Investigating Technostress *in situ*: Understanding the Day and the Life of a Knowledge Worker Using Heart Rate Variability

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Abstract

The proliferation of information and communication technology (ICT) throughout workplace and home life is thought to increase feelings of being overloaded, drained, and/or burned out. This phenomenon is termed "technostress." In this relatively new line of research, scholars have employed predominantly questionnaire surveys and experiments to investigate the phenomenon. This paper argues for an interpretive, theory building approach for studying technostress, motivated by two shortcomings of these data collection techniques: questionnaire surveys rely on potentially imperfect participant recall, while experiments cannot find root causes of technostress during the course of a normal work day. Linking periods of bodily-experienced stress measured by heart rate variability with qualitative data enables an interpretive, theory building approach that allows for a richer understanding of whether and how ICT contributes to stress.

1. Introduction

Due to the incorporation of ICT into every aspect of modern life, workplaces and working conditions have undergone profound changes. Individuals rely to a large extent on ICT. However, ICT also evokes negatively connoted opportunities. By obliterating space and time as formerly decelerating mediators, ICT redefines the boundaries of teams, organizations, and home life versus work. Thereby, it has the potential to shorten response times physically but also in the sense of social expectations.

Scholars convincingly argue for conceiving of the proliferation of ICT throughout workplace and home life as a double-edged sword. Increased exposure of workers to ICT is thought to contribute to stress levels, thereby negatively affecting workers' quality of life and even their health. This ICT-induced phenomenon is termed "technostress". It is defined as "any negative impact on attitudes, thought, behaviors, or body physiology that is caused either directly or indirectly by technology" [21, p. 5]. The concept of technostress in the literature covers a wide array of stressors that potentially result in increased strain on a worker: increased workload [10], constant pressure to adapt to new technologies [2], increased complexity of new devices [2], technology breakdown [18], etc.

Research on technostress relies primarily on two techniques. One employs questionnaires that collect participants' recall and evaluation of stressful events. A second simulates what are hypothesized to be stressful situations and experimentally examines the degree to which they cause stress. Both techniques have limitations in the degree to which they capture the contextual contingencies of a stressful event: the first is limited because it relies on participant recall, while the simulated environment of the second may not reflect real life. Additionally, both techniques are suitable for *testing* whether a particular phenomenon causes stress, but neither technique is suitable for *finding* what influences stress in the workplace. This is particularly important given the relative newness of technostress as a research topic. Given the current thrust in IS research to move beyond a simple cognitive view of human experience to encompass the material, bodily experience, and moods of individuals in both empirical research (e.g. neuro IS) and theory (e.g., practice theory, socio-materiality), the existing technostress research presents empirical and theoretical gaps.

In this paper we present a set of qualitative techniques for using heart rate variability, which is a measure of bodily experienced stress, to gain a better understanding of how specific ICT-artifacts and events affect stress levels in the daily work of participants in modern workplaces. Some of our assumptions about technostress are presented next, which highlight the limitations of the current methods in understanding stress as a contextual phenomenon. We then evaluate methods that allow for measuring bodily experienced stress over the course of a workday (in situ). The main section of the paper discusses how to complement heart rate data using other data collection techniques. Finally, we discuss the strengths and weaknesses of the techniques and conclude by proposing an interpretive theory building approach using multiple methods.

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2. Stress in the modern workplace

The proliferation of ICT into every aspect of modern life is undisputed. Its incorporation into daily practices has led to enormous shifts in working conditions. The US National Institute for Occupational Safety and Health (NIOSH) observes that the "revolutionary changes in the organization of work have far outpaced our understanding for work life quality and safety and health on the job." [13, p. 1].The increasing reliance on ICT supports changes in individual job characteristics and tasks as well as leading to other, more flexible, work arrangements. These changes take their form in trends like process reengineering, organizational restructuring, and flexible staffing [7, p. 14].

However, changes in working practices are seen as a double-edged sword that may yield positive outcomes but may simultaneously create strain due to work intensification [6, p. 106]. "The final outcome seems to be very much dependent on the context into which practices are introduced" and the ways they are implemented [7, p. 32]..

2.1 Technostress in IS literature

The IS literature is largely oblivious to the phenomenon of technostress. Surveys and experiments represent the dominant data collection techniques of the rather few studies. Survey research has been used when testing broader impacts of technology on workers' stress levels. As examples, Wang et al. [20] researched the effect of different organizational cultures on the level of technostress by means of a survey, and Ragu-Nathan et al. [16] examined the effect of technostress on organizational life (e.g. job satisfaction, commitment).

Experimental research has been used to test more narrow direct impacts on stress. Riedl et al. [18] conducted an experiment in which participants were confronted with a simulated online merchant whose web site crashed during their interaction and measured its effect on users' levels of cortisol. In a natural experiment, Mark et al. [12] had volunteers take several days off from email and compared their heart rate variability. Other experiments have examined whether stress arises from an increasing speed or difficulty while playing a video game [10] and a memory test involving the recognition of words to investigate mental stress during computer work [8].

The relatively few articles that have been published about technostress share similar assumptions about ICT-related stressors. Some of the supposed root causes frequently mentioned are: (1) an increasing pace of work and/or changes in work practices, (2) the technology itself not working as expected and/or the complexity of working with it, and (3) increasing interruptions due to multiple communication channels.

Given this relatively small set of assumptions, questionnaire surveys and experiments were obvious choices as methodologies for studying technostress. Certainly, these positivistic approaches can confirm or refute the contention that such things do indeed cause stress, yet their shortcomings have left unanswered questions about the root causes of technostress.

2.2 Weaknesses of current approaches

The weaknesses of these methodologies come from two different directions. First, individuals at work may be generally unable to comment about what their stress level was while performing a particular task. Once the task is finished, the memory of the stress it caused may pass quickly. Even during a stressful event, a person may be motivated to "act cool" and/or feel that they are experiencing positive stress (i.e., eustress or flow [10]).

In a survey, the researchers carefully craft the questionnaire in order to statistically prove correlations between assumed stressors and strain. In addition to the problem that participants need to accurately recall their experiences [3], this technique masks out the sometimes paradoxical experiences of ICT: the same user might experience ICT as simultaneously relieving and stressful. In addition, questionnaires rarely offer the possibility to differentiate between different technologies, referring to 'ICT' or 'technologies we use' as stand-ins for a portfolio of ICT-tools or functionalities (e.g. [2, 16, 19].

The second general weakness is in experimental studies. In the simulated environment of a controlled experiment, the rich context of a workplace is lost and the experimental treatment is brought to the forefront [3], masking away the conscious feelings of what caused the stress – in essence, a successful experimenter knows that their treatment caused stress, but doesn't know *why*.

Overall, the questionnaire and experimental approaches to studying technostress narrow the field of study, limiting the research stream to confirming that a relatively small set of events leads to stress in relatively few work contexts. Given the newness of technostress as a phenomenon of interest, there is a need for theory building methodologies that can identify stressors more broadly. Without these, the technostress field runs the risk of empirical incrementalism [3].

2.3 Stress as a contextual phenomenon

In a work context, ICT are an array of tools that workers use to accomplish tasks, that is, they select and/or are prompted to use an ICT when the context suits. Taking the perspective that ICT are tools in use, one would expect a worker to not be particularly conscious of their use unless and until their context dictates that the technology as a tool has broken (cf., [15]). For example, one might be preparing a report for submission. While things are going smoothly, the tool one uses is engaged in a non-reflective fashion, and the use of the tool does not cause stress; rather, the context of work might cause stress – one is expected to work at top speed in order to meet the deadline. In essence, we can assume that in this context, the deadline causes the stress, not the technology.

When the technology suddenly breaks down, for example when Word suddenly crashes and corrupts the report file, this breakdown becomes an obstacle in the way of achieving one's goal. In this case, the malfunctioning equipment comes to the forefront – one must first deal with the breakdown in the equipment before the goal can be accomplished.

We suggest viewing stress as a multi-dimensional phenomenon (e.g., [14]). The effect of any single stressor is mitigated by factors such as context, personality, or coping behavior. Thus, technostress needs to be viewed in context – computer breakdowns are only stressors when one's context dictates it, and researchers therefore must understand the underlying contextual causes of technostress before being able to give advice. We also argue the need for a relatively fine-grained approach for examining technostress in context.

Such an approach should combine physiological, conscious, and contextual capture of evidence: (1) contextual data should be captured in routine work situations (in situ), (2) data about stress levels should be captured over an extended period of time in order to capture the transformation of an individual from being relaxed and engaged to being under stress, and (3) data should be collected across a range of individuals and organizational units. We developed four evaluation criteria for judging the appropriateness of theory-building research techniques for studying technostress.

First, the technique should measure both stress as perceived by the participants as well as their bodily experienced stress. If bodily experienced stress is measured, a researcher is able to differentiate between whether an event "causes stress" versus an event that is "stressful," even though the participant him/herself may not be able to differentiate between the two. For example, a person might think of a phone call in which his/her boss gives them a new assignment as being stressful because it caused their workload to increase. However, a measure of bodily experienced stress might show that their stress level was actually normal during the phone call, but increased in the time period after – indicating that the phone call caused stress.

Second, the technique should be able to differentiate at the event-level. Thus, techniques that rely on participant recall of their day or general workplace stress via questionnaires would not reveal enough about the role of ICT in causing stress for the purpose of developing theory. In addition, the technique should be able to measure changes in stress over the course of a workday.

Third, the technique should allow studying of stress as it is experienced in situ. This means that the researcher must be able to obtain rich contextual data from the participant and/or by scanning their environment.

Fourth, instruments for measuring stress should be unobtrusive – the participant should experience their workplace naturally during the course of measurement. The participant should also be able to experience their day normally, without being shadowed by an investigator or having to arduously log individual events in a diary.

The remainder of this paper investigates and evaluates qualitative methods for obtaining participant-provided contextual information that complement a quantitative measure of bodily experienced stress. As Cicourel has reminded us, literature on research methods typically leaves out the mundane details of how to do it in practice [4]. Many of those details will be provided here.

3. Studying stress physiologically

We noted earlier that one limitation of a questionnaire is that is relies on participant recall. Fortunately, the body's actual response to stress can also be measured. In this section, we will discuss a number of issues surrounding the measurement and analysis of data about bodily experienced stress. These include: equipment required, how to instruct and guide participants to ensure good measurements, and how to analyze the data. In our discussion we will note the weaknesses that led us to refine the technique.

3.1 Established techniques of measurement

Two physiological reactions to stress are well-established and have been successfully used in research: cortisol levels and heart rate. Regarding the former, changes in the level of salivary cortisol can be measured using a cheek swab to confirm whether a specific experimental treatment led participants to experience stress [18]. However, salivary cortisol is limited in that it rises and falls slowly over time and is therefore typically measured about 30 minutes after the supposed stressful incident occurred [18, 10]. In addition, it varies over the course of a woman's menstrual cycle, meaning women are normally excluded from such studies. Due to these limitations and the obtrusiveness of taking a saliva sample after each potential stress event, this technique is not easy to employ for investigating a full work-day in-situ.

Stress levels are also bodily reflected in one's heart rate, which can be constantly measured over the course of a day. When one is under stress, the heart rate typically rises, but, more importantly, the variability of the heart rate diminishes. This occurs because one's sympathetic nervous system engages the "fight or flight" reflex and counteracts the parasympathetic nervous system. Thus, decreases in heart rate variability (HRV) indicate increased stress levels. HRV has been employed as a means for confirming that particular experimental treatments caused stress [10, 9, 12]. When compared with cortisol measurements, HRV is better able to measure bodily experienced stress at an event or task level because such stress is reflected immediately in the measure.

HRV is measured by comparing the amount of time between heart pulses. The best means of measuring heart pulses is using an electrocardiogram (ECG), which involves the placement of electrodes on a person's chest and abdomen, and can be measured with portable equipment.

3.2 Measuring Heart Rate in situ

Despite its advantages, measuring the heart rate by an ECG comes along with several downsides. First, the apparatus is quite expensive. Yet, more importantly ECG measurements are much more intrusive to the participant. The electrodes attached to the body are likely to obstruct natural behavior and physically constrain the participant's movement. Thus, it is less likely that the participant will 'forget' being part of a study. We believe that heart rate belts are a more promising means of gathering heart rate data, although their accuracy is slightly lower.

In order to capture heart rate data from a participant, one needs to have them wear the belt in a way that it will best capture their data. This means that the belt needs to be across the lower part of the chest, with both electrodes in contact with bare skin. A small film of gel can be used on the belt's electrodes to get better contact. Because the belt needs to be worn under the clothing, participants will normally wish to put the belt on in private. In our context, the researcher and/or assistant usually explained all of this using their own body as an example, being careful not to give the impression that the belt could be worn over the clothes.

The chief difference between the data captured using an ECG and the data captured from a heart rate belt is that a belt only records the R portion of the heart beat, which is the strongest electrical impulse received by the heart. Because an ECG captures the entire wave, researchers can more easily find a misread heart beat in the data – one can look for the other portions of the wave to make sure that the wave was accurately recorded. When an chest-mounted heart rate belt is used, misread beats are only known because they are not plausible – either the beat is too close to or too far from the surrounding beats. From our experience, virtually all misread heart beats are caused by a combination of physical movement of the participants and poor connection of the belt electrodes to the skin. However, relative to the volume of data collected, misread beats are typically very rare when gel is used (less than 1% of beats). The example graphs shown in this paper show the raw data from our belts, with no artifact correction. Artifacts can be seen in Figure 1 at the time the participant has just put on the belt, which are typical.

Inexpensive heart rate belts simply transmit the heart beat data, and the data must be read by another receiver/storage device. When this approach is used, the participant should be aware that they should not put their hand over the belt or cross their arms, which blocks the radio signal. Belts such as the Suunto Memory Belt store the heart rate data internally. Once stored on a device, the information must be extracted and transferred to software that can read the data. Kubios HRV is a commonly used open source application for analyzing heart rate data.

Typical measurements of heart rate variability that are reported in academic articles are the standard deviation of normal to normal intervals (SDNN), root mean square of the normal to normal interval (RMSSD), and percentage of adjacent pairs of normal to normal intervals differing by more than 50 milliseconds (pNN50). Frequency components can also be derived, which represent the extent to which the sympathetic or parasympathetic nervous system has influence on the heart rate: high frequency (HF) and low frequency (LF), as well as their ratio (LF to HF) (e.g., [11, 17, 10, 9]). All of these measurements are strongly age influenced [1], so differences among similar participants (e.g. [9]) and/or differences for single subjects from a baseline (e.g., [10]) are often used to standardize measurements. Broadly speaking, RMSDD is the most commonly reported measure, being especially suited for short-term measurements (less than 8 hours).

In conclusion, using memory belts to measure HRV seems to be the least intrusive technique that still allows researchers to establish a bodily reaction to stressors in situ with a fair amount of reliability at the event level.

4. Managing pure data

Gathering HRV-data over the course of a full work-day results in many data points – a fit person with a resting heart rate averaging 60 beats per minute would have over 28,800 beats in their heart rate graph in an eight hour period (typical full day graphs for our participants have between 30,000 and 40,000). Through a visual analysis of this data, a researcher can identify periods and time-events that were more stressful than others. Yet, considering the task to identify ICT-related stressors in the workplace, the researcher is truly "lost in data". Pure data does not allow one to trace stressors.

Therefore, this section ventures to explore different means to mitigate this limitation. We strive to find means that are least intrusive but allow for triangulating HRV-data with events and time periods in the workday of the participants in order to measure experienced stress in situ at the event level. Bearing this in mind, we employed and evaluated seven means to make sense of the data.

Figure 1 shows a heart rate graph of a person that wore a heart rate belt beginning at 15:26:04 for 13 minutes and 12 seconds. In the graph, the vertical (x) axis indicates the participant's heart rate in beats per minute, while the horizontal (y) axis indicates the time of day. Each point on the graph represents a heartbeat. The timing between the beats is driven almost entirely by one's breathing during the periods of relaxation, and by parasympathetic factors when one exerts oneself and/or is under stress. Through visual inspection, one can observe that the person was quite relaxed during the time between 15:28 and 15:29 because of the broad, sine wave pattern in that portion of the graph. There is a short period of stress right after the belt is put on and another period of stress between 15:35 and 15:36, characterized by a narrower pattern in the graph. However, there is no way to understand the stressor(s) without obtaining further meta-data that puts the graph information in context.

If one was conducting an experiment in a controlled setting in which time periods of relative stress and relaxation should have occurred, one can compute the HRV statistics for those time periods. However, when a participant is working on their own tasks in situ, one must know the beginning and ending points of time periods when the person was under stress, when they were relaxed, and when the person was working normally.

This additional contextual information can be obtained by asking the participant what was happening during specific time periods. Yet, this raises several problems that will be discussed in a later section.

Observation: One way to overcome the potential recall and participant bias problems is to observe the participant over the course of the study period. The participant whose graph is shown in Figure 1 was observed starting after the period when the graph begins (as we noted earlier, participants normally wish to put on the belt in private). This observer noted that the participant began a deep breathing exercise at 15:27 (observers and participants that only record times to the minute are typical, even when told beforehand that the belt reads data to a fraction of a second). At 15:29, an iPod was brought out and prepared for game play, then at 15:31, the participant began playing a smartphone game. This game becomes increasingly more complicated until the player is unable to keep items on the screen from colliding. At 15:36, this participant's game ended.

If this had been an experiment, one would compare the difference between the baseline (relaxed) values of RMSDD with the treatment (stressed) values (e.g., [10]). In this example, the participant has the highest heart rate variability during the deep breathing exercise: RMSDD equals 63.3 during the period from 15:28:00 to 15:29:00. The participant is at their most stressed right before they lose the game: RMSDD equals 25.8 during the period from 15:35:18 to 15:36:18. The RMSDD statistics for the remaining examples will not be shown, but they were all lower in the stress conditions than in the relaxed conditions. The different ages and fitness levels of the participants account for some of the differences in baseline heart rate and HRV when comparing across the graphs.

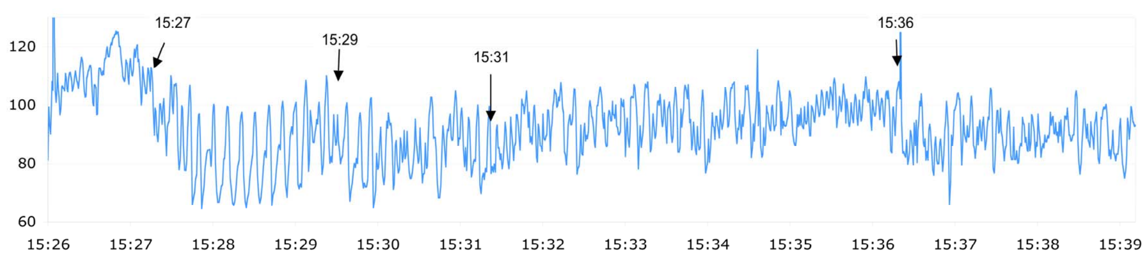

Figure 1. Heart rate graph

Thus, stressed and relaxed conditions should be compared within subjects.

Although direct observation enables the external recording of what the participant experiences over the course of a day, it is limited in that the observer may not completely understand the context in which the participant works. Furthermore, observation is likely to change the behavior of the participant and may bias the results, either by increasing or decreasing stress.

One further disadvantage of a direct observation approach is that the observer may not be able to determine in real time that the participant is doing something that puts them under stress and may not record an observation, either simply due to not understanding the context or because the participant is not exhibiting a behavior that the observer recognizes as important. In this case, the observer observed the play of the game and noted when the particular events occurred, but did not record when the participant made audible cues that the observer later realized showed the participant was under stress; specifically, the observer noted during the debriefing that the participant had audibly gasped because of a near collision about one minute before the end of the game, which appears to be reflected in the graph at about 15:34.

Interviewing/Debriefing: Because it is important to link what has happened in the context with the bodily experienced stress, a researcher should plan on conducting an interview with each participant. In preparation for the interview, the researcher identifies a set of events and/or periods of interest in the heart rate timeline and asks the participant for information about what they were doing during a particular time period, what they were doing before, what event caused them to change tasks, and whether the participant found these to be stressful or not.

With just the heart rate data, however, its granularity means that the researcher is likely to want more details about what happened than the participant can effectively recall. Without any other means of improving recall, the participant can be expected to only be able to give information about the most salient and/or stressful events in the timeline. Additionally, recall may actually be biased by the participant's tendencies to forget why a particular event or task caused them stress once the stress is gone. This makes interviews by themselves a very crude means of putting HRV data in context. But, when combined with memory aiding techniques, they are the most powerful means for understanding stress in situ.

When preparing for and conducting interviews, the researcher would normally ask questions about specific time periods and events shown in the timeline. Referring to Figure 1, the researcher could ask about the times from 15:27-15:29, from 15:29-15:36, and the shift at 15:34, which may also be an important stress-triggering event.

Diary Method: One way to overcome the recall problem is to have the participants keep a diary of what they do throughout the course of the day to as fine a level of detail as possible. In our studies, we asked them particularly to record face to face and phone conversations, and when they read or sent emails.

Once the belt is removed and returned by the participant, the researcher can choose either to look at the heart rate data in the context of the diary, or to do a blind pre-analysis of the heart rate data. When doing a blind analysis, the researcher looks at the heart rate graph for breaks in stress levels. Looking at our second example graph in Figure 2, a researcher can see by visual inspection that the participant was engaging in a relaxing activity at the beginning of the graph, and then switched to a more stressful activity. The researcher could then ask for more details about what happened to cause the change, and the participant could use their diary as a memory aid. Normally, the researcher would not show the participant the graph and would not offer cues about the stress levels during the activity, simply asking what happened at 9:34, what the participant was doing before and after 9:34, and whether or not they found those activities stressful.

In the example shown in Figure 2, the participant's diary said that they got off the phone with their boss at 9:32 and began working on an assignment that they had been given. The heart rate data shows that the participant was under less stress during the phone call than while he/she was working afterward. The jump in heart rate is most likely due to their physical motions of hanging up the phone and shifting in their chair to begin working again (and suggests that he/she hung up

Figure 2. Participant returns to work after phone call

the phone at exactly 9:33:45). Interestingly, the participant reported that they felt that the phone call was stressful because it involved some negotiation over what needed to be done, while he/she felt the work afterward was relatively straightforward.

With a blind analysis, the participant keeps the diary to him/herself and can choose not to disclose information if they wish, which can be desirable when participants are working in sensitive areas.

Alternatively, the researcher can obtain the diary from the participant and use it as a filter to find events for which the participant will be likely to have contextual information. This must be explicitly arranged by the researcher before the study period(s). The filtered analysis saves time for both the researcher and the participant because the researcher won't ask in the interview about events that they won't be able to recall or are outside the researcher's field of interest; however, this can filter out stressful events or periods that the participant might not have thought were worth noting. Thus, the researcher may also wish to identify stressful periods that are not in the diary.

In either case, participants will generally not note detailed enough information – either not fine-grained enough, or lacking the contextual information that shows why they were or were not under stress – and must be interviewed about specific events later.

Communication and Use Logs: A means for gathering more detailed information is to use log file information from information and communication systems. This increases the calibration potential because this information is sometimes captured to the second, but logs also do not capture contextual information, and should thus be considered as a more precise diary that also requires follow up interviews.

Figures 3 and 4 show the graphs of a participant at the time the email server shows that he/she received two different email messages. In the first graph, the received email appears to have a slight effect on the user – a physical movement is shown, which may correspond to him/her shifting to click on and read the mail. The participant reported that this was an email from a colleague that contained a document in response to an earlier request, and that he/she read the document with interest. The second graph, in contrast, shows no effect at the time the email is logged as being received, but an intense period of stress about 30 seconds later. The participant was unable to explain why their heart rate showed them to be under stress because the email itself was simply an "FYI."

Communication and use logs are limited in that face to face encounters and phone calls in most cases would not be captured by the logs, nor would the use of any other systems that don't have logging capabilities. Because of this, a researcher will wish to have participants also keep a diary of events that are not logged. Logs should also not be considered a perfect representation of what the participant saw and did: for example, email logs record when a message was sent and when it was received at the server of email client, and not when the person actually saw the message. In the graph shown in Figure 4, the causes of the stress are unclear, and the participant was unable to explain what happened: he/she may have been working on another task that caused the stress, may have been distracted by the email which caused stress, or may have been stressed during the time between when the email alert appeared on their screen and they actually

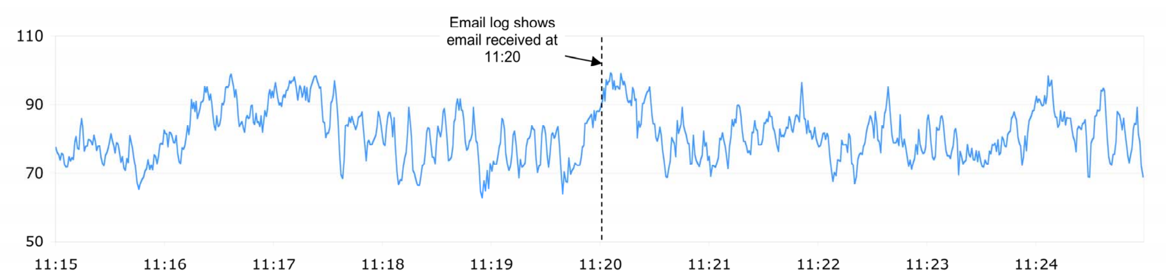

Figure 3. Non-stressful email

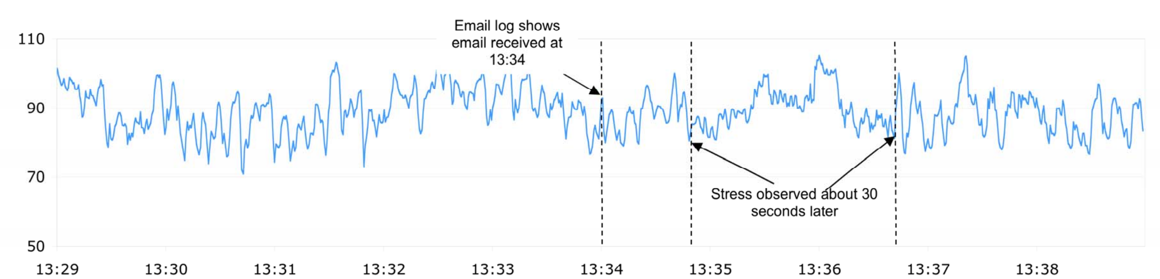

Figure 4. Email receipt associated with stress

read the email and found it was nothing.

Finally, Logs do not typically capture all of the behaviors involved in using an ICT. For example, a researcher might be interested in the time when a person began composing a stressful email, while the log file only shows the time when the email was sent.

Screen recording: Using screen recording software, it is possible to capture all of the use of ICT. In our studies, the participants considered such information to be private, meaning that the researcher had to use the blind analysis technique and request information about certain time periods. Logs and/or a diary can help filter the periods of interest, and capture non-ICT communication such as phone calls and face to face communication.

Figure 5 shows a change in the heart rate variability for a participant at 13:38 from being relatively relaxed to stressed. In this case, contextual information is lacking, so the participant was asked to consult the video record of his/her ICT activities.

The participant responded that he/she had been engaged in working on translating a document, but had taken a break to look at online political news. Because the reasoning behind technostress suggests that taking a break would be associated with relaxation [5], we pressed for additional information, to which the participant responded that there is not much stress while working on a steady, flowing task, but that stress is produced if there is an urge to switch to another task, regardless of how important it is.

Video Capture: Finally, a researcher may wish to capture as much detail as possible and use live video capturing techniques. This enables the precise timing of events, can potentially capture all channels of communication, and even show the participant's focus of attention. Multiple cameras or body mounted cameras can be used if multiple physical locations are desired. The principal problem of this technique is that it rivals shadowing in its intrusiveness, and alters the behavior of others that meet with the participant.

We were able to use this technique with one participant, but only were able to make a video of their phone. Using this we were able to confirm the phone call stress pattern seen in Figure 2 through exact timing of when the call was answered to when it was hung up – relatively relaxed during the phone call, while more stressful after hanging up.

As a final note on screen and video capturing, we found that recording an entire day results in large files. Our participants did not report any problems with the recording; yet, the large files proved to be difficult to review when participants attempted to switch to specific times.

In summary, we have outlined several techniques for supplementing heart rate data in order to obtain contextual information about what causes stress in situ. Circles in Table 1 indicate how well the techniques we have discussed so far meet the criteria set up in section 2.3 (● = fully met, **○** = to some extent, ○ = not met).

Table 1: Technique strengths and weaknesses

	Perceived/ Bodily Stress	Event Level Data	Level of Intrusiveness	Richness of Context Data
Survey	●/○	○	○	**○**
Experiment w/HRV	○/●	●	○	○
Experiment w/Cortisol	○/●	**○**	**○**	○
Observation w/HRV	○/●	**○**	●	○
Interview w/HRV	●/●	**○**	**○**	●
Diary w/HRV	**○**/●	**○**	**○**	**○**
Usage Log w/HRV	○/●	●	○	○
Screen Capture w/HRV	○/●	●	●	○
Video w/HRV	○/●	●	●	○

Generally speaking, a researcher will wish to employ a mixture of techniques. Given our aim to study a full work-day in situ, observation is probably the least useful overall because it takes so much of the researchers time with almost no benefits over other approaches. Because we wish to complement bodily findings with the individual's sensemaking, most of the other techniques should be combined with interviewing. Despite its shortcomings, interviewing enables a researcher to investigate the individual

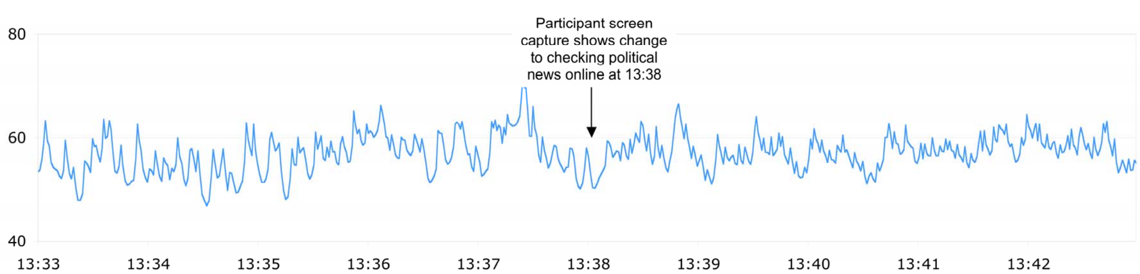

Figure 5. Change from working to looking at news online

perception of stress and its causes. Ethically speaking, researchers need to understand that heart rate data can uncover potentially sensitive information to the participants. Because the heart rate is monitored constantly and fairly unobtrusively when wearing a belt, the data may reveal things that the participant did not realize about their workday. For example, a participant might not consciously realize that they are uncomfortable when talking to a particular colleague, and may not wish that a researcher or anyone else knows that he/she was under significant stress during what would normally be considered a routine conversation. Furthermore, the heart rate belts are worn at all times, meaning they can reveal some physical and emotional information during times that the participant would normally have an expectation of privacy, such as while at lunch or in the bathroom. For this reason, a researcher would normally want diary information that shows when the participant was on breaks, for the bathroom, for lunch, or whatever reason, so that these periods can be excluded from analysis.

Overall, heart rate data analysis using our technique relies on a participant's sense making, making it an interpretivist approach. It can be used for theory confirmation as part of a natural experiment if combined with blind data analysis techniques.

5. Discussion

The wide proliferation of ICT alters how people conduct their work. However, the outcomes of technology use in the workplace are not deterministic. On one hand, workers enjoy increased flexibility, joy and relaxation while on the other hand, aspects of overload, frustration, or control frame technology differently. We emphasize that stress is a complex phenomenon that is highly contextual, meaning it reflects several aspects of an individual's disposition, the social or group setting, effectiveness of coping strategies, available media portfolios and associated usage practices. These circumstances led us to question the usefulness of established data collection techniques for such research. At the moment, we feel the best approach to this area is explorative, both methodologically and theoretically. In order to develop a contextually grounded understanding of technostress, we deem it necessary to complement physiological measurements with qualitative, in-situ data.

The initial trials of our methodology suggest that HRV in combination with qualitative techniques that enrich the bodily measured data with contextual information are a good means for understanding how ICT influences stress levels in modern workplaces. Using our techniques, researchers can also confirm hypotheses by identifying events a priori that should lead to stress in a participant's diary or usage logs. For example, we found the pattern of increased stress after some types of phone calls to carry across individuals to the point that we could identify with relatively high accuracy when such a phone call had occurred in another participant's heart rate graph. A methodology that confirms theories in situ has an advantage over experimental methods in that context is preserved.

One downside to obtaining heart rate data over the long term is that a researcher focusing on minutiae can become inundated with data. A day's heart rate graph consists of a very large amount of data, and may contain 20 or more episodes of stress. When combined with the most finely grained observational techniques like screen capture or video, a researcher runs the risk of wanting more details than their participants wish to provide. We found it best to limit ourselves to requesting details about between eight and twelve time periods or events per participant..

We suggest our portfolio of techniques is a means to examine stress as it is experienced in the context of workers. We have seen in our preliminary studies that particular events that would be predicted to cause stress under the current frameworks may not be experienced by participants bodily. By identifying such occurrences over the course of a worker's day using heart rate variability, a researcher can learn of potential stressors that would not have been predicted before.

6. Conclusion

In this paper, we have presented an overall research approach and assessed a variety of techniques for studying technologically induced stress in situ. Overall, our multi-method exploratory approach facilitates theory building in this relatively new area of study. Our techniques rely on a quantitative measure of bodily experienced stress, heart rate variability, together with interpretive methods for tying the heart rate variability data with contextual background.

Clearly, there is more to understand about whether and how ICT causes stress in the modern workplace. Our preliminary tests suggest that the current understanding of technostress as resulting from being mentally overloaded and/or too often interrupted is probably too simplistic and too decontextualized.

We suggest that six observational characteristics of technostress should inform research approaches geared towards a broader understanding technostress. First, there are ambivalent outcomes of technology use in the workplace. Second, while some aspects of stress are perceived consciously by individuals, some individuals might dwell on it while others ignore or even negate it. Third, other parts of stress are not even consciously recognized, and are only measurable in physiological readings. Fourth, while experiments show the impact of distinct stressors on individuals, occupational stress research suggests (e.g. [22]) that stress is a complex phenomenon. Fifth, although stress can be measured as a temporary and locally isolated phenomenon, its impacts on individual well being seem to result from long term effects. Finally, while physiological measurements are valid to establish the level of stress they provide virtually no clues about the source or cause of stress.

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