Identifying Temporal Rhythms using Email Traces

Completed Research

Joschka A. Hüllmann
University of Münster, Germany
huellmann@uni-muenster.de

Simone Krebber
University of Münster, Germany
s_kreb01@uni-muenster.de

Abstract

In the past, work was governed by the natural rhythms of the physical world, but organizations increasingly distribute their work along the temporal dimension. This leads to varying temporal rhythms, which depict recurring patterns of activity in time, among workers, enabled by communication and collaboration technologies. The routine use of technology generates activity log data called digital traces, which promise an opportunity for a data-driven inquiry into temporal rhythms. While research using digital traces is scarce, various vendors claim to identify daily working hours based on email traces. Our study explores the use of email traces for an inquiry into daily and weekly temporal rhythms by triangulating quantitative results with interviews. Contrary to the vendors' claims, our results show that the usefulness of email traces is limited to identifying aggregated and stable temporal rhythms.

Keywords

Temporal rhythms, digital traces, email, working hours

Time and the Changing Nature of Work

"Organizations exist in time and space."

(Lee and Liebenau 1999, p. 1035)

The academic literature on organizational time posits that work must be seen in a temporal context. Since work practices are influenced by time and individuals enact temporal structures within the organization (Lee & Liebenau, 1999; O'Leary et al., 2014), time is a relevant factor for studies on work (O'Leary et al. 2014). This topic is gaining momentum since the distribution of work increases along the temporal dimension (Nicolini, 2007), visible in varying temporal rhythms of workers. Temporal Rhythms are recurring patterns of activity in time such as rest periods, meetings, or start and end times of work. In the past, work was governed by the natural rhythms of the physical world (Barley & Kunda, 2001), but in times of the changing nature of work, the spanning of temporal boundaries by technological means increases. Examples include part time work, temporary contingent work (Kalleberg & Epstein, 2001), or global organizations operating in different time zones (Ancona et al., 2001).

Spanning temporal boundaries requires links between asynchronous workers. McGrath (1990) calls establishing these links "time bridging", which is the coordination of work activities running in different temporal rhythms. The bridging of differing temporal rhythms among knowledge workers is facilitated by communication and collaboration technologies. It requires coordination, synchronicity, and temporal alignment for effective collaboration (Reddy et al., 2006). Facilitating this coordination and alignment presupposes explicit management, control, and scheduling (Fenwick & Tausig, 2001; Kalleberg & Epstein, 2001). At the same time, managers have less control over the working times of their employees and must maintain awareness of their workers' temporal rhythms (Carmel et al., 2010; O'Leary et al., 2014; Saunders et al., 2004). This is exacerbated by an increase in project-based forms of organizing (Hüllmann & Kroll, 2018), which does not follow an orderly schedule, but instead is socially organized with routines and interruptions (Nandhakumar & Jones, 2001). If time is not managed effectively, discoordination will lead to temporal conflicts and performance losses (Reddy et al., 2006).

The first step to effectively manage and schedule time is to explore and understand the temporal rhythms in play within the organization. Previous studies investigate how daily temporal rhythms are structured by means of qualitative analyses such as observations, videotapes, diaries, or interviews (e.g. Nandhakumar and Jones 2001; Poels et al. 2017). Recent surveys show that 9-5 workdays are still the most popular in the US (Beers, 2000), the United Nations (International Labour Organization, 2011), and Germany (Backhaus et al., 2018; Wöhrmann et al., 2016) with a typical working week from Monday to Friday (Anttila & Oinas, 2018). However, Barley and Kunda (2001) note that it is difficult to observe workers' actions in a dispersed workplace, e.g. temporal dispersion, concurrently. To address this, Barley and Kunda (2001) suggest the analysis of digital traces. Digital traces depict activity log data generated through the routine use of technology. Although the analysis of digital traces does not capture the full context of work, widespread adoption of technology for bridging temporal rhythms provides opportunities to identify and understand temporal structures within knowledge work (Østerlund et al., 2020). As of now, research on temporal rhythms with digital traces is scarce, while various vendors, e.g. Microsoft, already claim to identify temporal rhythms in digital traces from Office 365 data for the purpose of time management. The decision of the European Court of Justice in 2019, that employers are responsible for documenting the working hours of their employees, may increase the demand for such software. As email is a crucial tool for knowledge workers (Nandhakumar & Jones, 2001), email traces present a promising starting point for identifying temporal rhythms, and have been used by tools such as Microsoft Workplace Analytics (Microsoft, 2020). In our study we aim to validate the approach of using email traces for research into temporal rhythms by triangulating the quantitative results with findings from interviews. We contribute an explorative account into daily and weekly temporal rhythms. Contrary to the vendors' claims, our results show that the usefulness of email traces is limited to identifying aggregated and stable temporal rhythms.

On Temporal Rhythms and Digital Traces

According to Lee and Liebenau (1999), time is mostly conceptualized in two diametric ways, namely objective (or clock) time and subjective (or social) time. The objective concept of time sees time as a continuously running clock, a natural phenomenon that is unaffected by humans (Lee & Liebenau, 1999). Conversely, the subjective concept of time understands it as temporal structures (social structures related to time) that are shaped by humans, and govern human agency (Orlikowski & Yates, 2002). These temporal structures are embedded in the organization, and manifest themselves in temporal rhythms that describe recurring patterns of activity in time. The patterns of activity range from daily micro events of individuals and groups such as starting and ending a workday, taking breaks, performing tasks, or holding meetings to meso- and macro patterns of activity such as the regular occurrence of weekend work, monthly balance of accounts or the annual Christmas party of the entire organization. Hence, temporal rhythms are a multilevel phenomenon, which is observable on an individual, organizational, or societal level, and for daily, weekly, yearly, or other intervals (Ancona & Chong, 1992). The rhythms are malleable and vary over time (Jackson et al., 2011; Tyler & Tang, 2003).

We distinguish previous studies on temporal rhythms based on their methodical approach into two groups: (1) established methods such as interviews, observations, and surveys, and (2) digital traces. The analysis of digital traces for the purpose of inquiring temporal rhythms has seen an increased interest since the year 2000 (see Table 1), because the bridging of different temporal rhythms is enabled by communication and collaboration technologies. Digital traces are activity log data on a fine-granular level, typically a by-product of using communication and collaboration tools, heterogeneous in nature, e.g. structured and unstructured. Coming in high variety and volumes, this data can include single computer actions, which results in a detailed depiction of employees' activities in time (Hüllmann, 2019; Østerlund et al., 2020).

Poels et al. (2017) explore the temporal rhythms of medical staff using meeting tapes, diaries, and semi-structured interviews and identify different themes to understand rhythms. Nandhakumar and Jones (2001) use participant observation and meeting minutes to understand how time of a project team is socially organized rather than management-imposed. Tyler and Tang (2003) investigate email rhythms and responsiveness of employees by conducting interviews and observations. Perer et al. (2006) analyze email archives. The latter two studies reveal a dyadic aspect of temporal rhythms, i.e. the rhythms are negotiated and aligned based on the communication partner. National surveys show that most people work 40 hours a week from Monday to Friday and that the 9-5 daily rhythm is still dominant, despite losing popularity (Anttila & Oinas, 2018; Backhaus et al., 2018; Beers, 2000; International Labour Organization, 2011; Wöhrmann et al., 2016). Studies based on digital traces include Begole et al. (2002), who use activity log data from computers and identify different rhythms according to the day of the week or the location. Wang et al. (2012) analyze timestamps of downloads to inquire about the rhythms of academics, while Claes et al. (2018) examine timestamps of commits to identify rhythms of programmers. Both studies on timestamps identify start and end of the workday and reduced activity at lunch time. They observed less activity on weekends.

Study	Who?	What?	Method
Poels, Tucker & Kielema 2017	Medical staff	Temporal rhythms	Videotapes, diaries, semi-structured interviews
Reddy, Dourish & Pratt 2006	Medical staff	Temporality	Interviews, observations, policies, meeting notes, procedures
Nandhakumar & Jones 2001	Project team	Understand the temporal structure	Participant observation, meeting minutes
Tyler and Tang 2003	Sun & HP employees	Email rhythms and responsiveness	Interviews and observations
Begole et al. 2002	20 users	Daily rhythms	Activity logs from computers
Wang et al. 2012	Academics	Test 9-5 hypothesis	Timestamps of downloads
Claes et al. 2018	Software developers	Estimate working time of programmers	Timestamps of commits
Perer et al. 2006	Ben Shneiderman's emails	Rhythms of relationships and collaboration	Visualizations and clustering

Table 1 – Related Work. The shading of rows indicates that these studies are based on digital traces.

On the one hand, the studies based on established means aim at grounded research in situ, interpreting documents and transcripts to produce insights for theory building. Their approach faces the challenge that technology enables employees to bridge boundaries, e.g. in global teams. Such work constellations across boundaries render it difficult to observe people in temporal context at the same time over extended periods using methods such as interviews, documents, and surveys (Barley & Kunda, 2001). Another challenge is that the individual perception of time varies according to the environmental factors experienced by an individual (Orlikowski & Yates, 2002). On the other hand, digital traces seem to promise objectivity. The studies we list here provide descriptive measures of temporal rhythms. They look at aggregated activity as well as meta data and perform statistical analysis. Despite the promise of objectivity, digital traces do not offer any context for interpretation, and suffer from impression management (Hüllmann, 2019). Furthermore, it remains unclear how accurately digital trace data estimates patterns of activity of individual workers, which is a prerequisite for subsequent analyses into temporal rhythms. It is uncertain, how trace data such as email messages represent the actual work actions and practices being performed. Research combining the established methods and digital trace analysis in a complementary manner is lacking. It may produce new ways to elucidate the phenomenon of temporal rhythms, as suggested by Østerlund et al. (2020). In this study, we triangulate email trace data with interview data to validate digital traces as an estimate of patterns of activity in time. For this validation, we explore daily (start and end of workday, breaks) and weekly working rhythms (weekend work), and question if the combination of both methods yields novel and robust insights.

Methods

We conduct an explorative study with a small sample size to examine each participant's temporal rhythms in detail through extensive interviews, and (partly manual) analysis of email traces. We quantitatively scrutinize email data of employees using visualizations and other descriptive measures. Then, we conduct semi-structured interviews, using the visualizations as interview prompts for each participant. Participants are two academics and two product managers from a data-analytics-as-a-service startup, enabling us to get insights into two different work contexts. The groups were selected, because both are knowledge workers with considerable temporal autonomy. The startup participants use technology flexibly and show a high diversity in tasks, with predictable and recurring tasks being seldom. The academic participants work independently and exert control over their daily and weekly temporal structuring. Additionally, we analyzed the data of one of the authors of this paper to get a baseline understanding of how the data can be interpreted and what meaning can be extracted from the data (equivalent to Begole et al. 2002; Perer et al. 2006). For all participants email is the primary means of electronic communication. Despite organizational policies on working hours and presence times, all participants enjoy temporal flexibility in terms of home and mobile office, remote work, and working hours. Table 2 describes our sample.

	Group academics (n = 2)	**Group start-up (n = 2)**
Age	21-40	21-40
Gender	Male, female	Male, male
Policies: - daily hours - weekly hours	8 hours Monday-Friday, 40 hours/week	8 hours Monday-Friday, 40 hours/week
Hardware	Laptop, mobile phone	Laptop, mobile phone
Communication technology	Email	Email
Tasks	Research, Teaching, Administration	Product and business development, meetings and management of clients, projects, and staff
Total Emails	1,700 and 5,000	2,000 and 2,400
Observation period in years	2017–2019	2017–2018

Table 2 – Sample Description.

Because incoming activity does not require an active user, we only consider “outgoing actions” for the quantitative analysis. For example, we do not consider receiving an email for the analysis, whereas sending an email or a meeting invitation is considered. We explore the regularity of the events daily start time, end time, breaks, and weekend work (see also Begole et al. 2002; Claes et al. 2018; Wang et al. 2012), because they are the “frame” in which all the work is carried out and they determine when the work is performed (Kalleberg & Epstein, 2001), also revealing if the participants follow the 9-5 daily work rhythm.

We calculate the start of the workday per person by taking the median of all first messages of the day over the whole period. The underlying premise is that the first action of the day marks the start of the workday. Given multiple outliers, the median was chosen over the mean. The end of the workday is determined in the same way, by taking the median of all last messages of the day. We determine the meal break by calculating the outliers from the differences between subsequent bins of the histogram of actions per 15-minute interval—outliers, because we only include relevant frequency differences (see visual explanation in Figure 1). Outliers are detected by calculating the standardized values and checking whether the resulting value lies within the interval spanned by the outlier thresholds of 2 and -2 (identified by manual tuning). The resulting outlier differences are ordered chronologically. In this result list, we label each negative difference followed by one positive difference as a break. The email traces are extracted from Outlook, Thunderbird, and Microsoft Graph. Instructions and the R code are available online[1].

Given the estimated events, in the following also referred to as working hours, from the quantitative analysis, we discuss the results with the participants during interviews to see if the estimated times are accurate, to identify deviations, and to check if any temporal rhythms are missing. The interviews take around 45 minutes and focus on the individuals’ working behaviors. They ask how people structure their typical workday temporally, addressing the start and end of the workday, as well as breaks and resting times. Participants are asked to evaluate the digital trace analysis results. We investigate the email writing, communication and general working behavior to understand how well traces represent the work being performed. To explore weekly rhythms, we ask questions about weekend work and working times over the course of the week. Information about holidays and periods abroad are gathered at the end of the interviews.

[1] https://wiwi-gitlab.uni-muenster.de/j_huel12/organizational-rhythms-public

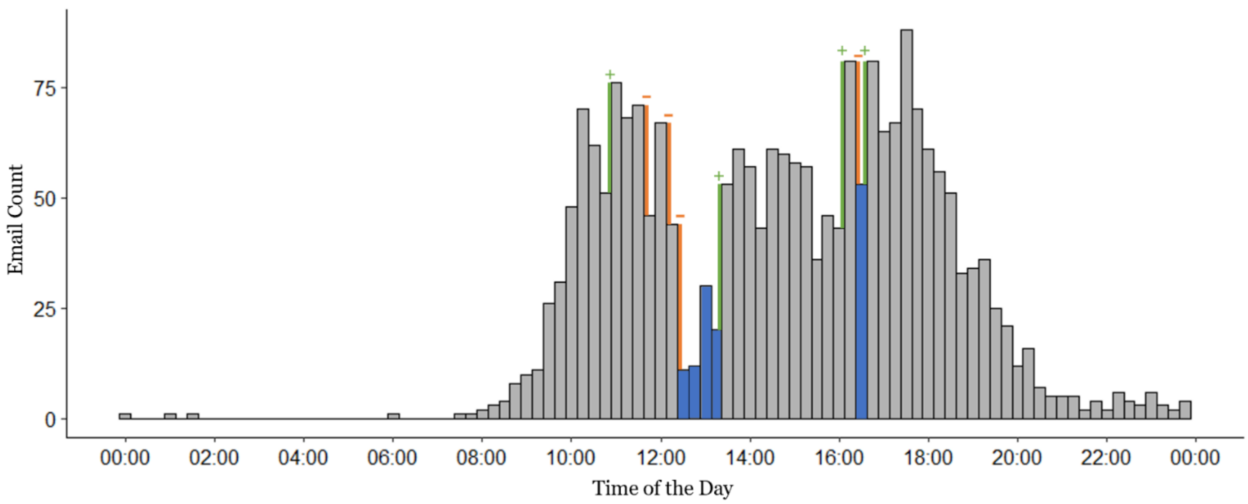

Figure 1 – Break Identification. Green (positive difference) and orange (negative difference) lines indicate the relevant differences (identified using standardized differences and a threshold of 2/-2) between a bin and its successor bin. Blue bins are the breaks identified based on the definition of a significant negative difference followed by a significant positive difference.

Findings

For daily rhythms, we identify start and end of a workday, a regular lunch break as well as regular short resting times. Focusing on weekly rhythms, we recognize that most work is performed on weekdays, with reduced work on the weekend. In the results the startup workers are labelled as persons A and B, the academics are labeled as persons P2 and P3, and the author is labelled as person Z.

Table 3 compares the results of the trace analysis and the interview for each person and is visualized in Figure 2. The fit indicates how accurately the estimations from the email trace analysis match the interviewee responses. It is illustrated by the shading of the background. A fit between interview and trace analysis results regarding start and end of the workday is given if the median (identified in the trace analysis) lies within the stated time interval in the interviews. A fit regarding the meal break is given once 50% of the trace analysis interval overlaps with the interval derived from the interviews. If the two intervals do not overlap with 50% of the trace analysis interval but with at least 15 minutes a light fit is given. For short resting times and the proportion of weekend work, the table shows the results where available.

Person	Start Data	Start Interview	End Data	End Interview	Meal Break Data	Meal Break Interview	Short Resting Times Data	Weekend Work
A	**10:27 am** [-20 min; +15 min]	~ 09:00 am	**06:04 pm** [-23 min; +32 min]	05:00pm – 08:00 pm	12:30 pm – 01:00 pm	12:00 pm – 12:45 pm	–	3.17 %
B	**10:09 am** [-11 min; +7 min]	~ 09:00 am	**06:08 pm** [-21 min; +23 min]	–	12:30 pm – 01:30 pm	12:00 pm – 12:45 pm	04:30 pm – 05:45 pm	0.93 %
Z	**11:34 pm** [-13 min; +53 min]	09:00 am – 10:00 am	**05:30 pm** [-31min; +35 min]	05:00 pm – 06:00 pm	11:45 am – 01:00 pm	12:00 pm – 01:00 pm	02:15 pm – 03:15 pm	6.12 %
P2	**09:33 am** [-17 min; +18 min]	08:00 am – 09:00 am	**04:55 pm** [-32 min; +20 min]	05:00 pm – 06:00 pm	12:30 pm – 02:00 pm	12:00 pm – 01:00 pm	–	2.11 %
P3	**09:46 am** [-8 min; +16 min]	08:00 am – 08:30 am	**04:31 pm** [-15 min; +15 min]	04:30 pm – 06:00 pm	12:00 pm – 01:15 pm	12:00 pm – 01:00 pm	–	2.68 %

Table 3 – Time Intervals. Dark grey shading indicates a fit between interview and traces, middle grey indicates a light fit, and light grey no fit. If no comparison is performed the cells background is left white. Results of the fields holding a "-" could not be retrieved. The minutes specified in the "Start Data" and "End Data" columns indicate the 95% confidence interval of the median (in bold) and span the time intervals in which people start/end their workday typically.

For the **start of the workday**, the trace analysis deviates from the interview by 30 to 90 minutes. It estimates the start times later than the interviewees suggest. The highest difference is visible for person Z, whose start of work interval is estimated 90 minutes later than the interview suggests. The lowest difference is visible for person P2 at 30 minutes later. Person Z commented: "*Most often [I start] between 9am to 10am. Rarely earlier than 9am*". Both groups share a similar level of deviation. The width of the confidence interval in which people start working does not reveal a difference between start-up and academic workers. Except for person Z, academics start their workday earlier than start-up workers.

The estimated **end of the workday** is within the stated time range of the interview for three of five people (Z, P3 and A). For them and for person P2 it is close to the lower limit of the time span they suggested in the interview. The reference value of the interview of person B is missing. In the interview, person B stated the end of his/her workday being "*Not specific. It varies*" without providing a time interval. All interviewees mentioned that the end of the workday is more flexible than the start, depending on what current tasks need to be done. Person A remarked not having a regular time for ending work: "*Not really, varies greatly depending on workload and meeting schedule. Usually between 5pm and 8pm*". The academics (besides person Z) start their workday earlier, and subsequently they end their workday earlier than the startup workers do. Looking at the width of the confidence interval in which they regularly end their workday no difference between start-up and academic workers is observed.

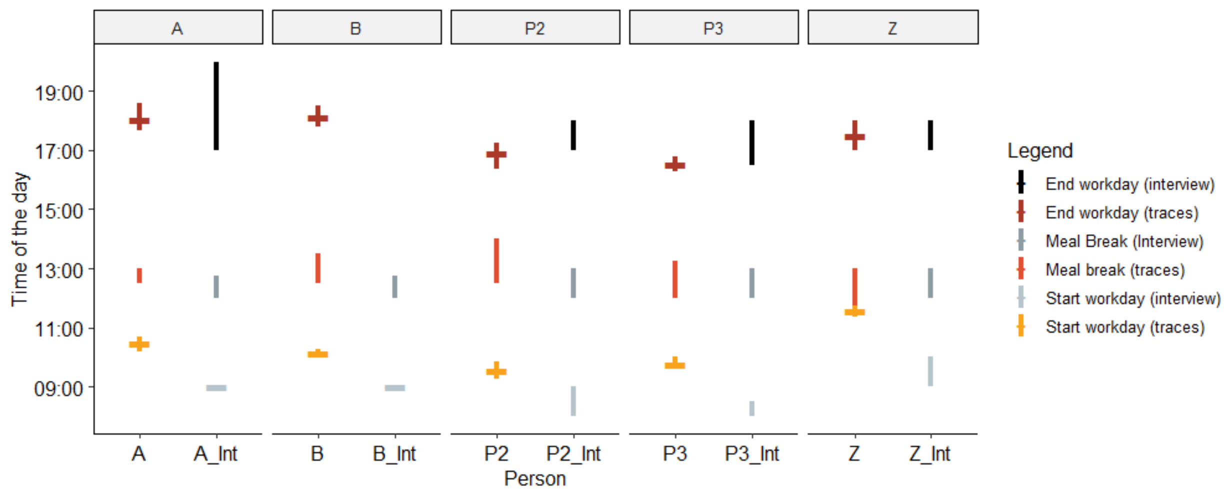

Figure 2 – Regular Working Times. A horizontal line indicates a point in time, whereas a vertical line constitutes a time interval in which the respective event usually happens. On the x-axis the results of the trace analysis and the interview results are grouped by person.

Each participants' activity shows a clear **break in the middle of the day**. For person P2 and both startup workers the reduced activity starts around 12.30pm. Comparing the results of the three workers, Figure 2 shows the shortest break (30 min.) for person A, followed by person B (1 hour). Person A mentioned: "*[Meal break] is more or less exactly at noon (12pm) and lasts for 30-45 minutes*". For person P2 the time span of the break, as seen in the graphic, is the longest (1.5 hours). This doesn't mean that s/he is taking longer breaks but could mean that s/he has very heterogenous break patterns throughout the observation period. The reduced activity of persons Z and P3 start earliest (11.45am and 12.00pm) and last for one hour +/- 15min. The results of the trace analysis suggest that there is no difference between startup workers and academic workers.

We detect **short breaks** at the same time of a day taken regularly. Figure 3 shows an additional break in the afternoon for persons Z and B. This contrasts with the answer of interviewee person B, who mentioned the schedule for short breaks is "*not specific*". Person Z states that at "*3pm/4pm a coffee break*" takes place regularly, which is taking five to thirty minutes. The result of the data analysis however reveals a break for person Z which takes up to 1 hour. Person P2 highlights in his/her interview that s/he does take shorter breaks in the afternoon but not regularly. According to person A the short breaks are not planned and rather spontaneous.

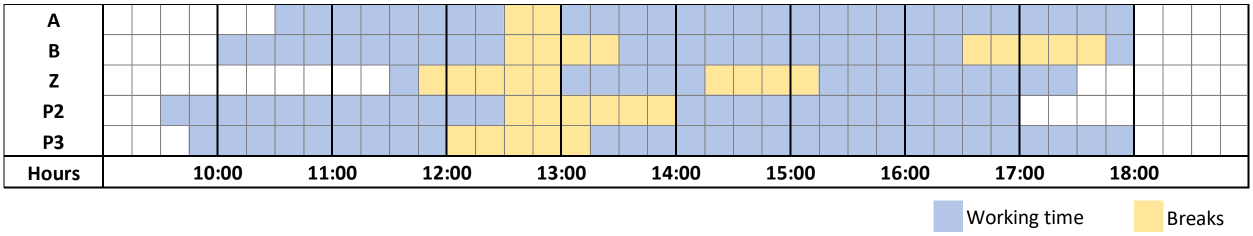

Figure 3 – Regular Working Times Over the Day.

Activity on weekends is reduced compared to Monday through Friday. With a proportion of 6% of the total number of sent emails person Z has the highest weekend workload. In comparison, persons A, B, P2 and P3 have a lower workload on the weekend. Persons A and P3 sent 3% of their total emails on the weekend each, while person P2 sent 2% of his/her emails on the weekend and person B has the lowest workload on the weekend with 1% of his/her total sent emails. Person B underpins this observation with his/her statement of working "*sometimes but rather seldom*" on weekends. Person P3 highlights that "*weekend stays weekend*" and that s/he is strictly separating work from private life.

Both groups generally do not work on weekends, and we do not find temporal differences on when the workday starts. Conversely, the academic participants take longer meal breaks than the startup participants, and the end of the workday is more flexible for the latter.

Discussion

In this study, we have explored daily and weekly rhythms of knowledge workers through email trace analysis and interviews. The results show that the workers in our sample have defined hours for start, end, and lunch break in a workday, with two workers mentioning coffee breaks. They perform their work during the week from Monday to Friday, with weekend work being the exception. This supports other studies that find clear start, end, and break times, with less activity on the weekend (Perer et al., 2006; Wang et al., 2012). Our findings suggest that the sample conforms to the dominant regular working hours of the developed countries of the United Nations (Anttila & Oinas, 2018; Backhaus et al., 2018; Beers, 2000; International Labour Organization, 2011; Wöhrmann et al., 2016), where work occurs between 7am and 7pm, with a lunch break and mostly 5 days a week. The participants' use of their temporal flexibility remains an exception, as they mostly adhere to their default working hours policy.

Nandhakumar and Jones (2001) state that, despite the fixed start, end, and break times, the temporal structuring with regards to tasks and task schedule is organized through social routines and interruptions, but not preplanned. In our interviews, person P2 reported a similar experience: "*Usually I don't take short breaks, except someone interrupts me for a conversation*". Our findings show that the rhythms of the workers are aligned, with overlapping breaks and intervals for starting and ending work. This indicates that the rhythms and temporal schedule among the interviewed workers are synchronized (Reddy et al., 2006). Part time work, shift work, and other non-regular working time situations may yield more complex schedules and different rhythms per person (e.g. Begole et al. 2002). Other studies with a qualitative approach identify different rhythms and are completely detached from the hours of the day, meaning that they do not consider the hours of the day, but only the sequence and duration of activities (e.g. Poels et al. 2017). Contrary, our interviews and analysis assess the hours of the day, when work is performed. For this, we distinguish between work and non-work time intervals of the day. Conversely, other studies identify different types of rhythms and temporal structures within the intra-day based on rich longitudinal observations that we are lacking (e.g. Poels et al. 2017).

Our sample reveals discrepancies between the results of the trace analysis and the statements in the individual interviews. In the interviews, persons A and B try to come up with explanations for the differences observed. Person B remarks that s/he might "*need a certain setup time: coffee, chit chat with colleagues, but also some regular meetings*". This explains why the start of the workday is estimated by the trace analysis to be at a later point in the morning than stated by the person. Person A underpins the explanation of person B. S/he notes that a misleading average is provided by the data due to late email timestamps resulting from meetings in the morning before s/he is looking into the emails. The same applies to the end of the workday, where biased estimations occur because of meetings in the late afternoon.

Looking at the discrepancies, the end of the workday is estimated with a better fit than the start of the workday, despite interviewees disclosing that they always start at the same time, but may end work at different times. Likewise, Begole et al. (2002) argue that start times can be estimated more accurately than end times, in cases where people start their workday with email (see also Nandhakumar & Jones, 2001). However, the participants in our study neither start nor end their day with email necessarily, as pointed out in the interviews, increasing the noise and rendering estimation of start and end times based on email traces more difficult.

Time slots of short resting times can be identified for two people. However, the email traces are agnostic to non-electronic work, so that less activity during the day could indicate that the person works offline as "*pauses of activity are part of the rhythms and not an absence of rhythm*" (Poels et al. 2017). A meal break around noon is identified for all participants. The measure for weekend work is the only one which clearly fits the statements of the interviews. None of the participants perform significant work on the weekend, which is reflected in the results of the trace analysis. Nevertheless, we are only able to identify the proportion of emails sent on the weekend related to the total emails sent. The question when work on the weekend appears and which patterns people follow—for example every weekend a few emails or one weekend with a whole day of emails—remains open.

The discrepancies between interviews and digital trace estimation indicate that email traces alone do not yield reliable insights on the question in which time intervals people are working and what rhythmic patterns they follow. In particular, an accurate estimation for the working hours of single days is infeasible due to the low number of emails per person per day in our sample (cf. Table 2). Instead, we could only identify stable patterns in aggregated data by sticking to email traces. With finer-grained or more digital traces available, detailed inquiries into the temporal rhythms of single days is feasible (e.g. Begole et al. 2002). Despite that, our sample shows that the accuracy of estimating working hours based on email traces depends on the individual working styles (degree of flexibility), the usage of technology during work and the email writing behavior. This has previously been mentioned by Nandhakumar and Jones (2001), who found that the pace of work varies among people, tasks, location and time. While digital traces are generally suited to inquire about temporal rhythms, different types of temporal structures can be identified with varying difficulty, depending on the extent of digital traces being available for analysis. Besides, the analysis of digital traces does not provide an objective account of how work is performed. Instead, email traces are subject to impression management, e.g. scheduled emails (Hüllmann, 2019; Østerlund et al., 2020).

Managerial Implications and Future Work

Technology use enables working across temporal and spatial boundaries but at the same time it introduces more complexity into the alignment and coordination of temporal rhythms (McGrath, 1990). The analysis of digital traces generated from routine technology use, may help to address the increasing complexity and provide valuable insights into the temporal rhythms of workers. Any computational analysis based on digital traces can be automated and visualized in the form of management dashboards. Vendors are already promoting such analysis dashboards based on digital traces. For example, Microsoft Workplace Analytics shows after hours work, hours spent on email and suggests how such data should be interpreted (Microsoft, 2020). Even though email is a crucial tool for knowledge work (persons P2 and P3; and Nandhakumar & Jones, 2001), we conclude from our analysis that sent emails being the *only* measure to derive working hours is not accurate enough. In our sample, it does not show the employees' real working times per day. Instead, finer-grained or more digital traces are required.

Overcoming the stated limitations, the analysis of digital traces does enable managers to get indicators of the temporal rhythms of their workers for the purpose of explicit management and coordination. Such indicators can be used to improve work effectiveness, because increasing awareness of the worker's rhythmic patterns leads to more precise scheduling and workforce planning as well as synchronicity in teams (Bergiel et al., 2008; Fenwick & Tausig, 2001; Kalleberg & Epstein, 2001; McGrath, 1990). Another potential indicator is that of overwork and compliance with existing time regulations. In 2019, the European Court of Justice (ECJ) decided that employers are responsible for documenting the working hours of its employees, to ensure legal compliance with policies such as the minimum rest period, or maximum daily and weekly working hours (PR No. 61/19, judgement in case C-55/18). Despite the opportunities, managers need to be cautious while analyzing the digital traces of their employees. Impression management and concerns of workplace surveillance and privacy influence employee satisfaction and perceptions on productivity. Monitoring and interpretation of digital traces should go hand in hand with transparency and other means of data collection, such as interviews or observations.

Due to the exploratory nature of our study, the sample size is small, and the generalizability limited. We expect it to serve as a starting point for further investigations into the triangulation of digital traces and qualitative data for inquiring temporal rhythms. The triangulation enables seeing the phenomenon from different perspectives (Østerlund et al., 2020), strengthening the reliability of the findings. We see prospects for this approach, in case of a boundaryless workplace such as geographically or temporally dispersed locations, rendering the observation of temporal structures difficult. A limitation of digital traces is that their analysis is agnostic to non-electronic activities and as such always underestimates the activity and work of employees (Begole et al., 2002). In our study, we were unable to infer temporal structures for single days, because the traces were not fine-grained enough. Instead, we only analyzed aggregate patterns. Prior to the analysis, we removed all holidays and standardized the time zones, because they biased the estimation. Future work should collect more data in breadth and depth, i.e. increase the sample size and use data beyond sent emails, e.g. windows event logs such as login or logout events. Since temporal rhythms are a multilevel phenomenon, further attention should be paid to interdependencies of individuals, groups, and organizational structures, including individual preferences, social norms, and expected work behavior. Further work should look at social influence and dyadic aspects, relating social networks to temporal rhythms (cf. Perer et al. 2006). Email trace data can be analyzed with a natural language processing approach to infer meta data about the projects and tasks being worked on. When and how work on the weekend is triggered and which factors are responsible for it requires further investigation. Despite the open questions, we expect the analysis of digital traces in combination with other means of data collection to be a worthwhile undertaking for an inquiry into the temporal rhythms of the boundaryless workplace. The triangulation enriches the quality and reliability of insights that can be gathered from empirical data, especially in flexible and boundaryless workplaces.

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