Cultivating a Team Mindset about Productivity with a Nudge: A Field Study in Hybrid Development Teams

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While there has been significant study of both individuals and teams of knowledge workers, research has focused largely on one or the other, with less focus on the interaction between the two. In this paper, we explore the tensions between the individual and their team, focusing on the choices an individual makes towards their own productivity versus their team's productivity. We developed a technology probe with a team nudge that fosters recurring reflection and prompts individuals to consider how their team helps them to be productive. We examined its impact through a longitudinal field study with 48 participants. We chose to undertake this study with software development teams as they are examples of knowledge workers who collaborate on a shared set of tasks with specific goals. Our exploration took place with hybrid development teams, which have increasingly become the norm. Our analysis of a total of 8338 hourly self-reports and 1389 daily diary entries found that the team nudge increased participants' productivity ratings and team awareness, led to participants spending more time on their own tasks, reshaped their perceptions of themselves and their team, yet, in general, did not increase team cohesion or affect well-being.

CCS Concepts: • **Human-centered computing** → **Field studies**; • **Software and its engineering** → **Programming teams**.

Additional Key Words and Phrases: Team Nudge, Team Cohesion, Productivity, Self-Reports, Diary, Reflection

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1 INTRODUCTION

Scholars across a variety of disciplines, including management and economics (e.g., [9]), psychology (e.g., [68]) and human-computer interaction (e.g., [54]), have long aimed at improving the productivity of individual knowledge workers. This earlier work has considered several factors, including *individual* (e.g., demographic aspects, habits, beliefs), *situational* (work, available resources, distractions) and *social* factors (interactions with co-workers, supervisors and other stakeholders) of productivity [53]. Studies have demonstrated the various ways in which interactions with supervisors and co-workers can affect an individual's productivity. For instance, having a supportive

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supervisor has been linked to increased productivity [7, 45]. Working in a highly cohesive team has been further found to enhance individual productivity [24]. Recent trends toward hybrid or remote-only work, however, have made regular and cohesive teamwork more arduous, resulting in increased workplace loneliness, lower team cohesion and team awareness and in turn, negatively impacted teamwork and productivity [16, 31, 46].

Scholars have also considered factors that affect knowledge work in distributed collaboration, where members of a team may work from different and changing workplace locations. Bosch-Sijtsema and colleagues, for example, found that team task, team structure, team work processes, workplace and organization context may have an impact on performance and productivity [10]. Work from this literature tends to focus on the team over the individual.

In this paper, we explore the tensions between the individual and the team, focusing on the choices an individual makes toward their own individual productivity versus their team's productivity. We focus on software development teams as they are examples of knowledge-worker teams who collaborate on a shared set of tasks with specific goals. Software development has been characterized as involving inherently collaborative and intense knowledge work [52] by individuals organized into multiple, often fluidly defined, teams [60]. For software developers to be productive, they have to continuously balance their individual task work, such as their main coding tasks, with collaborative activities to help their team and avoid others being blocked. With the emerging global trend of work occurring in hybrid environments especially with the COVID-19 pandemic (e.g., [56]) and developers prioritizing individual work over team collaboration [22, 65], this tension between individual task work and productivity versus helping the team, which is often considered to impede the individual productivity, has only increased.

To reshape how a developer considers helping others is productive or not and cultivate a team-oriented mindset about productivity, we developed a technology probe with a team nudge and examined its impact on software developers in a longitudinal field study with 48 participants. In a *baseline* phase, we used our technology probe to collect rich data on individual developers, using hourly self-reports and a daily diary. In the subsequent *intervention* phase, we added a *team nudge* in the form of an additional question to the daily diary that asked "How did your team help you to be productive today?". Over an average of more than 9 weeks for each of the 48 study participants, we collected a total of 8338 hourly self-reports, and 1389 daily diary entries. In addition, we had 3 surveys, one at the beginning, one at the midpoint and one at the end to collect data on participants' teams, team cohesion and burnout.

We analysed the quantitative and qualitative data and found, amongst other results, that the team nudge increased participants' productivity ratings and team awareness, led to participants spending more time on their own tasks, and reshaped their perceptions of themselves and their team, yet, in general, did not increase team cohesion or affect well-being. In summary, this paper makes the following contributions:

- A technology probe together with a method for performing a longitudinal field study that allows to collect a rich data set and examine the effects of a team nudge intervention on software developers' hourly and daily productivity perceptions, work patterns and well-being.

- Empirical findings on the impact of our team nudge and the technology probe on software developers from a multi-week field study with 48 professional developers working in a hybrid environment.

Overall, our findings suggest that our small daily team nudge has a positive impact on the individual level, encouraging developers to feel that they are making progress on their own

tasks and to feel more productive in doing so while also reshaping perceptions of the team and collaborative work.

2 RELATED WORK

In this section, we discuss and review prior work on the developers' challenges with balancing individual- and teamwork, on team cohesion and awareness in hybrid/remote work, and on influencing mindsets through self-reflection and nudging.

2.1 Balancing individual- and teamwork

Software developers' workdays are typically highly fragmented, as two main activities are competing for developers' attention and time at work: their main coding tasks and collaborative activities with their team(s) [22, 47, 60]. Since software development work is highly collaborative in general, most developers cannot focus exclusively on making progress on their own work tasks. In fact, most need to actively engage in collaborative activities with their team and/or customers, including brainstorming on new features, participating in planning sessions, helping team members in case of questions or problems, and mentoring new colleagues.

Studies on software developers' work, expertise and productivity concluded that successful and innovative developers manage to find a good balance between individual- and teamwork. These developers, in turn, also consider such balanced days to be more positive and productive overall [6, 30, 40, 47]. However, balancing these activities remains a challenge for developers: While focusing a lot of time on completing one's own work can make the individual more productive, it may reduce overall team productivity as some team members might remain blocked on their tasks when not receiving any inputs or help from the colleague. Conversely, a developer who is frequently interrupted from their main coding tasks to support co-workers might have a positive impact on team productivity, but feel that their individual productivity suffers as a result. Frequent interruptions have further been associated with higher error rates, lower work performance, higher anxiety and increased stress, which is why many developers are actively trying to limit them [3, 19, 43, 48, 50]. On the other hand, receiving social support from supervisors and co-workers and being more open to communication in general, was shown to be positively associated with job satisfaction, well-being and reducing work-related stress [45, 61, 73].

Thus, it is crucial that managers, teams and especially individuals are actively striving to find such a trade-off, by learning how and when to prioritize focused individual work and when to prioritize teamwork [30, 60]. One key aspect in enabling better prioritization is having agency and control over one's own work, schedule and implementation of one's tasks [5, 37, 47]. As individual work becomes more autonomous and self-managed, interactions between team members will involuntarily decrease as workers focus more on making progress on their own tasks [37]. Our work aims to support developers prioritizing their time spent working on their own tasks versus helping their team, by increasing their awareness of their team.

2.2 Team cohesion and awareness in remote/hybrid work

The recent trends toward hybrid and remote-only work, accelerated by the COVID-19 pandemic, further complicate the balancing of individual- and teamwork. On the one hand, developers face new challenges intricate to working from home, such as distractions from family members or household work and reduced ergonomics [22]. On the other hand, since developers were no longer regularly seeing their co-workers physically at the office, they started prioritizing individual work over team collaboration, resulting in higher self-reported focus, productivity and control over work [22, 65]. Similarly, studies conducted prior to the pandemic on remote work and with knowledge workers more generally also showed increased levels of individual productivity [4, 44, 64].

However, the higher prioritization on individual work when working remotely resulted in developers spending less time with networking, taking social breaks, and managing networks and social ties [15, 22, 59]. On an *individual* level, in a recent study by Ford et al., software developers reported missing the social interactions with co-workers (83%), being less aware of their colleagues' work (65%), having difficulties to communicate with colleagues efficiently (57%) and having too many meetings as a result of less efficient communication (51%) [22]. On an *organizational* level, the shift to hybrid or remote-only work resulted in increased workplace loneliness, as well as reduced organizational commitment, organizational citizenship behaviors, team awareness and team cohesion [16, 31, 46]. As teams became less aware of their co-workers' current tasks and progress, work rhythms and location, availability for interruptions, satisfaction and well-being when working remotely, they started to communicate less efficiently and more in silos [74, 76], which further negatively impacted workers' perceptions of the importance and productivity of collaborative work.

Several approaches and tools exist to support *remote* collaboration, most prominently virtual communication apps (e.g., Microsoft Teams, Zoom) and tools to increase one's awareness about work and presence (e.g., TeamScope [34], WIPDash [8], awareness tool [26], WeHomer [20], or task tracking tools such as Jira [2]). In contrast to supporting collaborative teamwork through a technological solution, the present work studies how a team nudge that prompts developers to consider how their team helps them to be productive may cultivate a team-oriented mindset of productivity and affect team cohesion and productivity perceptions.

2.3 Self-reflection and nudging in the workplace

Besides approaches that visualize information to increase users' awareness about a topic, other types of interventions were studied to better understand their effects on workers' awareness, perception and mindsets of work-related topics. Most prominently, *self-reflection* has been applied to and studied in areas such as task switching or completion [1, 18, 19, 35], time management [35, 55, 58, 69], detachment from work [36, 71], well-being [17, 25, 28], productivity [49], and work habits [50], often in the form of diary- or journal-like setups. In these studies, users would reflect at regular intervals, either hourly (e.g. [49]), at task boundaries (e.g. [19, 35]), or daily (e.g. [14, 18, 50]). Self-reflection at short intervals may help workers to reflect more concretely about recent events *in situ* and identify just-in-time improvements to their current behaviors, such as taking a break or switching to another task [19, 49]. On the other hand, self-reflecting at longer intervals such as a daily or weekly basis, allows users to take a step away and helps with discovery (e.g. of new goals or sub-optimal habits) and reflection (e.g. on improving habits toward a goal) [39]. Beneficial of applying self-reflection is that it delivers insights into a user's real-world practices, can easily be integrated into existing workflows, was shown as a learning source, and that solely the process of reflecting about a topic often influences a user's behaviors (Hawthorn-like effect) [14, 19, 50, 72].

Nudging is another type of intervention that has gained popularity in health and social sciences as a way to influence behavior in a subtle and non-coercive manner [27, 66]. Thaler and Sunstein, who popularized the term 'nudge', described six types of nudges: incentives, understand mappings, defaults, give feedback, expect error, and structure complex choices [66]. A few examples of nudging in the workplace are to encourage physical activity in the office [67], keeping physical distance at the office during a pandemic [41], making more informed and desirable privacy decisions [33], or reducing use of distracting social media apps [75]. More specific to software development, nudges were used to accelerate completion of overdue Pull Requests [42] and to encourage tool use [12, 51]. In our work, we deploy a team nudge to cultivate a team-oriented mindset on productivity over the course of several weeks to study its impact on team cohesion, work patterns and individual productivity perceptions.

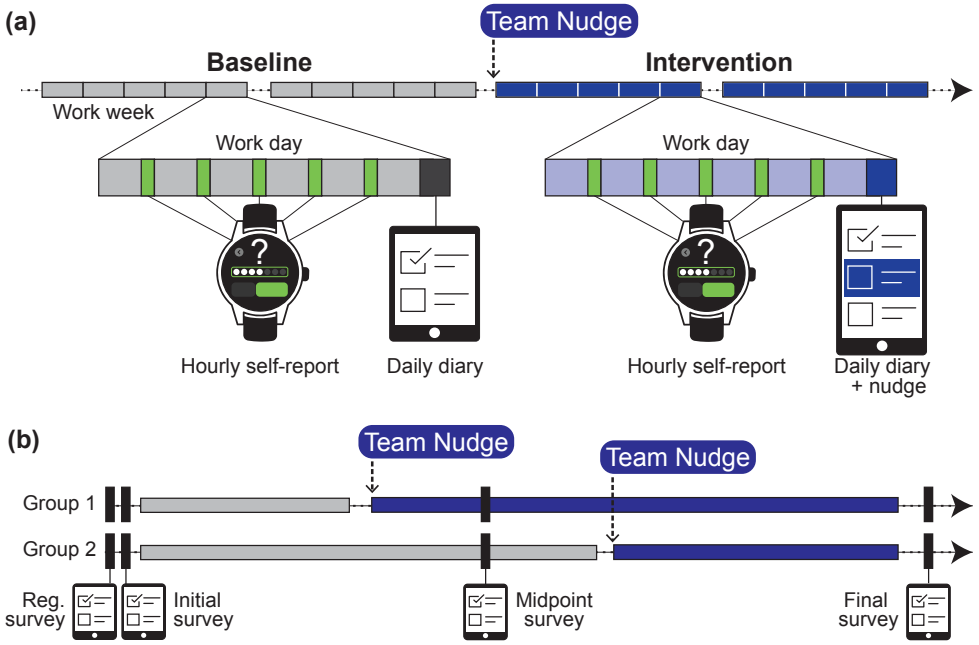

Fig. 1. Study design: (a) baseline and intervention phase, and (b) staggered team nudge deployment.

3 METHOD

We conducted a longitudinal field study in which we deployed a technology probe [32] with 48 participants over an average of 9 weeks to examine whether a small team nudge can reshape how people consider helping others is productive or not and cultivate a team mindset about productivity. In particular, we investigated the following research questions:

RQ1: *Can a team nudge that prompts software developers to consider how their team helps them to be productive be used to improve team cohesion, productivity perceptions, and well-being?*

RQ2: *Does such a team nudge impact how developers spend their work time?*

The study was split into two phases: a *baseline* phase and an *intervention* phase (see Figure 1(a)). In the baseline phase, we used our technology probe consisting of hourly self-reports on a smartwatch and a daily diary on the web to collect data on participants' workdays, their productivity, well-being, and their team interactions. For the intervention phase, we added a *team nudge* in the form of the additional question "How did your team help you to be productive today?" to the daily and weekly diary.

Overall, we designed our study to be staggered, with the intervention starting at different times for different groups of participants (see Figure 1(b)). We chose this design to be able to attribute the effects to the team nudge intervention rather than to a chance factor.

3.1 Technology probe: reflection and team nudge

Our technology probe consists of two components: a smartwatch application for hourly self-reports and a web application for the daily diary. The technology probe was designed to (a) collect rich and continuous data on users in a real-world setting by fostering them to *reflect* on their work and team interaction and (b) allow us to introduce and examine a *team nudge* for the intervention

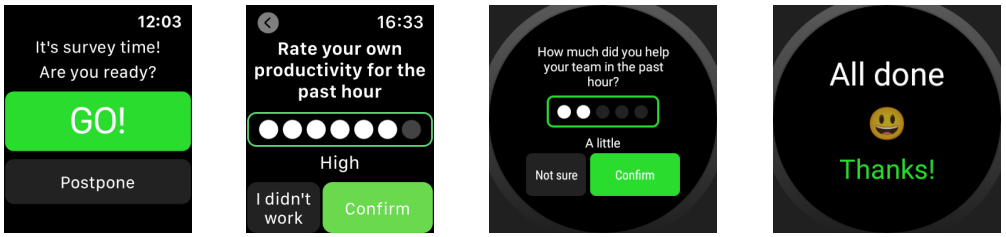

Fig. 2. Smartwatch application screens (from left to right): self-reporting prompt (watchOS), productivity rating (watchOS), rating on helping team (Wear OS), and final screen (Wear OS).

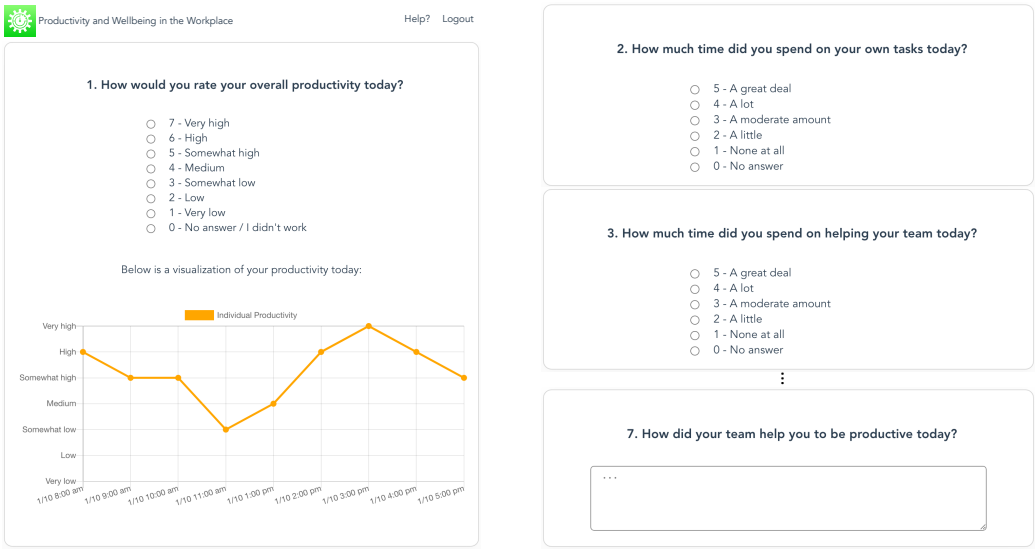

Fig. 3. Screenshots of the web application and sample questions, including the team nudge question (7).

phase while keeping in mind its disruptiveness and comfort. A prior pilot study[1] that examined the use of various devices for collecting hourly self-reports, including smartwatches, smartphones, and computers, showed that smartwatches are the most comfortable, least intrusive condition while also being considered the most accurate by users, even though no observable difference in the collected data was found across the different devices.

Reflection support. We developed a smartwatch application and a web application to prompt software developers to reflect on and continuously collect data on their workdays. When users install the *smartwatch application* from the app store, it asks them to specify their user ID, their regular days of work including workday start and end times, and when they want to receive an email notification for their daily diary. Once installed, the smartwatch prompts users every hour during their regular workdays and asks them to rate their own productivity, how much time they spend on their own tasks, how much they helped their team, and how well they spent their time for the past hour (see sample screenshots in Figure 2). To remind users to answer the self-reporting prompt, the application either plays a sound, vibrates, and/or shows a notification on the smartwatch based on their individual notification settings. Users are also able to easily skip the self-reporting prompt by selecting 'postpone'. After answering all questions, a final screen is shown, and the data is sent to a secured web server. To support the preferences of a broad range of users, we developed two

[1]Citation left out for anonymity/double-blind reasons.

versions of the application with identical features, one for the Android Wear OS, and one for the Apple watchOS.

At the end of each workday, our *web application* sends an email to each registered user that filled in at least one hourly self-report during the day and prompts them to fill out the daily (Monday through Thursday) or weekly (Friday) diary. The diary is accessible from any web browser, provides visualizations of users' hourly productivity- and time well-spent ratings of the day, and asks questions on their productivity, how they spent their time, their well-being, their work location, and the progress they made in terms of user stories and commits (see Figure 3 for a sample visualization and questions). The full set of questions is included in the replication package [23]. The weekly diary contained the same questions and figures as the daily one but included additional questions on the weekly progress and task cohesion.

Team nudge. The design goal for our nudge was to be minimal, yet to prompt people to pay more attention to the team as a relational source of productivity, rather than taking a more individualistic lens which may be the default. Therefore, we designed the nudge as the single question "How did your team help you to be productive today?" that we added to the daily and weekly diary after the baseline phase (see question 7 in Figure 3). This nudge allows us to examine how endorsing a more relational mindset about productivity using a single, and simple question and method might reshape how people consider helping others is productive or not, possibly increasing productivity perception, team cohesion, and well-being.

Prior research suggests that people's mindsets can be changed by prompting them to reflect on how this mindset applies in the relevant context in their everyday lives. For example, drawing on her seminal research on mindsets, Dweck [21] suggested that by asking participants to reflect on the question "What are the opportunities for learning and growth today?", participants will focus on how learning and growth can take place and their mindsets about intelligence will shift to more strongly endorse a growth mindset about intelligence over a fixed mindset. This reflection exercise strategy draws on the "saying is believing" effect as well as the principle that an individual's belief in an idea is strengthened when they are endorsing it in their own words [29], and has been utilized in growth mindset interventions across various contexts [13]. Interventions that incorporate such reflection strategies have further been shown to change mindsets in professional contexts. For example, Rogers et al. [57] developed a reflection exercise to encourage employees to endorse a growth mindset about personal and professional capabilities at work, by asking them to reflect on the opportunities for growth that their job provides for them and how these opportunities help them. They found that this reflection exercise effectively shifted employees' mindsets, such that employees endorsed a stronger work growth mindset.

For our study, we adapted the reflection to our context, by asking participants to reflect on how their team helps them to be productive, and thus supporting the mindset that their team contributes to their productivity. By prompting participants to focus on how their team can help their productivity, we anticipated that they would pay more attention to positive examples of when their team helped their productivity. As a result, we expected the reflection step to foster a more positive awareness of the team, as well as a more positive perception of one's own productivity and the team's productivity. This could hypothetically lead to more positive team-level consequences (e.g., increased team cohesion over time) and could also potentially prevent negative team-level consequences (e.g., frustration with the team), thus leading the nudge to potentially have further downstream positive consequences for employees (e.g., effects on burnout).

We piloted our technology probe for several weeks with multiple participants to ensure a smooth running and examine the ease and bug-free running of the self-reports, the diaries, and the team nudge.

3.2 Procedure

To examine software developers in a real-world setting and study the effect of our team nudge, we designed our study for a period of six weeks, with a 2- or 4-week baseline phase, depending on each participant's assignment in the staggered deployment of the the team nudge (see Figure 1(b)). Due to the Agile process applied at all teams, we chose a minimum of six weeks to capture several of the two week-sprints. Since participants were allowed to start once they received their smartwatch and the smartwatch delivery times differed by location, we added a buffer of several days at the start and end of the study. In addition, several participants continued to participate for several more days at the end of the study, resulting in a period of an average of 9 weeks per participant.

After a participant **registered** their interest in our study and we confirmed their eligibility to participate, we asked them to fill out an **initial survey** that contained questions on their team, team cohesion, their productivity mindset, and burnout as well as questions on their smartwatch preferences (Apple Watch SE, Samsung Galaxy Watch 4, or their own) and shipping information, as well as the consent form. After we shipped each participant their chosen smartwatch, we asked them to install our smartwatch application and register with our web application online.

Once participants registered and installed the smartwatch application, they started the study and resumed their regular work, during which they were prompted to fill in the **hourly self-reports** and the **daily** and **weekly diaries**. In addition to the initial survey, we had two **surveys** to capture data on participants' teams, team cohesion, and burnout: one at the **midpoint** and one at the end (**final**). After the final survey, we conducted semi-structured **interviews** with ten participants that we randomly picked to gain further insights.

The self-report, diary, and survey questions as well as the installation guides for the smartwatches can be found in the supplementary material [23]. The study was approved by our institutional ethics board.

3.3 Participants

We advertised for our study in several software development teams of a multi-national company with more than 30,000 employees. We used a kick-off event, invitation emails, and word-of-mouth to broadly advertise our study asking interested people to fill in an online registration survey. To be eligible to participate in the study, participants were asked to work in a team with 4 or more people and were required to own an Android phone or an iPhone 6 or later. Based on a first come, first served basis, we then invited interested/registered participants, up to a maximum of 50 participants.

In total, we recruited 48 participants from 17 different teams working for the multi-national company either from Europe or Asia. Participants reported that they were part of teams that ranged from 4 up to 60 team members (for one higher level manager), with an average of 13.9 (±12.4) members per team. All participants worked in areas related to software engineering and had a mean of 17.7 years (±9.6) of professional experience. The participants work in the fields of Software Development (28), Requirements Engineering (10), Business Management (5), Quality Assurance (4), and Support & Operations (1). Of the 48 recruited participants 39 identified as male, 8 as female, and one preferred not to disclose this information. The age of the participants ranged from 24 to 62, with a mean of 41.0 (±10.2). 28 participants (58%) were individual contributors, while 20 (42%) stated that they were managers, with anyone that played a leadership or managerial role on a team being considered a manager, including tech leads, delivery managers, and testing leads.

Participants received the smartwatch used for the study as compensation for their time and effort.

Surveys Questions - Team Cohesion (Online Survey) *All 7-point Likert-type scale from (1) strongly disagree, to (7) strongly agree*
Task cohesion
Q1. Our team is united in trying to reach its goals for performance.
Q2. We all take responsibility for any poor performance by our team.
Q3. Our team members have conflicting aspirations for the team's performance.
Social cohesion
Q4. Members of this team stick together.
Q5. Members of our team would rather go out on their own than get together as a team.
Q6. Our team would like to spend time together outside of work.
Self-Report Questions (Smartwatch)
Q1. Rate your own productivity for the past hour. *7-point scale: (1) very low to (7) very high; additional option 'I didn't work'*
Q2. How much time did you spend on your own tasks in the past hour? *5-point scale: (1) none at all to (5) a great deal*
Q3. How much did you help your team in the past hour? *5-point scale: (1) not at all to (5) a great deal*
Q4. Rate how well you spent your time for the past hour. *7-point scale: (1) very poorly to (7) very well*
Sample Diary Questions (Web Application)
Q1. How would you rate your overall productivity today? *7-point scale: (1) very low to (7) very high; additional option 'I didn't work'*
Q4. How much of your work was towards organizational goals today (..)? *5-point scale: (1) none at all to (7) a great deal*
Q6. If you helped your team or organization today, how do you think it affected your productivity? *7-point scale: (1) very negatively to (7) very positively; additional option 'I did not help'*
Q10. Where did you spend the majority of your time working today? *3 options: At the office, At home (remotely), In a different location (remotely).*
Sample Interview Questions (Audio/Video Call) *All open answers*
Q4. How do you assess your own productivity?
Q17. Was the reflection on your own work and productivity helpful to you, and if so, in which way?

Table 1. Collected data: sample questions.

3.4 Data Collection

For our analysis, we collected a range of quantitative and qualitative data from the three surveys (initial, midpoint, final), the semi-structured follow-up interviews, the hourly self-reports, and the daily/weekly diaries. Sample questions are shown in Table 1. The entire set of questions can be found in the supplementary material [23].

Surveys. In total, 48 participants answered the first survey, 38 answered the second survey, and 37 answered the last survey. All three surveys contained six items on team cohesion based on a scale by Lee and Wong [38]. For *team cohesion*, we collected two measures. The first, which assessed team task cohesion, was constructed as the average of the three questions related to task

cohesion (reverse scoring the item "Our team members have conflicting aspirations for the team's performance"). The second, which assessed team social cohesion, was constructed as the average of the three questions related to social cohesion (reverse scoring the item "Members of our team would rather go out on their own than get together as a team"). In addition, in all three surveys, we measured employees' levels of emotional exhaustion using four items by Wilk and Moynihan [70] (which we refer to as 'burnout' scale in the following). The final survey also included more general questions on the reflection and study.

Interviews. To gain a more in-depth understanding, we further conducted semi-structured interviews with ten participants who were randomly selected from the ones that completed the final survey. For the interviews, we were interested in the participants' nature of work, their perception of productivity, their definitions of their team, their perception of helping others with respect to productivity, and their impressions of the intervention and the team nudge. The interviews lasted an average of 54.5 minutes (±21.7) and were audio-recorded and then transcribed.

Self-reports and daily/weekly diaries. Throughout the study, we collected hourly self-report data and daily and weekly diary entries from the participants. In total, we collected 8338 hourly self-reports and 1389 daily/weekly diary entries. Each participant submitted up to 513 self-reports (mean of M=173.7, ±141.7) and up to 69 diaries (M=28.9, ± 19.3) over an average of 9.6 weeks (±3.8). Based on the collected daily diaries, participants worked on an average of 70.7% (±21.4) of their days remotely—either from home or a different location—and 29.3% (±21.4) of their days from the office, with a few participants working exclusively in the office (1) or remotely (4).

Note that after manual inspection of the data, we found that for a single one of the 48 participants, we had several instances in which we collected more than 3 hourly self-reports in a time window of less than ten minutes. Since we were not able to resolve which of the hourly self-reports to use, we removed the data for these irregular days for this participant.

3.5 Data Analysis

We performed statistical analyses on the hourly self-reports and the ratings of the daily/weekly diaries, including mixed-model and linear regression analysis on variables of task and social cohesion, productivity, and work patterns. In the analyses, we included all observations from all participants on the relevant variables (except for the irregularities for the one participant mentioned above). For the linear regression, we included all participants that had data on the relevant variables and excluded the ones that did not. For example, some participants did not fill in the midpoint survey, in which case we dropped them from the specific analysis that focused on variables of the midpoint.

We analyzed the interview transcripts and open-ended survey responses using the reflexive thematic analysis approach by Braun and Clarke [11]. One author led the process of gaining familiarity with the data and generating and identifying codes and themes, both inductively and deductively. Two further authors were involved in the initial coding and the reviewing and clustering of the themes. For the interviews, two authors independently coded all interviews and reviewed and discussed the codes and themes together before producing the final summary.

4 RESULTS

In the following, we present findings on the effect of the team nudge and our technology probe on team cohesion, perceptions of productivity, work patterns, and well-being. We also report on the more general impact of the team nudge and the reflection.

	Initial	Mid	Final
Task Cohesion	5.92 (±0.85)	5.80 (±0.86)	5.78 (±0.85)
Social Cohesion	5.23 (±0.95)	5.18 (±0.95)	5.09 (±1.06)

Table 2. Team cohesion mean and standard deviation by survey timepoint.

4.1 Team Cohesion

Overall, the *team nudge did not have a significant effect on team cohesion when comparing pre- and post-nudge.* Team cohesion ratings were generally relatively high across all teams from all participants and all three survey points in time (see Table 2). A paired t-test between initial (pre-nudge) and final survey (post-nudge) showed no significant difference in task cohesion from pre-nudge to post-nudge (M_{Diff}=0.16, t(36)=1.29, p=0.205) or for social cohesion from pre-nudge to post-nudge (M_{Diff}=0.07, t(36)=0.38, p=0.704). There is also no significant difference when comparing the task cohesion ratings from the weekly diaries pre- and post-nudge. A linear mixed model comparing the weeks before the team nudge intervention to the ones after (modeling participants as a random effect) shows a non-significant decrease from pre- to post-nudge of 0.1% (M_{pre}=5.54, M_{post}=5.53, B=-0.01, SE=0.08, t(214.41)=-0.13, p=0.918).

The *team nudge had, however, a significant effect on task cohesion when moderated by the initial levels of task cohesion of a participant's team.* Based on the staggered deployment of the nudge (see Figure 1(b)), we randomly assigned some participants to begin the nudge encouraging the mindset that their team contributes to productivity prior to completing the midpoint survey (i.e., to serve as a treatment group), and some participants to begin receiving the nudge after the midpoint survey (i.e., to serve as a control group). Thus, we were able to compare a group of 8 participants who had been completing the main study but had not yet received the nudge when they completed the midpoint survey to a group of 30 participants who had already received the nudge at the time of the midpoint survey. Then, using linear regression, we compared the mean of the group that had received the nudge (treatment group) to the mean of the group that had not yet received the nudge (control group). At the midpoint survey, there were no differences in task cohesion between the treatment group (M=5.72, ±0.94) and the control group (M=6.08, ±0.39), B=-0.36, SE=0.34, t(36)=1.06, p=0.298. However, there was a significant moderation effect by initial levels of task cohesion, B=0.68, SE=0.31, t(34)=2.18, p=0.036, such that members of teams with lower initial levels of task cohesion appeared to be adversely affected by the nudge, while members of teams with higher initial levels of task cohesion appeared to be positively affected by the nudge. Illustrating this difference, members of teams with the lowest initial levels of task cohesion (3.7 on the 7-point scale) who had received the nudge reported 27.6% lower task cohesion compared to members of low-task cohesion teams who had not yet received the nudge, while members of teams with the highest initial levels of task cohesion (7 on the 7-point scale) who had received the nudge reported a 4.6% increase in task cohesion relative to members of high-task cohesion teams that had not yet received the nudge.

There were no differences on social cohesion between the treatment group (M=5.12, ±0.92) and the control group (M=5.38, ±1.09), B=-0.25, SE=0.38, t(36)=-0.66, p=0.512. There was also no moderation by initial levels of social cohesion, B=0.25, SE=0.36, t(34)=0.69, p=0.496.

> **Finding.** *In general, the team nudge did not increase team cohesion. Yet, for members of teams with high initial levels of task cohesion, the team nudge had a positive effect, increasing it further, while it decreased for members from teams with low initial task cohesion.*

4.2 Productivity Perceptions

The *team nudge enhanced participants' perceptions of their own productivity.* A linear mixed model comparing days before the team nudge intervention to the ones after (modeling participants as a random effect) shows a significant increase in perceived productivity as a result of the nudge. After prompting participants to think about how their team helps their productivity, they reported a statistically significant 1.7% higher productivity in the daily diaries (M_{pre}=5.18, M_{post}=5.30, B=0.12, SE=0.05, t(1316)=2.28, p=0.023), with participants reporting gains of up to 8.8% in individual productivity. Similarly in linear mixed model analyses examining the hourly self-reports (modeling both participants and the particular date as random effects), participants reported a statistically significant 2.3% higher productivity during the intervention phase compared to the baseline phase (M_{pre}=5.22, M_{post}=5.38, B=0.16, SE=0.04, t(171.5)=4.44, p<0.001), with participants reporting gains of up to 19.2% in individual productivity. Participants also trended toward more strongly endorsing that helping their team affected their productivity positively in linear mixed model analyses examining the daily surveys, with a statistically significant increase of 1.1% relative to prior to the team nudge intervention (M_{pre}=4.80, M_{post}=4.88, B=0.08, SE=0.05, t(1239)=1.56, p=0.119). These effects did not differ depending on whether employees were working remotely or in home office.

Aligned with the patterns on team cohesion, the *effects of the team nudge on productivity perceptions are strongest for members of teams that were the highest in task cohesion at the start of the study.* A linear mixed model analysis shows that the initial level of task cohesion had a significant moderation effect with the team nudge on the daily productivity ratings (B=0.14, SE=0.06, t(1318)=2.23, p=0.026). In numbers, the teams that were highest in team cohesion (i.e., a 7 out of the 7 point scale) gained 4.2% in productivity, while those that were at the lowest level of team cohesion (i.e., a 3.7 on the 7 point scale) actually lost 2.5% in productivity. This pattern of the initial task cohesion level moderating the effect of the team nudge on perceived productivity also holds for the hourly self-report ratings, for which again there was a significant interaction with initial levels of task cohesion (B=0.15, SE=0.03, t(7468.4)=4.45, p<0.001). Illustrating this difference, members from teams with the highest levels of task cohesion gained 5.0% in productivity while members from teams with the lowest levels of task cohesion lost 2.1% in productivity. At the same time, there was no significant moderation by initial levels of social cohesion for either the daily measures (B=0.02, SE=0.06, t(1322)=0.39, p=0.697) or the hourly measures (B=0.05, SE=0.03, t(7386.6)=1.69, p=0.092).

> **Finding.** *The team nudge increased participants' productivity ratings, especially for members of teams with high initial task cohesion.*

4.3 Well-being

Over the course of the study, we collected data on participants' well-being, including how well they spend their time at work (hourly self-reports and daily diaries), and their burnout-related feelings (initial, mid, and final survey). A linear mixed model to compare the hourly time well spent ratings before and after deploying the team nudge (modeling the participants and the particular date as random effects) shows that the team nudge had a significant and positive effect on hourly time well spent self-reports (M_{pre}=5.42, M_{post}=5.49, B=0.08, SE=0.03, t(180.2)=2.30, p=0.023), increasing this by 1.0%. At the same time, there is no significant effect on the daily level, (M_{pre}=5.33, M_{post}=5.42, B=0.10, SE=0.06, t(1357)=1.52, p=0.130), amounting to a non-significant 1.4% increase.

We also measured burnout in the mid-survey such that we could compare the mean of the group that had received the nudge (treatment group) to the mean of the group that had not yet received the nudge (control group). At the midpoint survey, there were no differences in burnout between the treatment group (M=6.06, ±0.67) and the control group (M=5.88, ±0.35), B=0.18, SE=0.25, t(36)=0.73, p=0.468.

> **Finding.** *Overall, the team nudge had no consistent significant effect on burnout measures and on self-reported time well spent.*

4.4 Work Patterns

The team nudge also seemed to shape working patterns. We conducted a series of linear mixed models examining daily and hourly reports using the same procedures as in the previous sections. After prompting participants to think about how their team helps their productivity, they reported *spending more time on their own tasks during each day*, with a statistically significant 3.5% increase in time spent on their own tasks in the daily surveys (M_{pre}=3.47, M_{post}=3.65, B=0.17, SE=0.04, t(1315)=4.10, p<0.001) and a 2.5% increase in the hourly surveys (M_{pre}=3.57, M_{post}=3.69, B=0.12, SE=0.03, t(221.1)=3.73, p<0.001). At the same time, they reported spending an *equivalent amount of time helping others* with a 0.4% decrease, which was not statistically significant, in time spent on helping their team in the daily surveys (M_{pre}=3.04, M_{post}=3.02, B=-0.02, SE=0.05, t(1319)=-0.41, p=0.686) and a 0.01% increase, which was again not statistically significant, in the hourly surveys (M_{pre}=2.78, M_{post}=2.79, B=0.01, SE=0.03, t(193.4)=0.18, p=0.857). Finally, the team nudge led to participants reporting to spend less time working toward organizational goals, with a statistically significant 3.5% decrease in time spent toward organizational goals in the daily surveys (M_{pre}=3.06, M_{post}=2.89, B=-0.17, SE=0.05, t(1266)=-3.46, p<0.001).

Working more on own tasks after the deployment of the team nudge was moderated by initial levels of social cohesion (B=0.11, SE=0.05, t(1312)=2.18, p=0.029), such that members of teams with initially high levels of social cohesion were more likely to report working on their own tasks as a result of the nudge (a 7.3% increase) while members of teams with initially low levels of social cohesion were less likely to do so (a 1.1% decrease). There was no moderation by initial levels of task cohesion when it comes to the time spent on own tasks (B=0.02, SE=0.05, t(1315)=0.39, p=0.699).

> **Finding.** *The team nudge led to participants spending more time on their own tasks while spending less time working toward organizational goals.*

4.5 Participants' Perception of the Team Nudge

When asked about the team nudge in the final survey and the semi-structured interviews[2], participants' responses varied from it not having a significant impact to very positive effects. 18 survey participants (48.6%) and 4 interview participants (40%) mentioned that the reflection on the team's help did not change their perspective significantly. In several of these cases, participants mentioned that they already had a "team-centric focus" (S_6) or a "good reflection and transparency level" (S_{13}) before the study. Yet they also mentioned that while it did not change their perspective significantly, it "highlighted the time spent to support the team and the importance" (S_{38}) or as one participant stated: "I don't think it changed my perspective, but it certainly made me reflect on it, which, in itself, I think was a useful exercise. I sat back and thought you know, am I looking at this the right way [..]" (S_1).

Several participants—12 survey participants (32.4%) and 6 interview participants (60%)—explicitly mentioned several positive effects of the team nudge, in particular, that it increased the awareness of the team, the value of collaborative work and the team's help, and that it improved team interaction, team culture, and productivity. For example, participants stated that it creates a "higher awareness of what everybody is doing for the team" (S_{41}), that it made them "grateful for all the help and assistance that I have received for my tasks" (S_{45}), that it "creates a bond between team members" (S_1), and S_8 wrote that with the team nudge they have "seen [a] slight improvement on some

[2]We refer to participants in the survey and interview as S_X and I_X respectively.

of the team members support and interaction, which helped me to be efficient and productive". Furthermore, the team nudge triggered participants to reflect on their own behavior and mindset. I_8 said: I "got definitely like a new perspective in the sense that I was more aware when I disrupted [..] someone from the workflow, and I reflected on, hey, is it maybe better to write an email instead of skyping this person?", and I_9 stated the team nudge "made me more aware that even though I'm not doing the tasks I'm supposed to output, if I'm helping the team, then that is being productive, and I need to be a little less, maybe harsh on myself by not judging myself as being unproductive when I'm actually not, so I think that it has actually been positive for me to learn that one thing from the study".

> **Finding.** *The team nudge can reshape people's perception of themselves and others. Even in cases when it had no significant impact on participants' perspectives, it often fostered reflection and awareness.*

4.6 Effects of the Reflection

While the main focus of the study was on the effects of the team nudge, the hourly and daily reflection on work, productivity, and time well spent also had a very positive impact on participants. Most survey (78.4%) and interview (90%) participants reported that the reflection increased their awareness of their work time and the factors affecting their productivity. For example, I_7 stated that the reflection "[had] the most impact, those questions when you think about yourself [..] because then I reviewed what happened". In turn, the reflection led to participants better structuring and optimizing their day and work habits, increasing productivity and focus overall. S_4 wrote that from the reflection, "I learned to review my own work and to structure also the work better so that I could already see an improvement in my productivity just by measuring it" and S_{35} stated "I started managing my time well which helps me to finish most of [the] assigned tasks on time". Several participants also explicitly mentioned that the reflection was helping them to assess which meetings they should attend or not, e.g., "I skipped more meetings that I feel are not a productive use of my time [..] before I went to the meeting now I think about it first" (I_1), and to automate (redundant) tasks that "saves a lot of my manual work" (S_8).

In addition, the reflection made participants feel better about their work and about themselves. S_9 stated that the reflection "gave me confidence and boosted my willpower when I realize how well I am spending my time at work" and S_7 wrote "also for motivation when I did spend [my time] well it gave a good feeling. If not, I immediately asked myself what to change". It even helped to change the mindset about work-life balance: "it actually made me more grateful for my free time, and what I could do on that, and how I could enjoy of the day parts of the work day as well. It changed the mindset. Yeah, because I would have been doing that anyway. But it changed the mindset to make me appreciate it more. And I suppose, yeah, enforce it more as Yeah, This is something positive that you should be doing, and it helps you recharge during the day, and you know, taking breaks and stuff like that" (I_9).

Only a few participants (16.2%) mentioned that the reflection was not helpful since they, for example, "don't see any big productivity impediment" (S_{42}) for themselves, were "already very mindful about [their] own productivity" (S_{36}), or were not sure: "not really, although I was surprised, that my productivity seems to be more influenced by the daily situation more then by the time of the day" (S_{15}). Also, for most participants, the hourly self-reports were a good trade-off and "not too much and not too little" (I_8), and even helped to get "in the continuous flow of self-reflection" (S_7). For very few, they were too many, and one stated that "it confirmed my feelings but it also interrupted my 'flow' and took more time than I anticipated" (S_{43}).

> **Finding.** *Frequent reflection on work, productivity, and time well spent generally increased awareness, helped to optimize work habits and days, increased productivity, and improved participants' feeling about themselves, their work, and their work-life balance.*

5 DISCUSSION

The results of our study suggest that our minimal team nudge has a positive impact on the individual level, encouraging individuals to feel that they are making progress on their own tasks and to feel more productive in doing so while also reshaping perceptions of the team and collaborative work. Especially with the shift toward more hybrid work and the accompanying reduction in social interactions when working remotely, emphasizing the value of the team and cultivating a more team-oriented mindset on productivity with such a team nudge can be very valuable. In the following, we discuss our findings and design considerations for the team nudge and its deployment as well as limitations of the work.

5.1 Revisiting the Research Questions

Our study addressed two research questions: (RQ1) whether a team nudge can improve software developers' team cohesion, perceived productivity, and well-being; and (RQ2) whether it impacts the way developers spend their work time. Considering RQ1, we found that the team nudge did not increase team cohesion in general, yet when moderated by initial levels of task cohesion of a participant's team, it had a significant effect. Regarding participants' perception of productivity, the team nudge resulted in a statistically significant increase in productivity ratings. Participants further trended (statistically significant) toward more strongly endorsing that helping their team affected their productivity positively. The team nudge effect on perceived productivity was again significantly moderated by the initial level of task cohesion, with the strongest increases in perceived productivity for members of teams that had the highest task cohesion at the beginning. The team nudge had no consistent significant effect on measures collected on participants' well-being. The qualitative feedback provides further evidence that the team nudge can help reshape people's perceptions of themselves and others. Overall, the team nudge received varied feedback from participants, ranging from not having a significant impact to very positive effects. Yet, even for participants that stated that it had no impact, several mentioned that it fostered reflection and awareness. For participants that mentioned a positive impact of the team nudge, the effect ranged from an increased awareness of their own mindset, the team, the team's help, and the value of collaborative work, all the way to an improvement in team interaction, culture, and productivity.

Considering the impact of the team nudge on how developers spend their work time (RQ2), we found that participants reported spending more time on their own tasks during each day (statistically significant increase), an equivalent amount of time helping others, while spending less time working toward organizational goals.

5.2 More Team-Oriented and more Time on Own Tasks

While the team nudge increased participants' perception of the value of the team and collaborative work, it did not result in individual developers spending less time on their own tasks. In fact, the team nudge led to an increase in the time developers spent on their own tasks while not affecting the time spent helping others. This suggests that cultivating a more team-oriented mindset of productivity might help developers to feel better about their team and free them up to make progress on their own tasks. Our finding that the team nudge led to an even higher increase in the time spent working on own tasks for members of teams with high initial levels of social cohesion

(Section 4.4) further suggests the importance of a strong social bond with the team and how this, in turn, can lead to individual developers feeling more freedom to work on their own tasks.

At the same time, the team nudge also led developers to spending less time working toward organizational goals, which could, in turn, impact the organization negatively. However, given that the team nudge also increased participants' productivity ratings and that participants reported many other positive effects from self-reflecting and the team nudge, we anticipate that the decrease in time spent on organizational goals rather had a positive effect on the team and organization as a whole. Overall, we hypothesize that the effect of the team nudge with the increase in time on own tasks while maintaining time spent helping others is positive. Examining the optimal balance between time spent on own tasks versus helping the team or organization would be an interesting next step of research. Similarly, future work could examine the organizational value of a team nudge and its effect on team productivity.

5.3 Importance of Initial Team Cohesion

The findings on team cohesion (Section 4.1) suggest a potential limitation of the team nudge: if team cohesion is already low to start out with, then there may not be a lot for the team members to notice for how their team helps them to be productive and the nudge can not work well. In fact, the findings suggest that while the team nudge helps to "enhance" teams that are already quite cohesive by further boosting task cohesion, it is less effective and might even have a backfire effect for teams that are struggling rather than compensating for their team issues. These findings suggest that the team nudge approach should only be deployed when a team already exceeds a minimal task cohesion threshold.

We anticipated that the nudge could have differential effects in our study depending on team cohesion, as the nudge asks participants to reflect on how their team helps them to be productive. In teams that did not function well (i.e., low levels of team cohesion), we expected that participants might struggle more to answer this question, perhaps failing to come up with examples of how their team helps them to be productive. In such cases, we anticipated that the nudge could even backfire, i.e., as members of teams with low cohesion cannot think of examples of how their team helped them to be productive, it might reinforce the mindset that teams do not contribute to productivity, rather than changing mindsets in the opposite direction. This line of reasoning is supported by research on human cognition, which suggests that the ease or difficulty with which people can generate examples shapes people's judgments (e.g., [62]). For example, when people are asked to generate many examples of their assertive behavior (i.e., prompted to generate 12 examples), they struggle more to do so than when they are asked to generate fewer examples of their assertive behavior (i.e., prompted to generate 6 examples). The difficulty of generating the greater number of examples leads people to rate themselves as less assertive after having been asked to generate more examples of their assertive behavior rather than fewer [63]. Thus, in line with this literature, if participants had struggled to generate an example of how their team helped their productivity, then the nudge asking them about how their team helped them to be productive might have led them to perceive that their team does not help their productivity and has had the opposite effect on mindsets as we had intended.

Accordingly, we tested whether team cohesion may shape the effect of the nudge and whether the nudge may only have benefits among teams that had initial levels of cohesion. These findings are novel when applied to the literature on mindsets, illustrating how reflection exercises that can aim to encourage a particular mindset can backfire in settings where reflection may be impeded by certain factors. Future work should explore the threshold at which the team nudge becomes valuable and can help knowledge workers to notice the help that their team is offering.

5.4 Team Nudge Alone

In our field study, we examined the value of a minimal team nudge: a single question to prompt users to consider how their team helps them to be productive. For this, we added the nudge to our technology probe that further contained self-reports and a daily diary for participants to reflect on their work, their productivity and their team. While this method allowed us to collect a rich dataset on participants and the results suggest that the team nudge alone had a positive impact on participants, future work should explore how to best deliver the team nudge alone. Even though the technology probe as a whole was also considered to have a positive impact by a majority of participants (see Section 4.6), the high number of questions and frequency of reporting can become cumbersome and time-consuming as also stated by one participant. Therefore, finding the right trade-off between the value and combination of the nudge and reflection, and its effort and invasiveness needs to be further examined.

5.5 Limitations

For our analyses, we generally included all observations from all participants in the dataset, even if a participant submitted a low number of daily diary entries and hourly self-reports. While mixed-model analyses can handle missing data well, we also performed our analyses omitting the participants with low numbers and found no substantial difference.

For our study, we collected data from participants over a time span of an average of 9.6 weeks per participant, including several weeks of baseline data. While this time span provides some evidence that the team nudge can have a positive impact over several weeks, an additional study with a longer time frame is needed to examine whether the team nudge has lasting effects.

For our study, we focused on members of software development teams from a single multi-national company and the participant pool consisted of 81.3% men, 16.7% women and one participant that did not want to disclose the information. While our work focused on software development teams as they are one type of knowledge workers who collaborate on a shared set of tasks with specific goals, other types of knowledge work teams might have different needs for individual and team effort in their work. The population, demographics, as well as their type of work thus pose a threat to the external validity of the study. Therefore, the generalizability of our findings to software developers from other companies or also to more general knowledge worker teams might be limited. We tried to mitigate this threat by broadly advertising for our study within the company and by recruiting participants with a variety of backgrounds, coming from various teams of the company and working in different locations across Europe and Asia.

6 CONCLUSION

Knowledge workers, and particularly software developers, must often balance the work they perform individually to meet the goals they have been assigned with the work they need to perform to help the team progress toward its goals. Choosing to spend time on their own work can improve their individual productivity, while choosing to help a teammate may improve their team's productivity but lower their own. The emerging global trend of hybrid work has exacerbated the tendency for knowledge workers in the field of software development to prioritize individual work over team collaboration [22, 65].

We developed a technology probe with a team nudge that fosters recurring reflection and prompts individuals to consider how their team helps them to be productive. In a longitudinal field study, we evaluated its impact on 48 professional software developers over an average of more than 9 weeks, collecting over 8000 hourly self-reports and over 1300 daily diary entries from all participants. We also collected data from three surveys—at the beginning, midpoint, and end of the study—to learn

about participants' teams, team cohesion, and burnout. Analyzing the collected data, we found that the team nudge did not increase team cohesion, but it did increase participants' own productivity ratings. We also found that the team nudge shaped working patterns, with participants spending more time on their own tasks while spending less time working towards organizational goals.

The value of the team nudge is, however, affected by the initial levels of team cohesion. For teams with high team task cohesion in our study, the nudge boosted task cohesion, while it can backfire for teams with low task cohesion. For teams with high team social cohesion, our results suggest that the nudge helps members of the team feel more freedom to work on their own tasks. Examining the level of team cohesion for the nudge to develop its full potential will be an interesting next step.

Finally, our findings further emphasize the general value of self-reflection at work. While our analysis focused on the team nudge, participants reported highly positive effects from the general hourly reflection on the smartwatch and the daily dairy on the web application with respect to the perception of their team, their work, and their work-life balance. At the same time, too much reflection can be cumbersome and time-consuming, which is why we believe that the minimal design of the team nudge has a big potential. In general, though, finding the right balance between effort and value is essential for a long-term effect, and future studies are needed to examine this trade-off for promoting a long-lasting impact.

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