(a_i)) \cdot numPers(a_i) \quad (2)$$

$$TFC = \frac{PH}{AT} \quad (3)$$

$$TFC\% = \frac{\frac{PH}{AT} - 1}{numPers(team) - 1} \quad (4)$$

To obtain an initial impression of a team's **Fragmentation** versus **Togetherness**, our new metric **Team Fragmentation Coefficient (TFC)**, adapted from general descriptions of team fragmentation [65], divides the **PH** by **AT** (see Equation 3). The theoretical extreme values for the **TFC** are between 1 and the number of participants, with lower **TFC** values indicating more solitary work (fragmentation) and higher values indicating more joint activities (togetherness). **TFC** can also be standardized as a percentage of time spent together with others (see Equation 4, and column **TFC%**), which facilitates comparisons between teams of different sizes and is more uniformly interpretable.

In column **TNS**, we report the **Time-weighted mean Number of concurrent Subgroups** as suggested in [65]. This number expresses into how many subgroups a team divides on average during collaborative interaction. However, this metric was introduced for short-term collaboration (e.g., for a session of a few minutes up to a few hours). **TNS** presupposes that most team members are engaged in the collaboration for most of the duration of a session (i.e., they are rarely 'disengaged'). Yet, this does usually not apply to longer-term collaboration, as can be seen in our timelines. Consequently, the descriptive power of the **TNS** is severely limited for longer-term collaboration. We thus decided to introduce the **TFC** instead (but still report the **TNS** in Table 2 to illustrate our case).

Table 2 and Figures 3 to 6 show that the teams worked in different configurations, using varying working styles and modes of communication, as we had hoped to ensure through our case sampling. We describe the individual teams and their working styles in further detail as follows.

Team A (student group) reported 11 activities within a total time frame of 2 hours 59 minutes over two individual days that add up to 6 hours 4 minutes of **AT** (due to parallel activities) and 10 hours 37 minutes **PH**. Their work was relatively fragmented and, according to their logbook, they spent only 17 minutes (or 9.4 percent of the overall 179 minutes) together in plenary. For *Team A*, the **TFC** is 1.75 and **TFC%** is 25%.

Team B (student group, same task as *Team A*) spread its work over a large number of meetings with 17 activities on five individual days (see Figure 4). The **AT** was 10 hours 44 minutes (39 hours 15 minutes in **PH**). The **TFC** of *Team B* is 3.66 which is near to the theoretical maximum of 4 (also reflected by 88.56% **TFC%**) and indicates very low fragmentation, i.e., the team approached most of its activities together (leading to the high number of **PH**). In comparison, *Team A* seems to have completed their task remarkably quickly (see Figures 3 and 4). *Team A* finished their task within two sessions whereas *Team B* had seven sessions. In *Team A*, Amy started a quick preparation of the final presentation while the others were occupied with other work, leading to two subgroups (see the **TFC** and **TNS**). *Team B* spent more time on collaborative actions (expressed by the higher **TFC** and **TFC%**).

Team C (software developers in R&D project) reported 22 activities on 14 days over a period of one and a half months (see Figure 5), summing up to 48 hours 52 minutes of **AT** (89 hours 50 minutes in **PH**). *Team C*'s **TFC%** is 27.94% and **TFC** is 1.84—most clearly visible in several longer periods of single or dyad work, where the timeline is truncated to represent longer periods. This might mainly result from the team being already split to two different locations before WFH. This was reflected by their responsibilities (backend in one location, frontend in the other) and shows in the timeline as well: we see joint discussions complemented by work among the subgroups: backend P1&P2 (i.e., Chris and Craig), and frontend P3&P4 (i.e., Cameron and Carl, where Cameron was less active due to his part-time employment).

Team D (master student and supervisor), reported 262 activities on 74 individual days. Figure 6 shows 38 activities on 21 days during a two-and-a-half month period, amounting to approx. 25 hours from the perspective of the supervising professor (including joint activities). From the student's perspective, we obtained a spreadsheet with 230 rows, which additionally record her individual activities related to her master's thesis, amounting to 221 hours 27 minutes (i.e., 251 hours 48 minutes in total **PH**). The team's **TFC** is 1.02 (resulting in a **TFC%** of 2.09%), since the student and supervisor usually worked on the thesis individually (e.g., authoring and review). Please note that in Figure 6 no exact times are given for some shorter points of contact (via email), but both participants reported that these were mainly used for arranging meetings or exchanging documents and that 5 minutes is a reasonable average for the 12 cases.

5 RESULTS FROM GROUP INTERVIEW AND QUESTIONNAIRE

Below, we report the in-depth qualitative results from the semi-structured group interviews interwoven with answers to the questionnaire. The results are structured according to the categorisation presented in Section 2 but begin with the surroundings to provide

Table 2: Various metrics of the teams regarding their activities, duration and fragmentation. ^aFor Team D, the # of Activities are calculated from P2’s logbook (38 activities including 6 joint activities) in combination with 230 activities reported separately by P1 (minus the 6 joint activities also reported there). ^bThe TNS’ descriptive power is marginal in longer-term scenarios, as discussed in the text. ^cThe TNS for Team D was estimated.

Team	Team Size	# of Activities	Activity Time (in h)	Mean Duration (in h)	Person Hours	TFC	TFC%	TNS ^b
Team A	4	11	06:04	00:33	10:37	1.75	25.00%	2.66 ^b
Team B	4	18	10:44	00:36	39:15	3.66	88.56%	1.05 ^b
Team C	4	22	48:52	02:13	89:50	1.84	27.94%	1.00 ^b
Team D	2	262 ^a	246:38	01:15	251:48	1.02	02.09%	~1.0 ^{b,c}

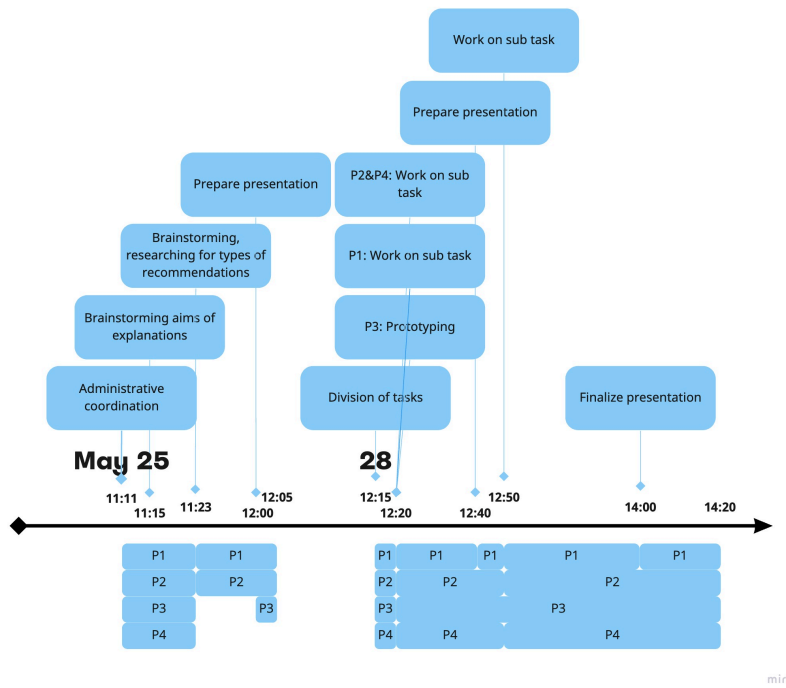


Figure 3: Timeline of activities in Team A. P1 through P4 correspond to Abigail, Alice, Amy, and Arnold.

a view of the team’s infrastructure and general situation before going into detail about effects on individuals and collaboration.

5.1 Surroundings - Being There

We asked the teams which hardware and software tools they used, whether they had the impression anything was missing, and how satisfied they were with the available infrastructure.

5.1.1 Physical Space. Concerning the work environment and hardware, all participants except one member of Team A (who used a desktop PC), worked with private or institution-provided laptops. Arnold (Team A) once used a graphics tablet to sketch while another team member watched via screenshare. Others stated that they desired some form of touch and pen input, especially for sketching or brainstorming. Furthermore, especially for reading notifications

and quick texting, (private) smartphones were used. Infrastructure-related problems were reported by Bella and Brooke (who occasionally had bad network quality), complaining that facial expressions and gestures were difficult to perceive or completely absent if no video was used in a meeting. In Team C, according to Chris, the lack of an external webcam (due to supply bottlenecks) was problematic, since using the laptop-integrated camera in combination with an external monitor resulted in an inappropriate view angle. A similar situation arose due to the lack of headsets, where, according to Chris, “a feedback effect is the first moment you want a physical counterpart again”.

All participants worked from their homes during the time of the study and had a sufficiently quiet environment (living either alone or having a dedicated room) and furniture suitable for office work.

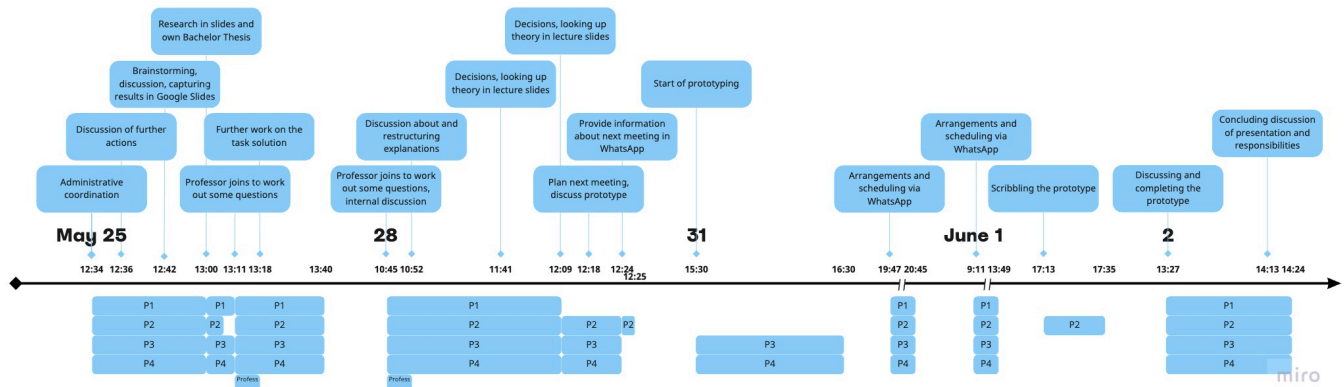


Figure 4: Timeline of activities in Team B. P1 through P4 correspond to Barbara, Beatrice, Bella, and Brooke.

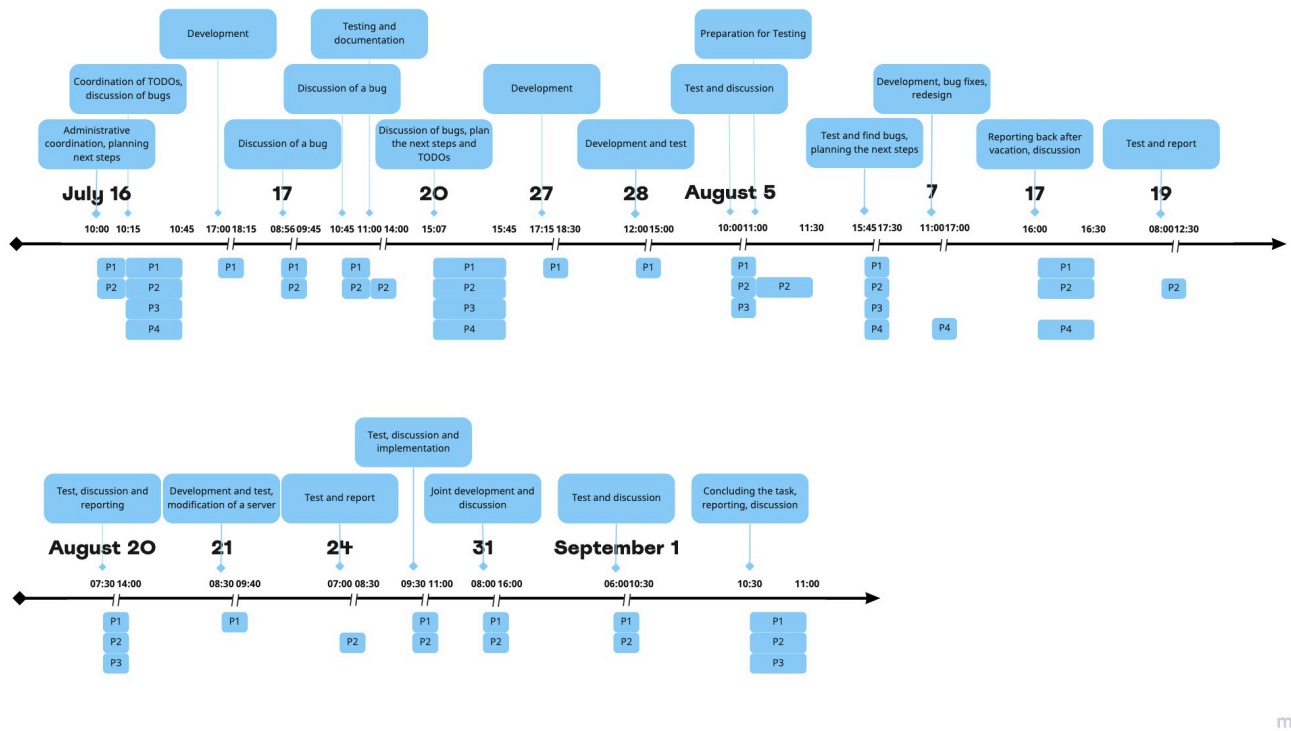


Figure 5: Timeline of activities in Team C. P1 through P4 correspond to Chris, Craig, Cameron, and Carl.

Learnings: First, our results confirm the rather obvious expectation that a stable and high quality internet connection is crucial. This comes as no surprise, but still raises the question: Why is it that in the early 2020s, we still have to discuss bandwidth? Current internet speeds are often faster than LAN speeds just two decades ago. Nevertheless, the comments of our participants show that considerations of how to handle such sub-optimal-connectivity

situations—and the inclusion of disadvantaged groups who do not have access to stable internet service—are necessary. Even in a relatively wealthy country (all participants resided in a country within the top 20 in GDP ranking), broadband connections were not always available in participants' homes in such a way that rich video conferencing tools ran smoothly. However, issues with connectivity were rather the exception than the rule. Further, we

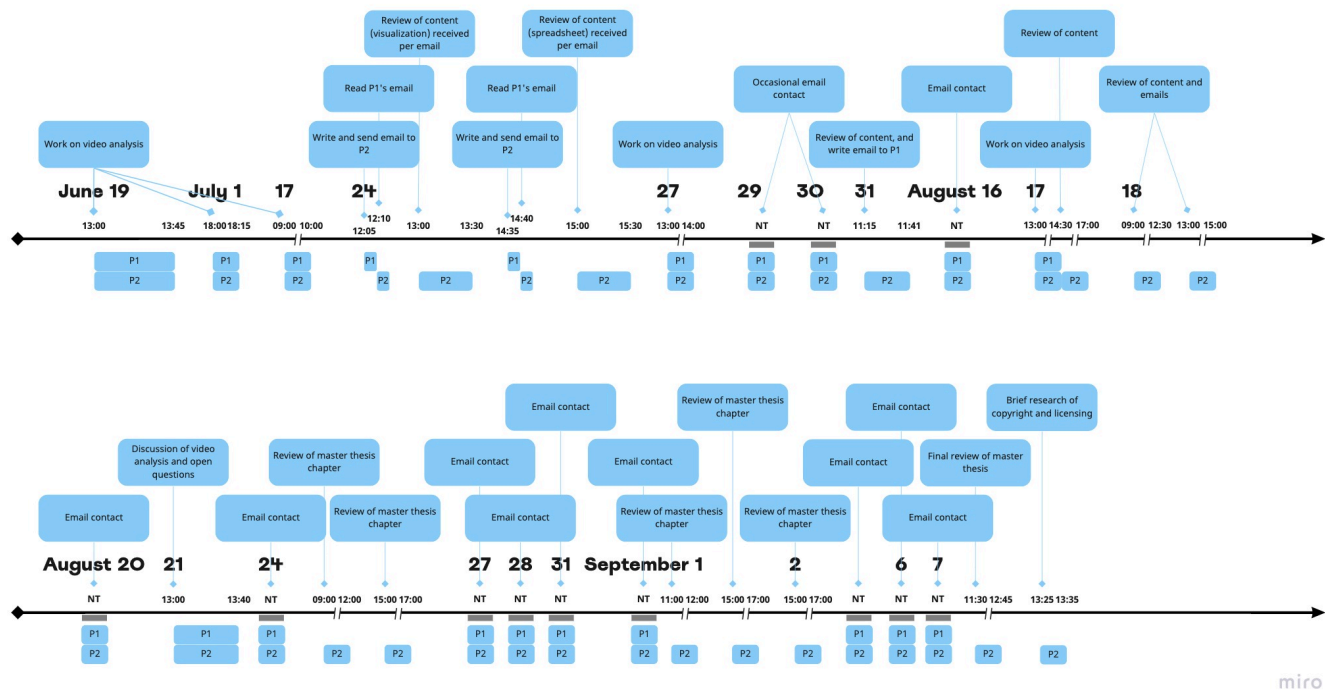


Figure 6: Timeline of activities in Team D (P2's perspective). P1 and P2 correspond to Daisy and Dora.

found that the home environment (furniture, etc.) is appropriate in a WFH setting if it is generally suitable for work. Additionally, we identified a challenge which probably affects all WFH settings: employees may often only have “standard hardware” (e.g., a laptop) available during compulsory WFH, which leads to problems that do not occur when working on-site. Adequate equipment with (external) cameras and headsets is a basic requirement for successful collaboration. For special tasks, specialised hardware (e.g., laptop with touch input) should also be provided, a requirement which often remains unmet by organisations due to financial limitations.

5.1.2 Virtual Space. MS Teams was the primary software used by all teams for VC and screen sharing (see Table 3). Barbara stated it is often better to not have too many different tools to keep track of:

“Right when we switched to distance learning it was confusing, there was BigBlueButton, then Zoom, then MS Teams. But then it settled down well. It is often better to have fewer functions, but these are collected in one place.”

However, although MS Teams includes chat functionality, Team A and B made heavy use of WhatsApp groups that existed before the study. Brooke added that this allowed them to use their smartphones. We assume that WhatsApp had a higher visibility for the students as compared to MS Teams (i.e., the university’s default solution). A common task for Teams A to C was the creation of sketches and wireframes for low-level prototyping (using Balsamiq and Miro). Team D preferred E-mail over chat for asynchronous communication, probably due to the hierarchy in the team (the

student at first hesitated to directly contact the professor via chat). Cloud services for sharing files were used by Teams A and B (Google Drive), and Team C (Nextcloud). Additionally, Team C used the version control system git to collaboratively work on source code. Finally, several tools for operational tasks were utilized (cf. Table 3).

Concerning the TTF, screen sharing in MS Teams was used by every team and was considered useful. Daisy explained that it is better than having a physical laptop positioned between student and supervisor: “Then it is not necessary that two people jostle for space but I have the entire screen for myself, which is a good thing!” Dora added that often a combination of viewing the shared screen and navigating the shared workspace itself (e.g., a Miro board) is important in order to have a separate view with individual control:

“I had the tool [i.e., Miro] open myself and not only via screenshare. That was important, because I often wanted to look somewhere in between, for example to check whether something discussed was not already inside somewhere else. So it was important to have control here, so that I didn’t have to say ‘please go down and then to the left’, which would have been more complicated.”

A negative aspect mentioned was confusion in finding channels in MS Teams: e.g., a search by Arnold for “Business Process Management” resulted in a list of 70 channels to sift through. In Team C, the organization’s policy to restrict creation of “teams” in MS Teams resulted in all communication being outsourced to chats. This led to lack of documentation of individual tasks, lack of categorisation, and thus more difficult retrieval of relevant information.

Table 3: Tools used by the teams.

Team	Tools for Communication & Coordination	Tools for Operational Tasks
Team A	MS Teams, WhatsApp, Google Drive	Google Docs, Google Slides, Balsamiq, PDF Viewers
Team B	MS Teams, WhatsApp, Google Drive	Google Slides, Balsamiq, Pen&Paper
Team C	MS Teams (Calls&Chat), Nextcloud, git	Research Prototype, Visual Studio, Notepad++, ScreenToGif, Greenshot
Team D	MS Teams, Email Client, Miro	MS Excel, Acrobat Reader, Google Scholar, Whimsical Mindmap, Picture Viewer

Concerning sketching and prototyping, different strategies were employed. Team A did not collaboratively sketch on a shared whiteboard but coordinated individual tasks verbally over a continual audio connection while working on individual and shared (e.g. Google Drive) documents in parallel. Despite previous experience, the initial enthusiasm about working together using Google Drive decreased as this turned into a “big mess”, e.g., through duplicate slides or documents. In Team B, everyone did individual scribble sketching before the team united the best ideas. While Beatrice used pen and paper for this, Bella and Brooke met in person³ to do the sketching in Balsamiq. In Team C, Chris and Craig (who worked from close offices before) identified a gap in tool support for drawing quick sketches. Before WFH, they usually drew during their shared in-office time by simply using pen and paper. Although collaborative sketching tools were known, they were not used due to poor integration into the available tool set and lack of pen input. Craig told us that he sometimes used tools like ScreenToGif to create short animations through screen recording (e.g., of solving processes) or Greenshot for enriched screenshots as a method of “collaborative debugging”. Chris added that these were nice tools to prepare material for meetings because they could record situations that might not be easily reproducible. Resulting short animations were posted in the MS Teams chat for others to immediately check or refer to during a later meeting.

Learnings: In accordance with previous work, our study shows that video conferencing tools are essential. Similarly, it shows that a well-organized work and collaboration environment is crucial and that the number of different tools that need to be used and coordinated should be minimised. Our study additionally reveals that users might be expected to use smart phone tools even though they are reluctant to install these on their private smart phones, leading either to the overriding of reasonable privacy concerns or to a gap between what team members “should” be using to collaborate, and what they are actually accessing. Furthermore, it shows that creative processes are oftentimes more difficult to perform remotely, partly due to the aforementioned lack of suitable hardware. Remote work might be easier to keep track of (e.g., through versioning) than copresent collaboration. However, the use of cloud services and file sharing systems requires compliance with individual rules and processes (e.g., who creates documents when and where, who is allowed to delete them), as well as organizational support (e.g., external access via VPN), in order to ensure an efficient exchange of documents.

³This in-person meeting was an exception and happened only once throughout the study.

5.2 Individual Aspects - Being by Yourself

In the following we summarize individuals’ personal and professional matters during mandatory WFH.

5.2.1 Personal Matters – Wellbeing. According to the group interviews (and logbooks, cf. Figure 3), Team A might have been particularly prone to VC fatigue (see Sections 2.1.1 and 2.3.1), which could explain why they worked on the task as quickly as possible. However, they were not completely satisfied with their results (everyone gave the second best score on the questionnaire). Although according to Abigail, the task did not take more time “because you do not have to leave the house [which eliminates commuting]” she said that it was a big challenge to sit “all day in front of the laptop”, which in the long run is much more exhausting than “being at the [university] and going from room to room”. Thus, Team A tried to complete tasks during the available time slots (according to the university’s timetable), so that they did not have to invest even more time online. As negative consequences, all teams identified a lack of social contact, less interaction within and, importantly, also between groups, leading to perceived extra effort. Furthermore, working was perceived as a less creative process by student teams (Teams A & B; however, Team C also reported less contact with other groups), because they reported not hearing from other groups, whereas in an in-classroom setting they would have been able to hear what the other groups were discussing and thus engage in a multi-directional, inspiring group process. Finally, constantly working remotely and having no meetings in person quickly led to a feeling of missing social contact. Abigail, for example, stated:

“There is no social contact at all, in the lecture you say almost nothing. In the tutorial, you only talk to the people in your own tutorial group and don’t hear anything from the others.”

According to Arnold, this was because students had to be attentive all the time, without small breaks including social chatter. He complained about sitting in front of his computer all day long and—even during breaks—not getting up and going anywhere (e.g., his balcony). Abigail agreed that, when she was “alone” (i.e., currently not in a meeting with others), she often remained seated. All in all, the group described the situation as challenging for personal wellbeing.

Learnings: We conclude that remote work saves time, which is positive (efficiency), but at the same time this is partly achieved via reduced interaction with others, which is rather negative. Exclusively remote work and collaboration tends to be more exhausting and the lack of social contact causes discouragement and reduced

creativity. We estimate that some of the negative effects were further exacerbated by the fact that next to WFH, regulations reducing private contacts were also in place at the same time.

5.2.2 Personal Matters – Boundaries. Beatrice complained that it is more difficult to coordinate activities when there are no fixed time slots reserved for classes and that usually (while being in-class) the team would have simply done some work in longer breaks. She thought private appointments could have been made more flexibly throughout the day because there was no fixed time reserved for classes. However, in actual fact, it seemed more difficult to find time for an additional meeting where everyone was free than before WFH.

As a negative consequence, Cameron felt that the social dimension was set aside a bit. Chris bemoaned the lack of coffee breaks and lack of social chatter (which is relevant also for wellbeing), as well as an attitude of “working around the clock” that made boundary management between work and leisure time more difficult. Bella added that “in general, the weekend wasn’t quite the weekend it used to be. There is no real boundary anymore because you are always available and online.” Interestingly, no team reported problems related to privacy, e.g., concerns about sharing pictures of their home environment. We hypothesize that this can be attributed to the teammates knowing each other well.

Learnings: Organizations can support remote collaboration by reserving time slots (even if no physical rooms are needed). Furthermore, WFH easily leads to longer working hours and blurred boundaries between private and work space (actively restricting availability as suggested in Section 2.3.1 could help). When team members know each other well, they have fewer privacy concerns (if not, team building measures are advisable prior to intensive remote collaboration). In our results, there was a discrepancy between how student teams A & B tried to cope with infringements on their work-life boundaries in comparison to the paid-work employees in Team C. The former (particularly Team A) tried to get the work done as quickly as possible in order to stay within the schedule, while Team C (paid workers) reported more blurring of boundaries (i.e., separation vs. integration of boundaries). One explanation for this might be the different motivational structure and/or performance requirements in an educational versus professional work setting. Another aspect which we hypothesize to play a decisive role in this regard are participants’ current personal living circumstances. Some participants lived alone, some with their parents, some with a partner, some in shared flats, and some had childcare or other family responsibilities. For example, when a child’s immediate needs have to be dealt with during working hours, some work necessarily shifts into later portions of the day or night. All of these factors are known to contribute to personal preferences and strategies on how to manage boundaries (see Section 2.1.2).

5.2.3 Professional Matters – Performance. We discussed the effort necessary to complete the current task in comparison to similar tasks completed on-site in the past. As positive consequences of collaborating remotely, Teams A and B agreed they worked more efficiently and effectively. These teams’ impression was that they did not increase the time spent (although their working habits changed, see “working around the clock”, Section 5.2.2), since they tried hard to accomplish the tasks within their schedules’ time slots

to prevent additional meetings (Team A) or meetings on weekends (Team B), and because commuting was not necessary (Teams A and B, Daisy of Team D). In Team C, efficiency was also felt to have increased due to quick responses in the group chat. According to Dora, another advantage of the online tools (e.g., Miro), was that the latest version was always accessible, which prevented efficiency losses from working on outdated versions (a problem when reviewing the master’s thesis, which was sent in PDF form at certain milestones instead of being shared via collaborative editor). In line with what was reported in Sections 5.2.1 and 5.2.2, efficiency was probably increased at the cost of eliminating social chatter. For example Arnold stated:

“Yes, [social chatter] is much less, also in the tutorials, but it was even worse in the lectures. You have to pay attention all the time and there are no lighteners such as stupid remarks, jokes where you laugh together, or digress from the topic.”

Team A also stated that the loss of social contact makes working much more exhausting in the long run, which might then lead to a decrease in productivity. Thus, measuring the actual working hours invested, the teams might have been more efficient while the perceived effort seemed higher.

Learnings: Our teams were more efficient and more effective with their tasks, working and collaborating remotely (partly due to lack of social chatter). Work was also perceived as more exhausting (cf. wellbeing). Paradoxically, the perceived effort was higher and the satisfaction partly lower (which confirms existing evidence) despite being actually more efficient (a novel finding which we term the “efficiency paradox”).

5.2.4 Professional Matters – Work Conditions. Regarding working habits, Teams A and C tried to split the tasks into subtasks and distribute them evenly to work on them autonomously. Exactly when, where, and how was up to the flexibility of each member. None of the teams reported that any members had failed to participate well in their tasks. As already mentioned in Section 3.1, roles and hierarchies in the teams were highly diverse. Nevertheless, the division of labor was mainly done from a functional perspective, i.e., people with the respective knowledge or preferences took on the respective tasks. Additionally, a certain level of expertise could also lead to greater implicit leading responsibility. Bella of Team B described how Beatrice had taken charge of the group because she was writing her bachelor thesis in that particular subject area and was therefore seen as more competent. However, according to Chris, the lack of clear formal roles (with the exception of being the product owner himself) in Team C resulted in confusion about whom to address because he lost track of responsibilities. He switched to addressing not a specific person but the “location” (i.e., the organizational unit which is further derived from the city the physical campus is located in) in the collaboration environment. Interestingly, due to the ambiguity of functional responsibilities, the (former) physical locations were used as proxies for message addressing (although actually irrelevant in this remote-only setting) and communication was thus directed less to individual persons and more to the “location” based also on the functional and organizational division. In this team, therefore, there was a perception

of two sub-teams of two people each. The communication impetus generally came more from a specific location side (represented by Chris and Craig) owing to asymmetric informational needs. In Team D, the hierarchy was stricter and there were clear roles, with Daisy as a student and Dora as a professor. Over time, the easy accessibility of the other location (Team C) or the professor (Team D) made it common practice for Teams C and D to quickly obtain help by convening online meetings, which again made work more flexible (“shorter paths”). To get an overall impression of the work conditions in the teams, we examined the average level of goal orientation (in German original: “Zielorientierung”), task achievement (“Aufgabenbewältigung”), team cohesion (“Zusammenhalt”), and mutual accountability (“Verantwortungsübernahme”) perceived by each team’s members, measured using the F-A-T questionnaire [46]. Further, we asked individuals to rate their overall satisfaction with the results of the collaborative task and averaged these results for each team (cf. Table 4).

Results show quite high ratings on all subscales, though Team A reported slightly lower values for the performance-related factors of the F-A-T (goal orientation and task achievement) than the other three teams. This finding was also echoed in Team A’s (relatively) lower overall satisfaction with their task result. Looking at the person-oriented factors (team cohesion and mutual accountability) reveals a slightly different pattern. All teams showed team cohesion near the maximum rating of 6, which may indicate that our data derive from an atypically harmonious sample of teams. In contrast, the two teams (A and B) consisting of a group of students show somewhat lower mutual accountability than either the professional research team or the advisor-student dyad—which may be explained by their shorter-term and less formal collaboration context. However, given the small sample size and the exploratory nature of the study, none of these descriptive differences were formally tested.

Learnings: All teams tried to organize themselves, distribute tasks and define responsibilities. While team members were flexible in organizing their tasks, they did not work fully autonomously due to the tight schedule (and pre-arranged time slots for meetings, which, however were perceived as positive, see Section 5.2.2). The remote setting did not lead to any new establishment of roles or hierarchy; existing ones remained but were softened (which is a novel finding that contributes to the existing still small body of evidence on roles and hierarchies). The teams identified themselves as teams, worked on a shared goal, had shared priorities and knew what to do. Potential problems (e.g., through uneven distribution of workload) were not explicitly addressed. The results of the questionnaire suggest that lack of mutual accountability was a slightly more relevant issue for student groups working on a class assignment than for teams working in longer-term, closer collaboration.

5.3 Collaborative Aspects - Being Together

5.3.1 Interaction. All teams stated that the use of communication tools had a very positive impact on cross-site collaboration. To gain further insights, we asked them about their impression of the existence and support of Buxton’s different communication channels (“media spaces”) [17, 18, 81]. The *task space* was predominant during collaboration and perceived as most important by all teams.

Further, the teams agreed on the existence of the *person space*, typically implemented by a list of participants and their video pictures. Smaller video pictures during screen sharing were not perceived as insufficient, as they at least allowed for peripheral awareness. Often, the video transmission was even deactivated or participants ignored it, concentrating on the area of the screen where the team was currently working (cf. task space). Regarding the *reference space*, the teams’ impressions were divergent. In Team A, referencing basically worked well. Potential referencing problems were solved by sharing the screen, highlighting, or verbal communication (e.g., giving slide numbers). Team B reported that questions such as “is my mouse pointer visible” occurred often. Beatrice added that during the semester, students even learned new vocabulary in relation to online meetings “because you have to be much more precise so that others understand what you are thinking.” In Team C, where referencing in a 3D model was a crucial factor, significantly more problems occurred. Chris, for instance, stated:

“The referencing—where am I right now, where is the attention—works much better when you are sitting next to each other. He [or she] can just take a finger and you can also see where the gaze is.”

Craig noted the problem that a person might suddenly start to scroll while another is still looking at something. This indicates a requirement for more explicit coordination when discussing an item. Craig also pointed to the request-control-feature in MS Teams, which the team did not use at all. In Team D, Dora explained that the reference space is mainly restricted to the area where one makes mouse gestures. She stated that she frequently used mouse gestures when working with Daisy, besides also resorting to them during her remote teaching activities. Dora also reported that one does this “almost automatically” when the screenshare is enabled. Moreover, Team D told us that the acoustic channel was usually combined for referencing (e.g., “Look at the concept XY!”), but according to Dora, if the jointly explored space is too large (e.g., in a big diagram), it can easily happen that not all participants look at the same area at the same time. Daisy suggested that it might be helpful if the other person got a mouse pointer via MS Teams as well, in order to be able to reference specific areas of the shared space independently (or do further operations depending on permissions) similar to Doug Engelbart’s “The Mother of All Demos”⁴. Both participants in Team D agreed that the reference space is implemented poorly or unnaturally, and Daisy added that seeing gestures depends a lot on camera angle and placement.

Learnings: Communication is crucial for team collaboration across different task domains. Complementing existing research, we utilized Buxton’s media spaces as both analytical lens as well as research subject. Our related findings can be summarized as follows: For teams that know each other well and basically agree on what they are doing, the person space seems to be least important (the opposite is likely true for teams that do not know each other beforehand). The task space is most important across all task domains, while the importance of and requirements for the reference space vary. Referencing was least well supported by the tools available to participants in our study.

⁴<https://dougengelbart.org/content/view/209/>, last access December 5th, 2022

Table 4: Mean team scores for the four F-A-T-subscales as well as overall satisfaction with the task result (SD in parentheses). Note. F-A-T subscale scores ranged from 1 (minimal goal orientation, etc.) to 6 (maximal goal orientation, etc.) while the 1-item satisfaction rating ranged from 1 (not at all satisfied) to 5 (very satisfied).

Team	Goal Orientation	Task Achievement	Team Cohesion	Mutual Accountability	Overall Satisfaction
Team A	4.81 (0.36)	4.75 (0.68)	5.34 (0.28)	4.63 (0.14)	4.0 (0.0)
Team B	5.17 (0.14)	5.13 (0.48)	5.88 (0.18)	4.88 (0.85)	4.5 (0.6)
Team C	5.29 (0.37)	5.13 (0.60)	5.66 (0.28)	5.38 (0.66)	5.0 (0.0)
Team D	5.17 (0.94)	5.13 (0.88)	5.38 (0.53)	5.63 (0.18)	5.0 (0.0)

5.3.2 Closeness. As already indicated by related studies summarized in Section 2.2.2, closeness can be viewed from different perspectives that focus either on social and personal closeness, or on professional closeness. Social and personal closeness overlaps with wellbeing (especially in regard to social interaction), as described in Section 5.2.1. Participants largely agreed that private social contact was reduced during the mandatory WFH period, posing challenges for the maintenance of personal social closeness. However, in this section, our focus lies on professional closeness, i.e., task-related closeness of team members based on their work-related interactions. We asked our teams about connectedness, i.e., how closely coupled they worked, whether there was a lot of independent work, and how often they met (this overlaps with working habits, see Section 5.2.4). We were also interested in how they felt they would have collaborated differently on-site. In Team C (and similarly for Teams A and B), the cooperation across the different locations seemed closer and more intensive than before. There were more frequent meetings (“more often it happened that we discussed five times a day”), but this was not perceived negatively, as the video calls took place in a well-considered and targeted manner, and helped to solve problems efficiently. Chris added that the team would not have advanced so far in the task without this form of cooperation and technological support (cf. also performance). At the same time, the collaboration among previously co-located colleagues became less tightly-coupled, including reduced meeting frequency. In Team D, the cooperation (due to different tasks and roles) was mostly loose. The joint meetings focused on strategic issues (e.g., how to structure expert interviews). Both members agreed that the frequency and length of the meetings changed during the course of the task. Daisy stated that at first she hesitated in asking for appointments. This inhibition quickly decreased, as meetings took very little time and effort, and she realised that this was not a problem (also see the findings related to hierarchy and roles in Section 5.2.4). Daisy mentioned traveling distance as the main factor that led to more frequent, shorter meetings, while she said that otherwise she would prefer fewer, longer meetings. Short questions were usually dealt with via email. Overall, this led to a feeling of increased connectedness and closer collaboration, also emphasized by Dora:

“From my point of view, the closeness of the collaboration was perhaps even higher. That also has to do with the perceived distance, for example, if I know that they’re driving here now and the appointment has been arranged weeks in advance and it’s a totally planned setting, then the distance feels greater than if you just have to do one click in Teams.”

Related to territoriality [75, 84], we asked what participants thought could be regarded as personal, group, or storage territories during their collaboration, and whether any of these were missing or poorly supported. Teams A and B built their collaboration around a shared storage territory on Google Drive and worked together in the sense of a group territory in Google Docs or Google Slides (cf. Table 3). Team A illustrated the trend away from personal territories towards group territories, e.g., via Abigail’s statement:

“It’s no use creating something alone and then you still have to discuss it afterwards. Then you’d better do it in [Google] Docs, which reduces coordination effort.”

However, teams reported frequent alternation between tightly (e.g., creating a presentation together) and loosely coupled tasks (e.g., research activities). Bella used a personal area by drawing sketches on her Apple iPad that she initially saved locally and only shared with others once she was finished. In Team C, there was a rigid separation between the private area (local repository) and the group area (code pushed to the server) (through the use of git). Nextcloud, which was provided by the organization, served as the storage area (in addition to the git server). Unlike Google Drive, however, Nextcloud was not considered a group area because “changes are not so easily noticed”. The heavily-used MS Teams group chat was seen as a kind of shared group area. Yet, according to Chris, this was complicated and a separate team would have been better suited as group area (e.g., tasks could have been managed better there).

In Team D, both members had their own local and personal territories and created group territories mainly during meetings, e.g., everything Daisy did concerning writing the thesis, evaluating data etc., was in her personal space. When artefacts were viewed via screensharing, there was a transition from the personal to a shared space, thus more similar to group territory; however, while sharing the screen, only one party had control. Daisy explained that they used verbal statements when one of them wanted to manipulate a shared UI “Uhm, could you please go back to...” (which also relates to the reference space, see Section 5.3.1). Matters around presence and social space were not addressed in the context of closeness by our teams. We attribute the former to the fact that teams were small (perception of members’ presence is relevant especially in large groups with loose collaboration), members knew each other well, and everyone was required to contribute.

Learnings: Some of our findings on closeness are in line with those of others, including non-work settings or pre-COVID-19

evidence (e.g., [25, 73]). For example, fewer connections and interactions between groups were observed, and the awareness of what was going on in other groups decreased. However, we additionally observed that the connectedness within a team paradoxically seems to have increased over distance, relatively independently of the nature of the task. The latter can, however, be a decisive factor for the importance of different territories, which has not been considered in detail in related work so far: the more interaction a task requires and the closer a collaboration gets, the more important group territory support becomes. Support for presence is not as important for small groups where roles and responsibilities are clearly defined. The increased professional closeness between team members was particularly strongly apparent in the team with the most distinct roles and the clearest hierarchy, but generally evident in all of our teams.

5.3.3 Sharing. After switching to WFH, some common behaviors and strategies for sharing and exchanging knowledge naturally had to be changed. As outlined in Section 2.2.3, virtual environments, administrative aspects, and personal factors (e.g., motivation) are decisive for a successful transfer to WFH. With suitable environments in place, some knowledge-intensive tasks were even easier to fulfill than before, e.g., jointly reviewing documents (Team D reported advantages of looking at a remote screenshare instead of competing for the limited space around a computer display on-site). Further, equitable access to shared resources was conducive to a free flow of knowledge. According to Team C, how well knowledge could flow was highly dependent on tool support. As mentioned above, Craig sometimes used a specialized tool (ScreenToGif), but the created artefacts—though helpful in themselves—did not integrate well into the shared knowledge base. Overall, Team C reported that they struggled to achieve a persistent knowledge base and many resources of mutual interest were simply posted to a shared MS Teams chat. Finding, structuring, and reacting to content was error-prone there; a Wiki, project management software, or similar tool might have been a better place to store the knowledge items created (including bug reports and short video figures). Craig argued:

“We could have done a little more task documentation and [recorded] when functionality was fulfilled for better traceability. We did this only in the chat history where you cannot follow a particular task.”

Chris identified a further disadvantage of using MS Teams chats for this purpose:

“I cannot reply directly to a chat message like in WhatsApp or similar applications. So I always have to refer to ‘Hey, we were talking about this and that and this is my answer’”.

Cameron explained that in a MS Teams team they would have had text threads instead of just individual messages that were chronologically ordered but not actually categorized. Finally, Teams A and B reported that a separation between the teams was introduced through WFH which was not there in prior classroom settings. Without peripheral attention to what other teams were achieving (sometimes referred to as ‘porosity’), creativity was curbed, as knowledge stayed strictly within the teams, creating information silos (cf. discussions on wellbeing and interaction).

Learnings: Our study confirmed that knowledge sharing is important for the quality of outcomes in collaborative work. Additionally, our study showed that equitable access to digitally shared artefacts can create a useful stage for knowledge sharing and exchange. While a small number of tools capable of supporting these activities is preferable, it should be possible to integrate specialized tools for minor miscellaneous tasks. Individuals should be made aware from the start about certain tools’ suitability as a maintainable, permanent knowledge base.

6 RETENTION OF PRACTICES

One of the supplementary aims of our study was to identify practices that have proven useful throughout mandatory WFH and remote collaboration, and have the potential to be beneficial in the future when integrated in non-mandatory WFH or on-site collaboration. We thus discussed this with our participants in the group interviews.

In *Team A*, Arnold stated that remote collaboration had worked better than expected and that he could imagine solving some collaborative tasks remotely in the future, e.g., when not everyone can be on-site easily. He saw such remote portions as an addition rather than replacement of existing ways of working. According to Abigail, some of the tasks worked even better in the purely-online mode, because people did not digress so much and therefore they were more efficient. Often, work was divided and everyone did their part of the work independently. “When you meet in person, you get to talk more about off-topic things.” While she emphasized the general importance of face-to-face meetings, she could also imagine increasing the portions of independent work through more division of labor in the future.

In *Team B*, Brooke would welcome more remote activities in the future, and felt it was more effective to save travel time for a meeting. According to Barbara, people hadn’t even thought about doing a lot of things remotely before COVID-19. She stated that the idea comes up much more quickly now, e.g., when people work together on-site but then complete the task remotely, adding that before the pandemic, individuals’ and rooms’ availability had to be clarified first: “Now it is easier to come up with the idea that you can do this via [MS] Teams or [Google] Hangouts. It wasn’t as present in the back of your mind before.” Bella added that it depends a lot on the task at hand:

“If the task is to create a document in a shared Google Docs anyway, it doesn’t matter if you sit next to each other or collaborate remotely. You can talk via Teams just as well. In programming, on the other hand, it’s better if you’re sitting next to each other and I can tell somebody to quickly hand their laptop over and I’ll take a look at it and maybe find the bug.”

Beatrice would wish for lectures to be remote in the future. She felt she was much more productive and attended almost every lecture, which otherwise might not always have been the case: “You could sit down right after brushing your teeth, at breakfast for the lecture, and that was a great fit.” Concerning an initial personal overload due to the multitude of different tools, Brooke remarked:

“The unified introduction and required use of Teams for study purposes made it more pleasant, because

otherwise it was always necessary to look for a common tool first, for example not everyone had Skype. It is important to have a common tool where everything really runs through it and not once Skype, then BigBlueButton, then Zoom.”

In *Team C*, Chris envisioned keeping cross-location meetings remote in the future, stressing that, even for co-located participants, it would be beneficial to use Teams from a documentation standpoint:

“Not just for audio and video but also chat. And not having to get up and go to a colleague for every question. I could even imagine doing screensharing even though you wouldn’t have far [to walk over to a colleague]. And you just meet for coffee more often. I can imagine that would be a good mix then, so I would certainly retain some of that.”

Cameron agreed with Chris’ comments and also thought that cross-location communication had gotten much better. Carl added that MS Teams had already been successfully established in this regard.

In *Team D*, Dora did not report any disadvantages of the remote setting but to the contrary stated that a lot of things worked better (e.g., reviewing documents together, sharing external resources like papers). Therefore, she would probably do supervisions mainly remotely in the future if students did not strongly prefer to meet in person: “It’s so much easier than it used to be.” Daisy already had a background of professionally working remotely:

“It was therefore familiar for me to communicate via meetings and e-mail. Compared to the job, one positive point [during the supervision] was that we always had the video on here. It’s definitely a positive aspect to see each other at least briefly. Furthermore, I will definitely work remotely often in the future.”

Dora summarized her experiences and future intention as follows:

“I can say very clearly that if it were up to me, I would do it exactly the same way again. Especially in such a small setting, I really don’t miss much personal contact. In other settings, coffee breaks and informal conversations in between are certainly missing. But all of that is usually not there in a thesis supervision, so it’s not missing here.

Both Dora and Daisy agreed that they really liked that the video was always on during their meetings to give the situation a more personal touch. Daisy remarked:

“The video is really important there, that you see how the other person reacts to you. It has a very strong influence on the feeling you get from a meeting. With video, it’s easier to see if the others think it’s great and are excited about it. It gives you a different motivation than if you have the feeling that the people in the meeting are hardly listening to you and you just want to get it over with as quickly as possible.”

Summary: All teams across different task domains and constellations agreed that at least part of their work was more effective. Further, some of the tasks benefited content-wise. All participants

considered doing part of their (collaborative) work remotely in the future. WFH and remote collaboration were seen as an addition to rather than replacement of other forms of work. Participants further stressed the general importance of video streams (although they had earlier reported videos as not always necessary, see Section 5), as well as adequate and joint tool selection and tool set minimization.

7 DISCUSSION

Apart from the discussions already provided in the learnings and interwoven with the presentation of results in Section 5, in this section, we summarize and discuss our results and contributions, and point out limitations inherent to our literature review and our original study.

7.1 Summary and Contributions

We have presented (1) a thorough literature review on pandemic-induced mandatory WFH and remote collaboration (Sections 1 and 2), and (2) the design and results of our original qualitative user study (Sections 4 to 6). Our research is clearly distinct from existing work, as we aimed at conveying a broad picture of mandatory remote collaboration in academic settings, facilitating cross-category conclusions. From the literature, we derived a categorization of effects mandatory WFH might have (cf. Figure 2, Table 1), which became the basis for structuring Section 2 and categorizing our findings (Section 5). We have shown that prior research is sometimes either inconsistent or lacking strong evidence concerning the effects of mandatory WFH or remote collaboration. Our findings—surprising as well as expected ones—are meant to further add to the existing pool of evidence with the aim of approaching higher consistency and a stronger evidence base. In Figure 7, we provide a concise visual summary of learnings (blue annotations mark novel findings), positive and negative effects, and recommendations for individuals and organizations. This additional contribution is intended as a tool for researchers and practitioners planning, supporting, evaluating or investigating remote collaboration. We expect our findings to be valuable to the scientific community but also academic institutions preparing for future WFH situations. While some of our findings confirm existing evidence, we contributed novel insights in almost all categories (excluding only wellbeing; see Figure 7).

Regarding our observation of bandwidth requirements explained in Section 5.1, it seems that from some individuals’ perspective, mediated communication richness (and the according hunger for bandwidth) seems to outgrow internet bandwidth availability, which is also highlighted by ongoing efforts to assess speed and improve connections for the broad masses [31]. As a fallback, current applications autonomously and seamlessly take measures to maintain the connection in cases of connectivity problems (e.g., reducing resolution, frame rate, or sampling rate). As our results show, such reductions in richness come at a cost (e.g., participants complained about a lack of visual cues). Our participants seemed to regret the lack of visual cues in such situations where there was an issue with connectivity or the camera was disabled. When applying Buxton’s media space theory, based on our observations, we estimate that the person space was the one that was most affected in such

cases (although our data suggest that an active camera is not necessary in all situations, it still is helpful in some). This is because many of the functions that can be counted towards the task and reference spaces often rely on less rich and/or less continuous representation in comparison to the person space's camera feeds (e.g., working on a shared document (task space) with remote cursors (reference space)), effectively lifting the burden on connectivity. Finally, the reference space in the current tool ecology was the one least supported according to our participants. We think that more widespread adoption of AR/VR technologies provides the potential to unify several remote persons in the same (virtual) space for referencing activities and closely coupled task work [33]. Of course, such technology will again lead to an increase in bandwidth requirements.

7.2 Limitations

In terms of the literature review, it must be noted that we focused specifically on mandatory remote collaboration, which may differ from voluntary remote collaboration in key points such as motivations, choice, preparations or responsibilities (as summarized, e.g., in [87]). Our analysis was also oriented more towards summarizing the state of empirical research and less on integrating all underlying theoretical explanatory mechanisms into an overarching theory of the personal, technical, and social ramifications of mandatory remote collaboration. We hope, however, that this initial research overview may help further such theories in future. Because the COVID-19 pandemic saw an explosion of research in this field, our literature review is of course also bounded by our date of search. Though we included also preprints and recent conference proceedings up to and including July 2022 when we conducted our search query, relevant data collected during the period of the first lockdowns are likely to continue to be published for the next few years. Some of the research gaps we identified may be filled in the foreseeable future (e.g., as has begun to be done in considering WFH and wellbeing [10, 15], boundaries [14], or interaction [40]).

Regarding the user study, several qualifications must also be mentioned. First, the small number of teams can be considered a limitation. We thus used richer, multi-faceted data to gain deep insights and selected our teams and participants very carefully (purposefully varying tasks and relationships). We believe that the insights we gained are valuable and reveal a lot about the mandatory remote collaboration of different teams of smaller size where participants know each other a-priori. Further similar studies, varying team constellations (e.g., larger teams, teams that do not know each other well) are expected to complement these insights in the future. Concerning generalizability beyond academia, at least one of our teams (C) engaged in paid work; thus its motivational structure might be similar to a business team's. Further, as a limiting factor of our methodology, we acknowledge that our data is based on self-reports, not direct observation. As a remedy, we skimmed the collaboration videos to check if anything supported or contradicted what was reported. We did not find any meaningful deviations from how participants portrayed the situations. It was, however, interesting that one team was seemingly more united in the group interview than the questionnaires suggested. Overall, the student teams (A & B) were more critical concerning how they perceived

the results of their own work as compared to the other teams (see, e.g., their lower rating of Overall Satisfaction in the questionnaire in Table 4). In all teams, we managed to build a good rapport with interviewees by showing our deep interest in learning about their problems and concerns, but also about the benefits of WFH. Taken together, these measures left us with the impression of a very open and honest basis of discussion in each interview—an interest we felt was reflected in interviewees' eager discussions. As we had hoped, the method of combining a group interview with individual questionnaires and taking into account both logs and recordings of the sessions helped to reduce possible bias resulting from viewing any of the sources in isolation.

8 CONCLUSIONS AND FUTURE WORK

According to our findings and expectations, the future of work is clearly shaped by the experiences organizations and individuals have gained through pandemic-induced mandatory remote work and collaboration. We hope that our study has helped to identify factors that contribute to successful inclusion of remote portions in collaborative interaction, either for future hybrid collaboration [65] or on-site settings that could benefit from remote portions, and expect these findings to open up new and exciting research directions. In addition to the above-mentioned further investigation of teams of different constellations, envisioned future work thus contains in-depth studies of non-mandatory partially-remote or hybrid collaborative work, and we expect many additional insights that complement our learnings related to mandatory remote collaboration. In the following, we extract a few concluding key messages we particularly strive to communicate to the community:

Remote persons are closer than they appear: Our results show that closeness, especially professional closeness, is not necessarily a matter of physical distance, it is rather strengthened or weakened by the work practices adopted and tools used. Closeness can result from an increased frequency in meetings (having more and shorter meetings). This increase is often a consequence of the lower perceived effort necessary to conduct a remote meeting (no commute, no room reservations) and the subsequently reduced hesitancy to schedule more meetings (see Section 5.3.2). Professional closeness among team members can and will increase over distance if facilitated accordingly, and communication paths might get shorter over distance. However, while professional closeness is important for successful collaboration, the results show that social or personal closeness could not be effectively augmented in our groups, most probably owing to the officially propagated restrictions of physical contacts at the time (see Section 5.2.1).

Mind the efficiency gap: Actual increased efficiency might go hand in hand with perceived increased effort and lower satisfaction (and vice versa). This "efficiency paradox" is one of several indicators showing that perception of the quality of work is linked to personal satisfaction and wellbeing (cross-factor dependency).

Social chatter might reduce distraction: Although counterintuitive, the importance of social closeness among team members means that social chatter helps them to stay motivated, focused and productive.

Interconnection between teams stirs creativity: Although teams work on individual, self-contained tasks, networking across teams

can help to promote creativity. Such contact should be institutionalized because it might not happen otherwise.

One tool can help to rule them all: Throughout different teams, our participants stressed the importance of a reduced tool set on the one hand and of one integrated environment where the collaboration has its home base on the other. Ad-hoc transitions between different tools hinder the efficiency of communication and collaboration and foster stress and discomfort. Nevertheless, a variety of tools for specific collaboration scenarios have evolved over the last few years ([41], for example, provides an overview of tools in the software development domain). Instead of further diversification of tools and a tight integration of collaboration support in specific tools, a generic plugin mechanism for (web-based) collaboration tools would be desirable. In this way, specific support in different media

spaces could be activated or deactivated depending on the scenario (e.g., virtual pointing aids (reference space) could be helpful during collaboration on a virtual whiteboard, while the transmission of gestures and facial expressions (person space) could be desirable in a group discussion setting).

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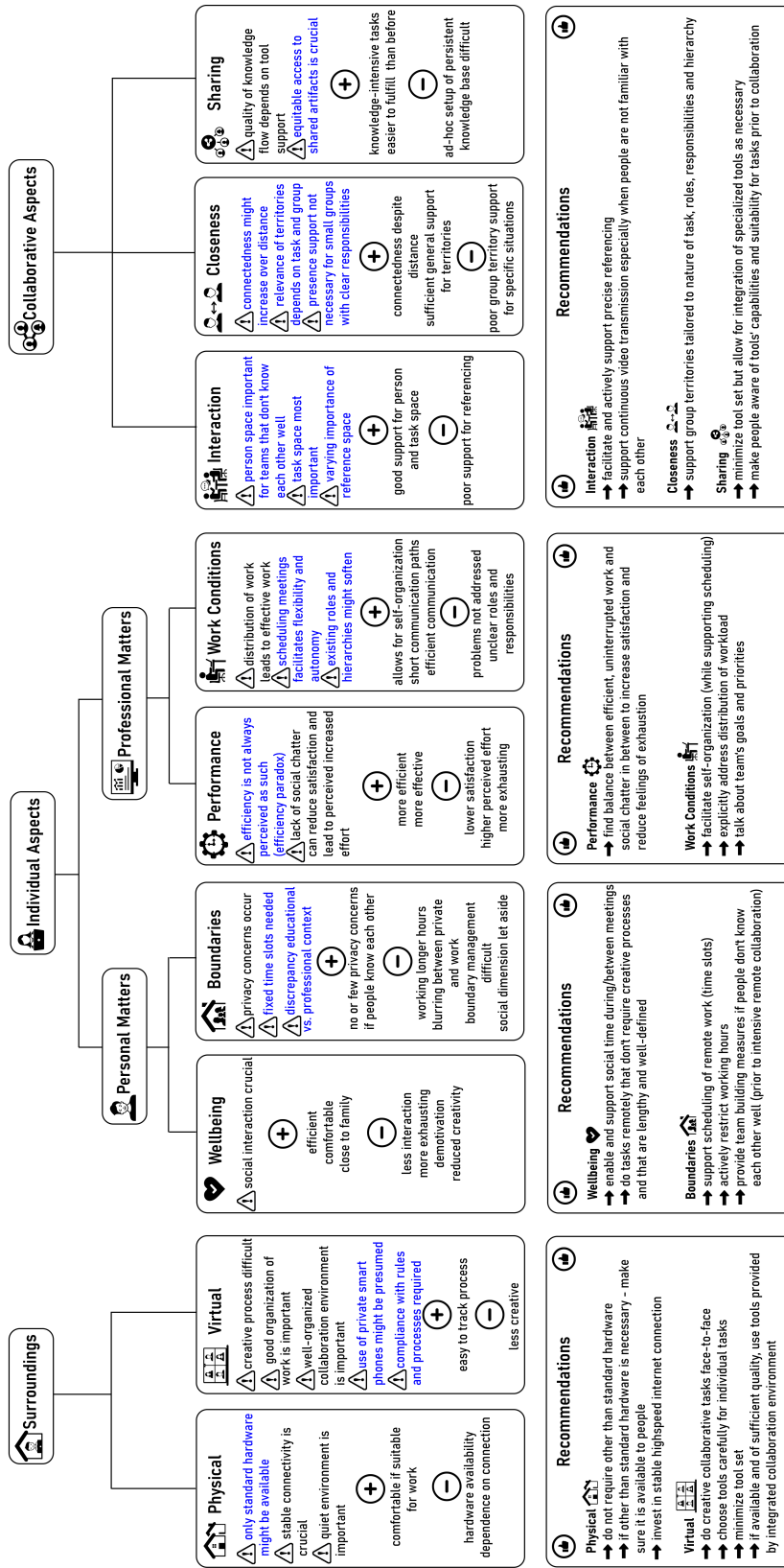


Figure 7: Summary of results of our original qualitative user study: general learnings (indicated with an exclamation mark), positive and negative findings (marked with a plus or minus sign, respectively) related to the categories identified and described in Sections 1 and 2 (in the order we used for presenting the results in Section 5), and recommendations to organizations and remote workers. Blue annotations mark novel findings (cf. earlier evidence). Credit for the icons goes to <https://luxwing.com/>.

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