Workplace Indicators of Mood: Behavioral and Cognitive Correlates of Mood Among Information Workers

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ABSTRACT
Positive wellbeing in the workplace is tied to better health. However, lack of wellbeing in the workplace is a serious problem in the U.S, is rising continually, and can lead to poor health conditions. In this study we investigate factors that might be associated with workplace wellbeing. We report on an *in situ* study in the workplace of 40 information workers whose mood was tracked for 12 days. We used a mixed-methods study using Fitbit actigraphs to measure sleep and physical activity, computer logging, and repeated daily surveys. We found that sleep and perceived productivity are positively correlated with affect balance (the balance of positive and negative affect), whereas concentration difficulty, and amount of time on workplace email, are negatively correlated with affect balance. Our model explains 48% of the variance of workplace mood. We discuss the value and challenges of multi-faceted measures of health as we move towards designing interdisciplinary digital health research.

CCS Concepts
H.5.3 [Information Interfaces and Presentation (e.g., HCI)]: Group and Organization Interfaces; K.4.m [Computers and Society]: Miscellaneous.

Keywords
Mood; well being; productivity; workplace; sleep; physical activity; actigraph; computer logging; digital health

1. INTRODUCTION
Wellbeing in the workplace is an important factor affecting health. Wellbeing refers to people's affective responses to situations and people they experience [6]. Not only is positive wellbeing tied to improved job performance, but also with better health [6]. However, lack of wellbeing in the workplace (one manifestation is stress) is a serious problem in the U.S and is rising continually [15]. Stress is related to negative mood; lowering stress can reduce negative affect [40]. In 2014, 64% of employees reported high levels of workplace stress [9]. Workplace stress in particular impacts overall quality of life: 83% of men and 72% of women report carryover effects into personal lives [2]. Reducing workplace stress and consequently improving workplace wellbeing is economically a good strategy, which may reduce costs due to absenteeism and workplace errors [22] .

Mood disorders related to work can have direct and negative impacts on health as they can escalate into major depressive episodes [4]. Stress can lead to negative coping behaviors which can lead to poor health conditions such as alcohol abuse [10], and increased body weight [26]. Workplace stress is associated with a 50% increased risk of coronary heart disease [25]. Negative workplace mood is also related to burnout, or professional exhaustion, which in turn is related to health problems and job engagement [35].

Understanding workplace wellbeing however is limited by current methodological approaches. It can be measured through a screening discussion (e.g. life-event interviews) with a practitioner or through well-validated instruments that measure mood. However, self-report measurement techniques are generally measured at a single time point or infrequently. While such instruments are well-validated to identify general mood or chronic stress, because they are measured at single time points they do not necessarily characterize acute or transient mood states, nor do they identify factors associated with well-being, especially when specific to a context. We maintain that a combination of methods that can capture continuous measures of activity, behaviors, and cognitive and affective parameters in a social and work context can more accurately characterize an individual's mood. This information could empower individuals to make changes in their lives.

The goal of this study is to investigate factors that can affect well being in the information workplace. Our position is that through identifying such factors it can increase awareness, which can lead individuals to make changes, which in turn can potentially improve individuals' health. There are multiple measures available for measuring wellbeing (e.g., mood, depression, and stress). In this investigation we focus on studying *affect balance* [27], a measure comprised of the relationship of positive to negative affect. We use a mixed methods approach to collect measures that we believe could be associated with, and which could potentially influence workplace mood: IT usage, physical activity, sleep patterns, and cognitive and affective states of participants. We take these measures of participants in their real world work environment as they are carrying out their normal work activities.

To address the limitations of single point time measures, we collect continuous data for some variables, and repeated daily measures for others. Our research question called for using varied methods, so we combined continuous computer activity logging with unobtrusive behavioral data collection and daily surveys. We tracked behavioral, affective and cognitive parameters of 40 information workers for 12 days in their *in situ* workplace environments.

2. Related work

In recent years there has been a growing interest in using digital devices to detect and improve mood. For example, the HappinessCounter recognizes smiles, detects frequency of occurrences and measures affect [39]. Due to behaviors related to smiling, participants reported experiencing more positive mood.

One of the few studies to examine mood in the workplace using unobtrusive measures is a pilot study of nine information workers by Matic et al. [31]. This study used smartphones to sense activity and correlated that with experience sampling of mood and active badges to detect social interactions. It was found that activity and social interactions were positively correlated with positive mood. In a study using an Electronically Activated Recorder (EAR) to record ambient sound in the environment associated with mood, it was found that positive mood varied around a diurnal cycle whereas negative mood did not [20].

Mood and cognition are intricately related: a person's affective state can influence how one evaluates their work. Experiencing positive affect can lead one to view their behavior more positively, and experiencing negative affect can influence one to adopt a negative evaluation of their work [16]. Further, positive affect in the workplace is associated with a number of favorable work attributes: increased work quality, motivation, creativity, productivity, group rapport, engagement, and satisfaction [36]. Negative affect in the workplace on the other hand is associated with negative workplace outcomes, and especially associated with workplace stress [36]. Positive affect had also been found to improve job performance [34]. In turn, the satisfactory completion of work activities leads to positive affect (e.g. [21]). Most studies examining workplace mood have relied on subjective reports, often done at a single time period. In this study, we obtain multiple reports of mood measures on a daily basis, and correlate this with other measures, some obtained through automatic data collection.

3. Workplace mood

A large body of research on mood has identified two dominant dimensions: positive and negative affect, consistently shown to be independent constructs, e.g. see [42]. However, others have suggested that positive and negative affect may vary according to frequency and intensity of occurrence [11]. The PANAS mood scale has been shown to be a reliable, internally consistent, and time-stable measuring instrument of these dimensions [41]. However, as people can experience more negative or more positive mood relative to the other dimension, the notion of *affect balance* [27] was proposed to describe the relationship of these two dimensions. The claim is that considering the relationship of positive to negative affect is a much stronger predictor of psychological mood than considering either dimension separately [19]. Therefore, in this study we use the concept of affect balance to represent workplace mood. A higher value of affect balance represents a higher value of positive mood relative to negative mood, and the converse occurs as well: a lower value of affect balance represents a lower value of positive mood relative to negative mood. Whereas there are multiple factors that could play a role in influencing workplace mood, as a first step we examine factors informed by a review of the literature. We examine physiological and behavioral variables of sleep and physical activity, a cognitive parameter of the ability to concentrate, and work activity indicators concerning workplace communication and productivity.

3.1 Sleep

A meta-analysis of laboratory sleep studies found that sleep deprivation significantly negatively impacts mood [33]. However, in contrast, a study of people sleep deprived for 24 hours showed no significant changes in mood, such as negative mood states of anger and anxiety [32]. The authors explain this using the notion that 24 hours of sleep deprivation is long enough to affect fatigue but not long enough to impact mood. A large cross-sectional survey study though did find a relationship between self-reported sleep disturbances and negative mood [28]. Based on these studies, we expect that the less sleep one has, the more it would negatively impact mood. Most studies of the effects of sleep deprivation and mood have been done in the laboratory or with surveys. To our knowledge, we are not aware of studies that have examined the relationship of sleep deprivation and mood where people have been tracked in an *in situ* workplace environment using both physiological ad subjective measures. Therefore, we hypothesize:

H1: Less sleep will be associated with a lower value of affect balance the following day.

3.2 Concentration difficulty

Mood could affect one's ability to concentrate at work, and vice versa. The term "presenteeism" refers to an individual's attention at work being impacted, e.g., by depressed mood, sleepiness or poor sleep patterns. In fact, a large survey study confirms that people who sleep fewer hours have greater difficulty in cognitively functioning in a work environment the next day [1]. Another survey study found that depressive mood and negative work performance are related; however, as it was single survey measure, it was not able to detect whether more transient concentration, e.g., on a daily basis, might also be related to mood [18]. We expect that there would be a relationship of cognitive functioning and mood, though the relationship may be cyclical in nature. Whereas cognitive functioning is quite a broad measure, as a first step, we focus on one aspect that we feel could be related to mood: concentration difficulty. We hypothesize:

H2: The more difficulty in concentrating at work will be associated with a lower value of affect balance on that day.

3.3 Workplace non-sedentary activity

Studies have consistently shown that physical activity is associated with higher positive mood in individuals [12]. A meta-analysis showed that physical activity can lead to improved mood states [17]. Studies though have generally been done using surveys of self-reports of physical activity [3]. One study used actigraphs, which are worn sensors for measuring activity level and sleep; a commercial example is the Fitbit. This study measured the level of physical activity in the workplace, finding that most people are sedentary [7]. An exploratory study that tracked nine people for seven days using smart phone sensing found a positive correlation between physical activity and positive mood in the workplace [31]. We build on this study with a larger sample of 40 people over a longer time period of 12 business days to further investigate this relationship. We therefore hypothesize:

H3: Less physical activity will be associated with a lower value of affect balance.

3.4 Workplace communication: email use

In information work, which our study concerns, the use of information technology, particularly the computer applications that people use, and the duration of time they spend on them, can impact workplace mood. Information workers spend over half the time on the computer, of which email use is a significant portion [29]. Research has shown that email use is associated with stress. For information workers, cutting off email for one workweek resulted in lower stress [30] and the duration of time spent on email was associated with higher stress [29]. Although the relationship of stress and mood is complex, studies generally show that stress is associated with negative mood [5].

While many studies have typically relied on self-reports of IT usage, research shows that such subjective measures grossly overestimate the time spent using information technology [8]. To obtain a more reliable measure of participants' IT use, we continuously logged our participants' computer activity as they conducted their normal work tasks. Therefore, we hypothesize:

H4: Higher email use will be associated with a lower value of affect balance.

3.5 Workplace productivity

Related to the research exploration of cognitive function and mood, poor cognitive function could coincide with lowered perceived workplace productivity. However, few studies have addressed the relationship of perceived productivity and mood. Productivity was found to be negatively related to a measure of communication technology overload [24]. Experiencing information overload can occur when one lacks the time to deal with information cf [14]. As mood is related to a feeling of overload and stress [5], we would expect a negative relationship of assessed productivity and workplace mood. We hypothesize:

H5: Lower perceived productivity will be associated with more negative mood.

4. Method

4.1 Procedure and participants

To investigate the relationship of factors that might be related to workplace mood, we conducted a mixed methods *in situ* study. We recruited 40 participants (20 females, 20 males) from a research division of a large U.S. west coast corporation. Participants were all information workers who worked in a variety of different job roles ranging from administrative support, researcher, engineer, and manager. For participating in the study, participants were compensated with a $250 gift card.

We had scheduled participants to be in the study for two work weeks. However, technical problems and scheduling issues sometimes interfered with the schedule. In those cases participants were run for longer than two work weeks. Participants averaged being in the study for 12 days. During the study period, computer activity at work was logged during all business hours. Before the study began, we met with each participant to explain the study procedure, install the computer logging software, instruct them on the use of the actigraph, and to explain the survey procedures. Participants were told to go about their normal workday activities as they would normally.

We gave participants a general pre-study survey where we asked a number of demographic and personality measures, not all reported in this paper. Participants were sent a daily evening questionnaire, where they reported their perceived productivity for that day along with several other questions.

Measure	Description
Affect balance	Measured by the PANAS mood instrument [41] at the end of each day. Negative mood score is subtracted from the positive mood score to create a measure of affect balance. Higher values represent more positive mood relative to negative mood.
Sleep	Measured by the Fitbit Flex actigraph which participants wore 24 hours a day.
Concentration difficulty	Measured on a daily basis, in the end-of-day survey, using a 7-pt. Likert scale for: I had difficulty in concentrating today (1=disagree, 7=agree)
Non-sedentary activity	Number of daily steps measured by the Fitbit Flex actigraph which participants wore 24 hours a day.
Email duration	Number of seconds spent daily/hourly on email as measured by computer logging.
Productivity	Measured daily, in end-of-day survey based on six dimensions using a Likert scale; A composite measure was created from the six dimensions.
Control Variables	
Job characteristics	Job demands, job decision latitude from JCQ [23] in the general survey
Age	Measured from the pre-study survey.
Gender	Measured from the pre-study survey.

Table 1. Summary of measures used.

We explained to participants that their data would be anonymous and aggregated and that no content would be collected. Upon completion of the study, interviews were done to understand participants' experiences. Participants reported that they followed the study procedures. However some other data collection methods not described in this paper (use of heart rate monitors, experience sampling) were reported to be uncomfortable at times. Participants did not report problems wearing the Fitbits or doing the daily end of day surveys.

4.2 Measures

Table 1 shows a summary of measures that we used, described as follows.

Affect balance was measured at the end of each day using the PANAS instrument [41], a psychometric scale that is well-validated. PANAS uses 20 adjectives. Participants respond to how well each adjective reflects their mood, using a 5-point scale from 1=not at all to 5=extremely. The scores result in two separate dimensions of mood: positive and negative. Each dimension yields a score that can range from 10-50. Affect balance is an index constructed by subtracting the negative mood score from the positive mood score and is a representation of the degree of balance of positive and negative mood for an individual [27]. The

higher the score, the more positive is one's mood relative to their negative dimension of mood. The PANAS scale can be used to measure mood at different time scales, by customizing the instructions. We used the PANAS scale in the end of day survey to measure participants' positive and negative mood for that day. Participants were instructed to respond to the adjectives based on their mood "for today." Our dependent measure was daily affect balance, i.e. a measure for each day of the study. Scores could range from -40 to +40.

Sleep was measured as the number of seconds in sleep, using the Fitbit Flex actigraph which participants wore 24 hours a day. The data was normally distributed with long tails. To improve normality we removed six outliers (more than +/- 2 SD's of the mean).

Concentration difficulty was measured at the end of each day in a survey. Participants were asked to rate on a 7-pt. Likert scale responses to a question concerning their work experience that day: *I had difficulty in concentrating today*.

Non-sedentary activity was measured as the number of steps for that day, using the Fitbit Flex actigraph.

Email Duration was measured as the number of daily seconds spent on email interactions. Time spent on email was logged automatically via custom-built Windows Activity Logging software which tracks every open application, which window is in the foreground, and whether the user is interacting with that window (with mouse, keyboard, touch, etc.). We measured the total duration of email client use. Email duration was defined as the number of seconds that the email client was in the foreground window, ending when the user either changed windows or the computer had no keyboard or mouse activity for a period of five minutes. Email duration was normalized.

Productivity. An objective measure of productivity in information work is a challenge to obtain. For example, for software developers, measuring lines of code written would not be an adequate measure as fewer lines of code written could result in a higher quality program. We therefore used a self-assessment of productivity. We constructed an index of productivity which was measured by six items included in the end of day survey: *"How much did you accomplish today based on what you had planned to accomplish?", "How efficient do you feel you were today in performing your work?", "How satisfied were you in what you accomplished today?", "How effectively do you feel you managed your time today?", "How would you evaluate the quality of the work you did today?",* and *"Overall, how productive do you feel you were today?"*. We used a 7-point Likert scale for measuring responses, with 1=not at all, and 7=extremely. The item dimensions had correlations ranging from .68 to .94, so we combined them additively to construct an index measure of Productivity.

4.3 Control variables

Because workplace mood could be affected by a number of different measures that could influence our variables of interest, we controlled for the following variables.

Job characteristics. Job role could influence workplace mood. For example, a researcher may have a large degree of job flexibility which could lead them to feel in a positive mood, whereas an administrative assistant may have less job autonomy which could make them feel more of a negative mood. Job roles could affect how much physical activity a person does in the workplace (e.g. a manager may walk around the workplace more) or could even affect how much email one needs to deal with. To control for such differences, we considered job roles. Rather than coding each individuals' job role, we found it more useful to consider job roles in terms of the two basic dimensions proposed by Karasek in his Job Content Questionnaire (JCQ) used to measure job strain: job demands, and job decision latitude [23]. Job demands is an index comprised of five items, e.g.: "*My job requires working very fast*", "*I am not asked to do an excessive amount of work*" (*1=strongly disagree, 4=strongly agree*). Job decision latitude is comprised of nine items and measures an employee's skill discretion and decision-making authority, by asking items such as: "*My job requires a high level of skill*" and "*I have a lot to say about what happens on my job*". The JCQ was given in the pre-study general survey.

Age and gender were control variables, as measured from the pre-study general survey. Age was measured in categories and responses were then combined into three categories based on the distribution of responses: less than 25 years; 25-40 years; over 40 years.

4.4 Analyses

We collected measures on a daily basis, averaging 12 workdays of measures per person. We used only full days of window logging (as the study setup was done in the morning, sometimes there were not full days of data collection), used weekday data (i.e., during the work week), used only days when the computer usage was greater than zero, and used only days when we obtained full days of Fitbit data.

For our analyses we used Linear Mixed-Effects Models (LMM), to account for the correlated data within subjects (measures were repeated measures on multiple days for each person). We ran LMM in SPSS using random and fixed effects. We used a random intercept for participants; all other factors in the model were entered as fixed effects.

5. Results

Table 2 shows descriptive statistics from our measures. Affect

Daily measures	Mean (SD)	Median	Min	Max
Affect Balance	9.21 (10.13)	7.00	-14.00	39.00
Sleep Duration	7 hr, 5 min (1 hr 33 min)	7 hr, 11 min	19 min	10 hr, 47 min.
Concentration difficulty (1, low-5, high)	3.01 (1.5)	3.00	1	7
Non-sedentary activity (no. of steps)	8085 (3338)	7691	714	18,977
Workplace communication: Email duration (min)	1 hr, 23 min (41 min)	1 hr 6 min	0	7 hr 54 min
Workplace productivity[1] (1, low-7, high)	27.7 (7.0)	28.0	6	42

Table 2. Average daily measures for participants. Measures are based on weekdays, full days of computer logging, and only on days when the computer was used.

[1]

Affect Balance	Coeff (SE)
Intercept	-11.22 (9.26)
H1: Sleep	.02 (.01)**
H2: Concentration difficulty	-.97 (.38)*
H3: Non-sedentary activity	.0001 (.0001)
H4: Workplace commun: Email	-1.33 (.51) **
H5: Workplace productivity	.44 (.10)***
Controls:	
Job Demands	-.12 (.20)
Job Decision Latitude	.17 (.07)*
Age: under 25[1]	-6.18 (2.04)**
Age: 25-40[1]	2.59 (1.92)
Female (reference is Male)	-3.43 (1.74)

Table 3. Coefficients and SE of fixed effects in the model. Affect balance was the dependent variable. ***p<.001, **p<.01, *p<.05, [1]Age: over 40 is the reference category.

balance had a possible range of -40 to +40. The mean affect balance was 9.21, which indicates that participants had an average positive affect balance, i.e. relative to negative mood. Average sleep was slightly over 7 hours, which is in the range of the recommended 7-9 hours of sleep. Concentration difficulty was mid-range on average. Mean physical activity was slightly more than 8000 steps, which is lower than the 10000 steps daily recommended for healthy adults [38]. Participants spent nearly one and a half hours daily on email. Workplace productivity was assessed as moderate 27.7, on the additive index which ranged from 6 to 42 (based on combining 7 Likert scale items).

Results of the LMM are shown in Table 3 of the coefficients and standard errors of variables tested for our hypotheses. An R^2 statistic for LMM must account for the variance explained by both the fixed and random effects. As there is no standard method for specifying an R^2 in LMM [13], we can provide an estimate of the R^2 using fixed effects alone. This value will most likely *underestimate* the amount of variance explained, as random effects are not included, and thus will provide a lower bound. An adjusted R^2 of the fixed effects alone in our model was .48, i.e. the variables in our model explained 48% of the variance of affect balance in the workplace. A LMM reports variance between and within participants. The model estimated between-subject variance as 42.41 95% C.I.= 34.59, 51.99], and within-subject variance was 12.97, 95% C.I. = [5.63, 29.88]. This result shows that both types of variance were significantly greater than zero, and there was far more variance between different participants than variance within participants over the multiple days of data collection. We next report the results of our hypotheses tests.

5.1 H1: Sleep

We found support for H1: Sleep is positively related to Affect Balance: the more sleep one gets the night before, the more positive is one's mood the next day, relative to one's negative mood.

5.2 H2: Concentration difficulty

As one measure of cognitive functioning, we asked participants at the end of the day how difficult it was for them to concentrate that day. A higher score represented more difficulty in concentrating. We found a negative significant correlation of concentration difficulty with affect balance: the more difficult it was for people to concentrate, the less positive was mood, supporting H2.

5.3 H3: Non-sedentary activity

We found no relationship of number of steps taken and affect balance. We thus reject H3.

5.4 H4: Workplace communication: Email use

As a measure for how information technology use might reflect mood, we focused on email use. We found a negative relationship of email use and affect balance: the less time spent on email that day, the more positive the affect balance is. We thus found support for H4.

5.5 H5: Workplace productivity

We found a significant positive relationship of perceived productivity and positive affect balance: the higher the rated productivity that day, the more positive was mood (relative to negative mood). This supports H5.

5.6 Control variables

Our control variables were the two work role dimensions of Job Demands and Job Decision Latitude, Age, and Gender. Job Demands was not significant. However, Job Decision Latitude showed a positive correlation: the more latitude in decision-making in a person's job, the more positive was their mood. Age was significant as a control: participants less than 25 years were significantly lower in positive affect balance relative to the reference group of participants over 40 years. Gender was not significant.

5.7 Exploring physical activity

Our result showing that number of daily steps (H3: non-sedentary activity) is not related to mood is contrary to other previous studies which showed that physical activity is positively related to mood. We decided to explore our data to see if we could uncover why our results differ. Perhaps one reason could be a difference in methodology. We examined the relationship on a daily basis, i.e., we related the number of steps taken that day to the assessed mood at the end of the day. We also used a Linear Mixed-Effects model which takes the nested data into account, as we averaged 12 daily measures per person. In contrast, the study of Matic et al. [31], who used smartphones to detect activity and experience sampling (EMA) to measure mood, used a Spearman correlation within subjects. We reanalyzed our data using a Spearman correlation, which does not take random effects into account, i.e., it does not consider that multiple measures are nested within subjects. Using a Spearman correlation, we found a significant positive correlation between number of steps taken, and Affect Balance (where higher values indicate more positive mood relative to negative mood), r=.21, p<.001. We then analyzed the two components of the PANAS score separately, positive and negative affect also using the Spearman correlation. We found a significant positive correlation of PANAS positive mood and number of steps taken: r=.17, p<.008. However, we did not find a significant correlation of PANAS negative mood and number of steps taken: r=-.06, p<.38. Thus, it appears that differences in methodology could explain the differences in our results from that of Matic et al., who found a positive correlation of physical activity and workplace mood. We further found that the number of steps is correlated with positive, but not negative mood. This suggests that physical activity could increase the positive

dimension of mood but does not impact the negative dimension of mood, at least, using our methodology.

6. Discussion

In this study, we examined workplace mood in relation to variables concerned specifically with the workplace experience. We hypothesized that variables related to sleep, concentration at work, physical activity, workplace communication, and workplace productivity should be associated with mood. In our exploratory analysis, we found that the fixed effects alone in our model (which is a lower bound estimate) explain 48% of the variance in mood, which explains nearly half the variance. In studies concerning human psychology and behavior it is not common to be able to explain so much variance.

Our study confirmed previous analyses showing a relationship of sleep and mood. However, our study was done *in situ* with both sleep and mood measures, as opposed to laboratory studies, or surveys where sleep effects have generally been measured [28], [33]. Thus, our study contributes to the literature showing that sleep effect findings hold *in situ* in the workplace as well.

Contrary to what studies have found showing that physical activity is related to positive mood [12], we did not find any such relationship. One reason could be that prior studies relied on self reports whereas in our study, participants wore actigraphs which provided more objective measures. Our results were also contrary to what was found with a study of nine participants using smart phone sensing and which found a positive correlation of physical activity with positive mood [[31]. However, we found that differences in analyses could help explain this. This highlights how critical it is to develop standardized methodological procedures so that results can be compared across studies. This will become an increasing concern as the range of sensor capabilities expands, enabling different types of health and cognitive measures to be captured and combined.

Email was inversely correlated with affect balance: the more time spent on email, the more negative a person's mood was, relative to their positive mood. This finding builds on results showing a positive correlation of email duration and stress [29] and with a study showing that absence of email in the workplace reduces stress [30]. Thus, email duration not only impacts stress, but is related to negative mood as well. Whereas it is not realistic for employees to completely cut off email, these findings strongly suggest that reducing time on email could improve one's workplace mood. In investigating the role of workplace communication, we only looked at email. In future work we will examine other workplace communication such as Instant messaging and remote synchronous communication.

As we expected, higher productivity was correlated with end of day higher positive affect balance. A mechanism to explain this relationship could be that negative affect is associated with lower energy. If people feel in a negative mood, for example, at the beginning of the day, it could result in less energy to devote to work. Low energy then in turn could be manifest as lower workplace productivity [37]. But of course, the opposite relationship could also be at play and needs further examination.

Interestingly, we found that Job Decision Latitude was associated with positive mood. Job Decision Latitude is a measure of a person's decision-making authority. This result suggests that people with more agency in their decision making at work may feel more positive. Perhaps the reason is that people who can be flexible in their choices of time management or on what tasks to work on, might feel more positive. Organizations might consider this result in defining work roles: enabling employees to have more job latitude could improve overall workplace wellbeing.

We looked only at one direction of our variables and their effects on end of day mood. However, the relationship of our chosen variables and mood can be bidirectional, and cyclical in nature. For example, poor sleep the night before can lead to difficulty in concentration during the next day, which in turn can lead to lower productivity and more negative mood at the end of the day. However, negative mood in turn can impact sleep, leading to a cycle of poor sleep and negative mood patterns. To uncover the relationships and directionality, further *in situ* and laboratory studies would be needed. Our study is a first step to identify the relationships.

It may also be that some of our variables may be mediators of relationships of other variables. For example, sleep can impact concentration difficulty. There may also be underlying covariates among our variables and mood as well. In future research we plan to identify the mediating relationships among our variables and their effects on mood.

6.1 Implications for digital workplace health

Our study has implications for the area of digital workplace health. First, we advocate that taking a multi-faceted view of a health phenomenon is important. Often studies focus on a single factor such as sleep or physical activity. Yet, multiple factors can be at play in influencing a health outcome such as wellbeing. By not considering multiple factors, important relationships could be missed. Correspondingly, it is important to control for other variables that could potentially influence the results (in our study, job roles, age, and gender). Second, our use of automatic data capture was accepted by participants. Sensors, such as actigraphs or the use of smartphone applications, can scale up, enabling larger groups to be studied. Data that can be obtained at an organizational level, or even societal level, could reveal numerous patterns of health behavior. Third, it is critical for researchers to develop common standards of measurement and analyses so that data can be shared and so that results can be compared. This, however is a challenge, as choice of measurement tools and analyses is often guided by institutional norms and by different disciplinary fields. We hope our study can stand as one example methodologically, moving forward.

6.2 Limitations

Our study had several limitations. A single daily self-report measure of difficulty in concentrating may not accurately reflect cognitive functioning throughout the day. In future studies, it would be preferable to give a more comprehensive cognitive test(s) and perhaps more often. Also, we only considered number of steps as non-sedentary activity. In future work we can examine more carefully the role of rigorous exercise on mood.

We logged email use but did not examine content as our workplace did not allow this. It could be that email content could lead to negative affect, e.g., if the email is assigning work items. Also, the sender of the email could influence affect. This could be followed up in future studies. In addition, logging does not capture email activity completely. For example, a person may interact with someone else who comes into their office while they are working on an email. The human interaction could lead to negative affect and not the email use per se.

We caution that correlation does not imply causality. We cannot attribute causal relations of our hypothesized factors and mood. We can only report correlations. To untangle causal relations, controlled laboratory or field studies are needed. Nevertheless, *in*

situ studies provide an ecological view of mood in the workplace whereas laboratory studies provide an abstraction of the world. Our view is that both types of studies are complementary.

The participants in our study were from a single workplace. Therefore, we can only generalize to workplaces that are similar--those that are high tech, with workers that deal with information work. Also, participants in our study were highly educated, all with at least a bachelor's degree, so we can only generalize the results to individuals with a similar educational background.

7. Conclusions

We conducted a mixed-methods *in situ* study with 40 information workers over 12 business days. We found that sleep, concentration difficulty, workplace communication (email), and perceived productivity are factors that contribute to explaining affect balance, a balance of positive to negative workplace mood. Our study shows that multi-faceted measures of health and cognition can be valuable as we continue to develop a field of digital health. However, standardizing procedures and analyses will become an increasing concern as the range of sensor capabilities expands, enabling different types of health and cognitive measures to be captured and combined. This is especially important as digital health will require interdisciplinary research. Interdisciplinary research is a challenge, as methodology and analyses are often unique to different disciplinary fields.

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9. REFERENCES

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