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# Effects of work-related electronic communication during non-working hours after work from home and office on fatigue, psychomotor vigilance performance and actigraphic sleep: observational study on information technology workers

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## ABSTRACT

**Objectives** This study examined the effects of work-related electronic communication (WREC) during non-working hours in the work from home or office setting on health.

**Methods** The study recruited 98 information technology workers in a 9-day observational study. They recorded work–life events (eg, work style (working mostly from home or the office) and duration of WREC during non-working hours) and subjective ratings (eg, current fatigue, sleepiness and depression) and wore a sleep actigraph to measure objective sleep variables before bedtime every day. They completed the Brief Psychomotor Vigilance Test (PVT-B) before bedtime for 4 days.

**Results** The frequency of WREC was significantly higher when working mostly from home than in the office ( $p<0.01$ ). In addition, the duration of WREC was longer when working mostly from home than in the office ( $p<0.001$ ). Linear or generalised linear mixed model analysis for fatigue, depression and PVT lapse revealed significant interaction effects between work style and WREC (all  $p<0.05$ ). Post hoc analysis showed that the longer the WREC, the worse the fatigue and depression and the lower the lapse on working mostly from the office (all  $p<0.05$ ).

**Conclusions** Longer WREC is associated with worse fatigue and depression and lower lapse of PVT (higher alertness) before bedtime for working mostly from the office. Workers, especially those working from the office, should minimise WREC during non-working hours to maintain good health. Therefore, companies, managers and other relevant stakeholders should refrain from contacting workers during non-working hours.

## WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Work-related electronic communication (WREC) during non-working hours is associated with health problems, but the effects of the interaction between WREC and work style (working from home or office) on worker health remain unclear.

## WHAT THIS STUDY ADDS

⇒ Although the frequency of WREC was significantly higher when working mostly from home than when working mostly from office, a negative impact of WREC, that is, the effect where the longer the WREC, the worse the fatigue and depression and higher alertness before bedtime, was observed when working mostly from office but not when working mostly from home.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Promotion of the right to disconnect may reduce WREC during non-working hours and health impairments due to WREC.

## INTRODUCTION

Use of work-related electronic communications (WREC; eg, email, telephone and messaging application software) during non-working hours is associated with health problems.<sup>1–4</sup> For example, Arlinghaus and Nachreiner<sup>2</sup> reported that the risk of health problems, such as musculoskeletal, psychological, gastrointestinal and cardiovascular, was higher in workers with work-related contact (eg, email or telephone) during non-working hours. Non-working hours include sleep and

leisure times,<sup>5</sup> which are important for recovery from work-related fatigue.<sup>3,6</sup> WREC during non-working hours may directly reduce sleep and leisure times and, thus, interrupt this recovery. In addition, WREC during non-working hours interrupts psychological detachment from work,<sup>3</sup> which also contributes to recovery from fatigue.<sup>7</sup> Therefore, WREC during non-working hours may directly and indirectly negatively impact recovery from work-related fatigue, and accumulated fatigue may lead to various health impairments.

In recent years, the work from home setting, referring to work that fully or partly takes place within the worker's own home,<sup>8</sup> has been rapidly and widely implemented after the outbreak of COVID-19.<sup>8,9</sup> Previous review articles reported that although it has a few advantages, such as saving commute time and increasing sleep duration, working from home also has disadvantages, such as increasing sitting time, inducing feelings of



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loneliness and isolation and blurring work–home life boundary, compared with working from the office.<sup>10–11</sup> Working from home uses information and communication technology (ICT); ICT can easily be linked to work in the workers' own home. However, ICT can also provide links to work during non-working hours. For example, Arlinghaus and Nachreiner<sup>2</sup> found that 38% of 22 686 workers were contacted through WREC (eg, email or telephone) during non-working hours during the previous year. Therefore, WREC during non-working hours may be more likely to occur when working from home. Moreover, the interaction between WREC during non-working hours and working from home, which lead to the deterioration of psychological detachment from work,<sup>3–10</sup> may cause more significant impairments on health. Conversely, working from home, which can save commute time and ensure sleep and leisure times for recovery from fatigue,<sup>10–11</sup> may reduce negative health effects due to WREC during non-working hours. However, the effects of the interaction between WREC and work style (working from home or office) on worker health remain unclear.

To fill the gap, this study examined the effects of the interaction between WREC and work style on the health of Japanese daytime workers. The present study conducted a survey on workers under the 'Information and communications' industrial classification, which held the highest percentage in the rate of telework adoption by industry in Japan.<sup>9</sup> The study tested the hypotheses that follow. The results of testing the hypotheses could provide novel knowledge regarding the effects of WREC during non-working hours on worker health.

Hypothesis 1: WREC during non-working hours is more frequent and longer for working from home than working from office.

Hypothesis 2: the longer the duration of WREC during non-working hours, the greater the health risks.

Hypothesis 3: the magnitude of health risks due to WREC duration during non-working hours varies across working styles.

## METHODS

### Participants

The study recruited the participants in October 2021 through an outsourced third-party research company, with a voluntary registrant database. The company sent invitations to 22 642 registrants, of whom 7533 accessed the survey website produced by the company. Participants were excluded using the following criteria: (a) those aged <20 or >59 years old; (b) those working less than 35 hours/week; (c) those who were shift or night workers; (d) those with a second job; (e) those with non-permanent employment (eg, part-time or temporarily employed); (f) the industry type was not under 'Information and Communications'; (g) those who never received WREC during non-working hours; and (h) those who responded inappropriately to the instruction manipulation check.<sup>12</sup> We also asked about the frequency of working from home and office (the question had five response options: (1) working from the office every day, (2) working from office is more frequent than working from home, (3) working from home and office occurred with the same frequency, (4) working from home is more frequent than working from office and (5) working from home every day). We then recruited 50 employees for each work style (working from the office (1 and 2) and working from home (4 and 5), online supplemental table 1). The first 100 registrants who agreed to participate in the 9-day observational study and who met the exclusion criteria and classification were included in the study.

### Procedures

The observational study was conducted from 7 November (Sunday) evening to 15 November (Monday) morning in 2021 (ie, the observation period lasted for 9 days) to collect data for a total of 1 week. The period was outside of the COVID-19 state of emergency in Japan. Within this period, the participants recorded their work–life events (eg, work style and duration of WREC during non-working hours) and subjective ratings before bedtime every day. They wore an actigraph to measure objective sleep variables every night. In addition, they completed the Brief Psychomotor Vigilance Test (PVT-B<sup>13</sup>) before bedtime on 7 November (Sunday), 8 November (Monday), 12 November (Friday) and 14 November (Sunday). Recording of subjective work–life events and PVT was conducted by a fatigue checker<sup>14–15</sup> on the smartphones of the participants. To reduce missing data, we sent a reminder email to the participants every day. After the observation period, participants completed a poststudy survey regarding their characteristics.

### Measurements

#### Work styles and WREC

The participants were asked every day about their work style of the day, period of time of WREC during non-working hours, affective valence regarding WREC and start and end of working hours before bedtime. The question on work styles had four response options as follows: (1) I worked from home all day, (2) I worked mostly from home but partially in the office, (3) I worked mostly in the office but partially from home, (4) I worked in the office all day. Work style was dichotomised into working mostly from home (1 and 2) and office (3 and 4, online supplemental table 1). The question on WREC gathered data on the duration (minutes) of WREC during non-working hours for each of the following media: telephone, email, application software with read receipts, application software without read receipts and video communication. WREC was then calculated as the sum of the time spent on these methods during non-working hours. Affective valence regarding WREC was assessed using a 7-point Likert-type scale (0=*very negative*, 7=*very positive*). If WREC occurred several times, then the participants reported affective valence regarding the overall WREC of the day.

#### Subjective ratings

Current fatigue, sleepiness and depression were measured using a visual analogue scale (VAS)<sup>16</sup> before bedtime, as VAS can measure these subjective factors in the same manner that may reduce the burden on participants. The VAS was used to measure fatigue, sleepiness and depression.<sup>17–19</sup> Scores ranged from 0 to 100, and high scores were associated with high levels of fatigue, sleepiness and depression. In addition, psychological detachment from work was measured using four questions (eg, 'I forget about work during the day's leisure time') rated using a 5-point Likert-type scale (1=*do not agree at all*, 5=*fully agree*) before bedtime every day, which is based on the Japanese version of the Recovery Experience Questionnaire, which has been proven to show sufficient reliability and validity.<sup>20</sup> In this study, the Cronbach's alpha coefficient for the scale was 0.952. The sum of the scores indicated the psychological detachment score in which high scores indicated better psychological detachment.

#### Psychomotor Vigilance Test

PVT-B presented a digital counter on the screen at irregular inter-stimulus intervals, which ranged from 1 s to 4 s on the screen. The participants responded to the digital counter as quickly as

possible. The duration of the task was 3 min. Vigilance performance was evaluated by the mean 1/response time (reciprocal response time, RRT), mean fastest 10% 1/response time (fastest 10% RRT), mean slowest 10% 1/response time (slowest 10% RRT) and number of lapses. A lapse is defined as a response time slower than 355 ms.<sup>13</sup>

### Objective sleep measurements (sleep variables)

The participants were required to wear the actigraph (FS-770; Kissei Comtec, Nagano, Japan) on their waist from 2 hours prior to bedtime until they wake up every day. The measured data were analysed using dedicated software (SleepSign Act V.2.0; Kissei Comtec). Time in bed (TIB), sleep period time (SPT), total sleep time (TST), sleep efficiency, sleep latency and wake after sleep onset (WASO) were calculated. The agreement rate between the actigraph and the polysomnograph was 85%.<sup>21</sup>

### Poststudy survey

A questionnaire was used to collect information about participant characteristics such as sex, height, weight (body mass index, BMI), one-way commute time, smoking status (current smoker, ex-smoker or non-smoker), alcohol consumption (0, 1–2, 3–5 or  $\geq 6$  days/week), marital status (single or married), number of people living together (0, 1, 2, 3, 4 or  $\geq 5$ ), number of employees (<20, 20–300,  $\geq 300$ ) and occupation (managerial workers, professional/technical job or other).

### Analyses

The ratios of days with WREC during non-working hours to all workdays were calculated, and Fisher's exact test was used to compare the frequency of WREC between working mostly from home and office. To compare WREC duration during non-working hours between working mostly from home and office, generalised linear mixed model (GLMM) analysis, which assumes Poisson's distribution of errors, was conducted on WREC duration. In addition, to compare working hours between working mostly from home and office, a linear mixed model (LMM) analysis was conducted on working hours. Work style was set as a fixed effect. Individual subject and day were set as random effects. LMM analyses for repeated measures can handle missing data.

To assess the effect of work style and WREC duration on worker health, LMM analysis was performed on subjective ratings, PVT performance (excluding number of lapses) and sleep variables. GLMM analysis, which assumes Poisson's distribution of errors, was conducted on the number of lapses in the PVT. Work style, WREC time (total time of WREC in minutes by telephone, email, application software with read receipts, application software without read receipts and video communication) and their interactions were set as fixed effects. Individual subject and day were set as random effects. As previous studies have reported that sex,<sup>22</sup> age,<sup>23</sup> commute time<sup>24</sup> and valence to WREC<sup>4</sup> are associated with outcomes (eg, fatigue, sleep and recovery), these variables were included in the fixed effects as covariates. For days when the participants chose 'I worked from home all day', the commute time was set to 0 hour.

In addition, the study performed LMM or GLMM analysis on the independent variables, which demonstrated a significant main effect of WREC and/or a significant interaction, to assess the effects of the methods of WREC. The times of communication (in minutes) through telephone, mail, application software with read receipts, application software without read receipts and video communication were set as the fixed effects. Individual

**Table 1** Demographic data (n=98)

Variables	n (%) or mean (SD)
Sex, female, n (%)	18 (18.4)
Age, mean (SD)	45.3 (9.3)
One-way commute time (min), mean (SD)	57.0 (57.8)
Body mass index, mean (SD)	24.1 (5.2)
Number of employees, n (%)	
<20	8 (8.2)
20–300	26 (26.5)
$\geq 300$	64 (65.3)
Marital status, n (%)	
Single	36 (36.7)
Married	62 (63.3)
Number of people living together, n (%)	
0	24 (24.5)
$\geq 1$	74 (75.5)
Smoking status, n (%)	
Smoker	18 (18.4)
Non-smoker (ex-smoker)	80 (81.6)
Alcohol status, n (%)	
Non-consumption	40 (40.8)
$\geq 1$ /week	58 (59.2)
Occupation, n (%)	
Managerial workers	24 (24.5)
Professional/technical job	52 (53.1)
Others	22 (22.4)

subjects and days were set as the random effects. Work style, sex, age, round-trip commute time and valence to WREC were included in the fixed effects as covariates.

All statistical analyses were conducted using R V.4.2.1.

### RESULTS

Two participants dropped out during the observation period. Therefore, the final sample size is 98 (mean age=45.3, SD=9.3). **Table 1** presents the respondent characteristics. Participants who worked mostly from home and those who worked mostly from office on all workdays were 23.5% (n=23) and 29.6% (n=29), respectively. With regard to WREC frequency, participants who never received WREC and those who received WREC on all workdays were 21.4% (n=21) and 21.4% (n=21), respectively.

The maximum amount of data (person-days) was 784 (98 participants and 8 days), but 29 were missing data, 294 were data that were not for workdays and 31 showed inconsistent data (the WREC duration before bedtime was longer than the duration between end of working hours and bedtime). Therefore, data for 430 person-days were obtained. Of these, 53.3% (229 person-days) were working mostly from the office, and 46.7% (201) were working mostly from home (online supplemental table 1). These work style data were used in subsequent analyses. Those who largely worked from home but partially in the office and those who worked mostly in the office but partially at home were only 10 (2.3%) and 11 (2.6%) person-days, respectively.

**Table 2** lists the frequency and amount of WREC and the mean working hours for working mostly from home and office. Fisher's exact test suggested that WREC frequency was significantly higher for working mostly from home (51.2%) than working mostly from office (35.4%,  $p < 0.01$ ). GLMM illustrated that WREC duration was longer for working mostly from home than for working mostly from office ( $\chi^2 = 49.268$ ,  $df = 1$ ,  $p < 0.001$ ).

**Table 2** Frequency and amount of WREC and working hours on working from office and working from home

	Overall	Working mostly from office	Working mostly from home	P value
n (workdays from 98 participants)	430	229	201	
Frequency of WREC during non-working hours, % (n)*				
Total	42.8 (184)	35.4 (81)	51.2 (103)	<0.01
Telephone	13.5 (58)	9.2 (21)	18.4 (37)	0.01
Mail	25.6 (110)	19.7 (45)	32.3 (65)	<0.01
Application with read receipts	22.3 (96)	19.7 (45)	25.4 (51)	0.16
Application without read receipts	12.1 (52)	8.3 (19)	16.4 (33)	0.01
Video	10.2 (44)	5.7 (13)	15.4 (31)	<0.01
Amount of WREC per one time (min), mean (SD)†				
Total	30.0 (60.4)	19.0 (46.3)	42.6 (71.2)	<0.01
Telephone	3.6 (12.5)	2.7 (10.9)	4.7 (14.1)	<0.01
Mail	9.3 (24.7)	6.1 (19.7)	13.0 (29.0)	<0.01
Application with read receipts	5.9 (17.2)	4.3 (14.8)	7.7 (19.5)	0.29
Application without read receipts	4.1 (15.5)	2.5 (12.3)	5.8 (18.3)	<0.01
Video	7.2 (27.6)	3.5 (19.7)	11.5 (33.9)	<0.01
Working hours (hours), mean (SD)‡	9.8 (1.6)	9.8 (1.6)	9.8 (1.6)	0.88

\*Fisher's exact test.  
†Generalised linear mixed model analysis.  
‡Linear mixed model analysis.  
WREC, work-related electronic communications.

LMM indicated that no significant difference exists in working hours between working mostly from home and office ( $F(1, 425.6)=0.022, p=0.88$ ).

Figure 1 presents the effects of work style and WREC on subjective ratings before bedtime. The LMM analysis on fatigue revealed a significant interaction effect ( $F(1, 153.2)=4.858, p=0.03$ ). Post hoc analysis suggested that the longer the WREC, the worse the fatigue for working mostly from office ( $F(1, 72.7)=9.915, p<0.01$ ). The LMM analysis on depression revealed a significant interaction effect ( $F(1, 151.8)=4.528, p=0.03$ ), and post hoc analysis demonstrated that the longer the WREC, the worse the depression for working mostly from office ( $F(1, 67.7)=6.812, p=0.01$ ). The LMM analysis on psychological detachment revealed a significant main effect of WREC ( $F(1, 146.4)=4.324, p=0.04$ ), which indicates that the longer the WREC, the worse the psychological detachment. The LMM analysis on sleepiness revealed non-significant main and interaction effects ( $p>0.05$ ).

Figure 2 depicts the effects of work style and WREC on PVT performance before bedtime. The GLMM analysis on the lapse revealed a significant interaction effect ( $\chi^2=6.982, df=1, p<0.01$ ). Post hoc analysis implied that the longer the WREC, the lower the lapse on working from the office ( $\chi^2=6.151, df=1, p=0.01$ ). LMM analysis for the mean RRT, slowest 10% RRT and fastest 10% RRT revealed non-significant main and interaction effects ( $p>0.05$ ).

The LMM analysis, on all sleep variables, revealed non-significant main and interaction effects ( $p>0.05$ ). The effects of work style and WREC on the sleep variables (TIB, TST, SPT, sleep efficiency, sleep latency and WASO) were shown in online supplemental figure 1.

Table 3 depicts the effects of each method of WREC on fatigue, depression, psychological detachment and PVT lapse. The LMM analysis of fatigue showed that the longer the video communication use during non-working hours, the worse the fatigue was before bedtime (coefficient=0.118, 95% CI 0.003–0.230,  $p=0.047$ ). The LMM analysis on psychological detachment revealed that the longer the telephone use during non-working hours, the worse the psychological detachment before bedtime (coefficient=-0.031, 95% CI -0.059 to -0.003,  $p=0.04$ ). The GLMM analysis on lapse revealed that the longer the email communication during non-working hours, the lower the PVT lapse before bedtime (coefficient=-0.012, 95% CI -0.018 to -0.005,  $p<0.01$ ).

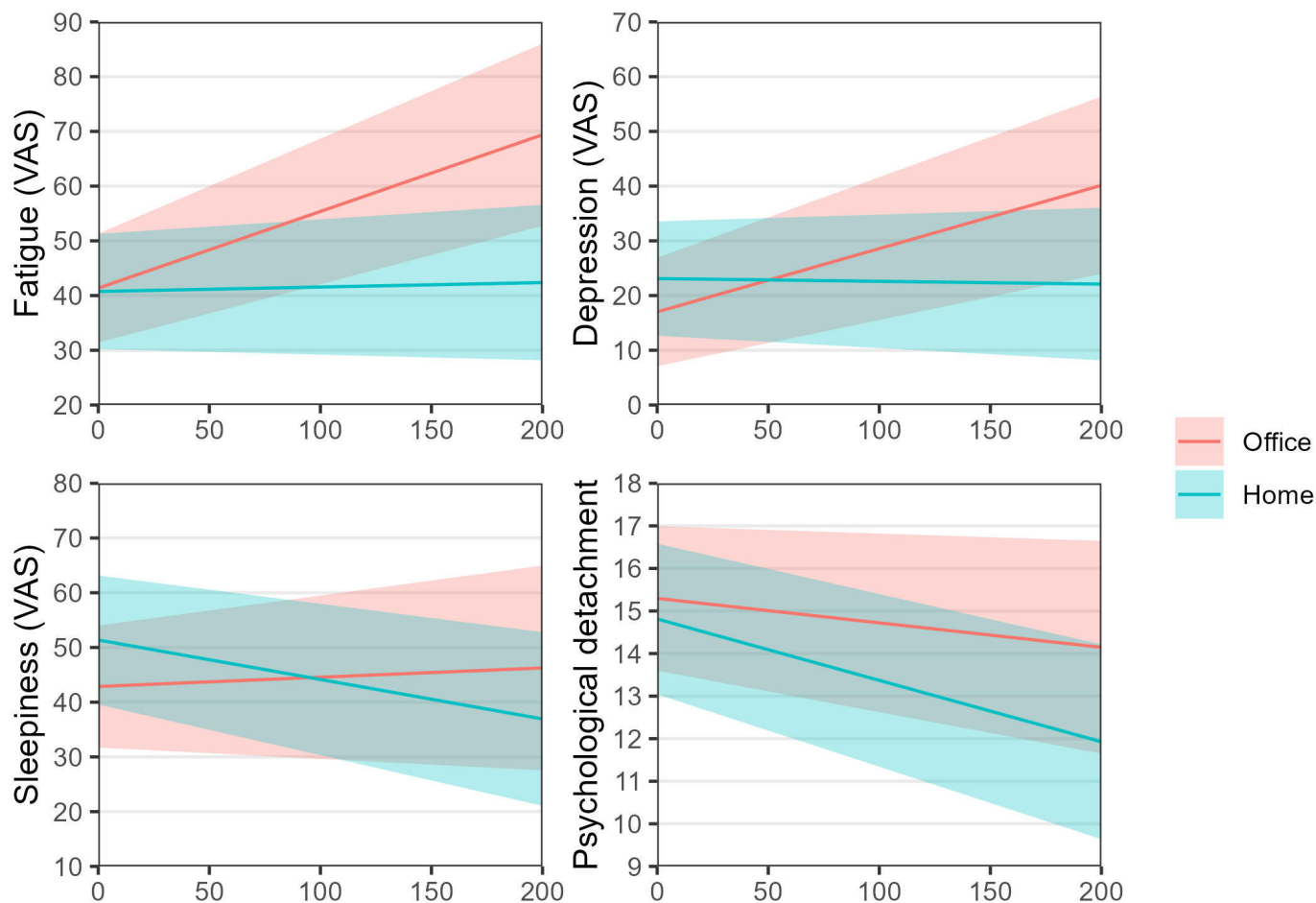
Sensitivity analyses regarding significant outcomes with adjustments for BMI, number of employees, marital status, number of people living together, smoking status, alcohol status and occupation resulted in similar findings (online supplemental table 2).

## DISCUSSION

The present study examined the interaction effects between WREC during non-working hours and work style on health. The results showed that (1) the frequency of WREC was significantly higher and that the duration of WREC was significantly longer for working mostly from home than for working mostly from the office, (2) the longer the WREC, the worse the fatigue and depression and the lower the lapse before bedtime after working mostly from the office and (3) the longer the video, email and telephone communication during non-working hours, the worse the fatigue, the lower the lapse and the worse the psychological detachment before bedtime, respectively.

WREC during non-working hours was more frequent and longer for working mostly from home than for working mostly from the office, which supports hypothesis 1. Working from home is a work style that uses ICT, and in this environment, WREC using ICT may be more likely to occur during working hours and non-working hours. This study also found that WREC during non-working hours reduced worker health, as was found in previous studies.<sup>1–3</sup> In response, several countries have legislated a 'right to disconnect', which is 'a worker's right to be able to disengage from work and refrain from engaging in WREC, such as emails or other messages, during non-working hours'.<sup>25</sup> The right to disconnect may reduce WREC during non-working hours and health impairment due to WREC. However, Japan and many other countries have not legislated the right to disconnect so far. Except in certain industries or emergency situations, minimising WREC during non-working hours would be beneficial to worker health.

As the WREC became longer, psychological detachment became worse. These results support hypothesis 2 and are consistent with the findings of previous studies.<sup>3</sup> In addition, the longer the WREC, the worse the fatigue and depression and the lower the PVT lapse before bedtime when working mostly from the office but not when working mostly from home. PVT performance reflects behavioural alertness, and total and chronic partial sleep deprivation deteriorated PVT performance.<sup>26</sup> This finding indicated that workers with longer WREC during non-working hours after working mostly from the office experience high levels of fatigue, depression and alertness before bedtime. These results partially support hypothesis 3. These results were adjusted for the emotion regarding WREC as a covariate and indicated that an increase in WREC duration leads to worsened fatigue and depression and increased alertness regardless of emotional valence (positive or negative) about WREC content.



## Work-related electronic communications during non-work hours (min)

**Figure 1** Effects of work style (working mostly from home or the office) and work-related electronic communication (WREC) during non-working hours on subjective ratings (fatigue, depression, sleepiness and psychological detachment) before bedtime adjusted for sex, age, round-trip commute time and valence to WREC. Lines indicate estimated marginal means. Fill indicates 95% CIs. Office indicates working mostly from the office. Home indicates working mostly from home. VAS, visual analogue scale.

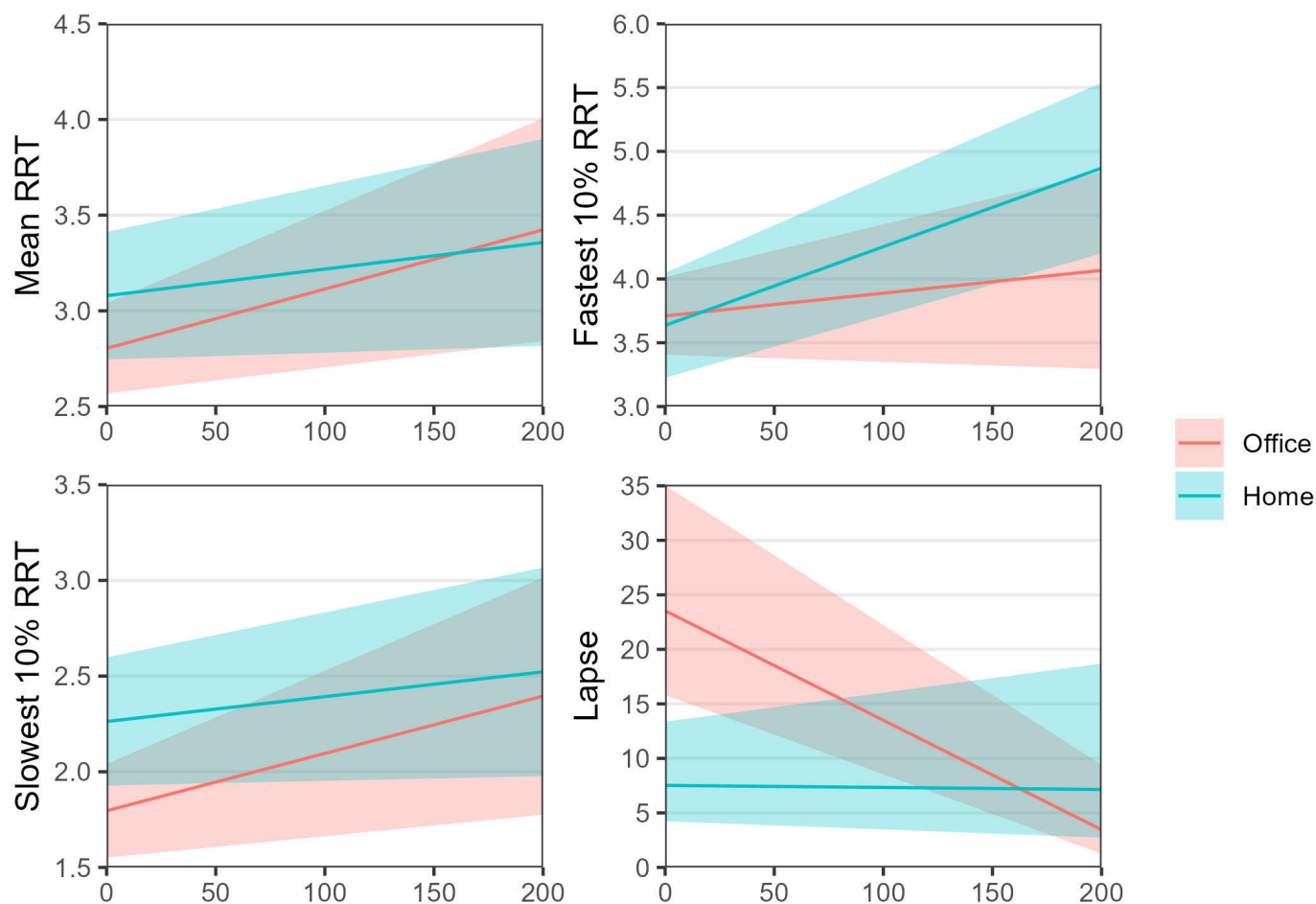
High arousal levels before bedtime lead to a deterioration in sleep quality,<sup>27, 28</sup> which may deteriorate the sleep function of recovery from fatigue. Conversely, the study found no significant main effects or interaction for objective sleep variables. This study did not ask whether WREC was received during sleep. The participants could have received WREC after reporting subjective work–life events (ie, during sleep). WREC, especially telephone calls, during sleep can increase WASO and deteriorate sleep quality. Therefore, further studies are required to elucidate this issue.

Alternatively, the study observed no significant effect of WREC on fatigue, depression and PVT lapse for working mostly from home, and the reason is unclear. A possibility is that working from home blurs the boundaries between work and private life compared with working from the office.<sup>10</sup> Meanwhile, working from the office has clear boundaries between work and private life locationally, and if those who work from the office receive WREC during non-working hours, they may feel that it interrupts their private life, which may lead to adverse effects. In addition, 23.5% of participants who were working mostly from home for all workdays may have used the WREC with ICT more frequently and for longer periods during working hours, such

that they may have become accustomed to WREC. This habituation to WREC may have reduced the negative effects of WREC during non-working hours.

Regarding the methods for WREC, the longer the email communication during non-working hours, the lower the number of PVT lapses before bedtime. Email communication requires a digital device such as a computer, smartphone or tablet and necessitates looking at a bright screen. Blue light, which is emitted by these devices, increases alertness,<sup>29</sup> which may increase arousal levels before bedtime and lead to the decrease in PVT lapse. In addition, the longer the telephone communication during non-working hours is, the worse the psychological detachment from work before bedtime will be. This result was consistent with those of previous studies.<sup>3</sup> Telephone communication during non-working hours reduces the leisure time needed to recover from fatigue and deteriorates psychological detachment from work; these outcomes may lead to restriction of recovery from fatigue. Furthermore, the longer that video communication continues during non-working hours, the worse the fatigue before bedtime becomes. Intensive and/or inappropriate use of videoconferencing tools causes somatic and cognitive exhaustion, as well as the so-called Zoom fatigue

## Workplace



## Work-related electronic communications during non-working hours (min)

**Figure 2** Effects of work style (working mostly from home and office) and work-related electronic communication (WREC) during non-working hours on Psychomotor Vigilance Test (PVT) performance (mean RRT, fastest 10% RRT, slowest 10% RRT and lapse) before bedtime adjusted for sex, age, round-trip commute time and valence to WREC. Lines indicate estimated marginal means. Fill indicates 95% CIs. Office indicates working mostly from the office. Home indicates working mostly from home. RRT, reciprocal response time.

(videoconference fatigue).<sup>30</sup> Video communication during non-working hours may also fit the inappropriate use of videoconferencing tools, and which may cause fatigue.

This study recruited workers identified as working in the information and communications industry, which showed the highest rate of telework adoption by industry in Japan.<sup>9</sup> In addition, the information and communications industry shows the second longest overtime working hours among all industry classifications in Japan.<sup>31</sup> These long working hours due to overtime work can lead to cerebrovascular or cardiovascular diseases<sup>32</sup> and mental disorders.<sup>33</sup> Kan *et al*<sup>34</sup> analysed the characteristics of

51 cases of cerebrovascular/cardiovascular diseases and 85 cases of mental disorders due to overwork between 2010 and 2015 among workers in the information and communications industry in Japan. They reported that many cases featured long working hours and aspects such as tight deadlines and dealing with clients. Furthermore, a survey on industrial safety and health conducted by the Ministry of Health, Labour and Welfare of Japan<sup>35</sup> reported that 26.7% (n=7831) of offices had workers who took leave for mental health problems of more than 1 month during the most recent year; this was the second highest ratio among all industries in Japan. Further, the study found that 11.7%

**Table 3** Relationship between each method of electronic communication and health variables of workers

Coefficient (95% CI)	Fatigue (VAS)	Depression (VAS)	Psychological detachment	Lapse (PVT)
Telephone	0.205 (−0.005 to 0.417)	0.140 (−0.060 to 0.341)	−0.031 (−0.059 to −0.003)*	−0.008 (−0.024 to 0.008)
Mail	−0.030 (−0.175 to 0.111)	−0.002 (−0.142 to 0.133)	0.003 (−0.018 to 0.023)	−0.012 (−0.018 to −0.005)*
Application software with read receipts	0.021 (−0.170 to 0.216)	−0.103 (−0.285 to 0.084)	−0.010 (−0.037 to 0.017)	0.009 (−0.002 to 0.020)
Application software without read receipts	−0.027 (−0.242 to 0.183)	−0.020 (−0.226 to 0.181)	−0.003 (−0.036 to 0.030)	0.001 (−0.016 to 0.018)
Video communication	0.118 (0.003 to 0.230)*	0.106 (−0.0001 to 0.215)	−0.014 (−0.029 to 0.001)	0.001 (−0.005 to 0.006)

\*P<0.05. Adjusted for work style, sex, age, round-trip commute time and valence to work-related electronic communication (WREC).

PVT, Psychomotor Vigilance Test; VAS, visual analogue scale.

of offices had workers who had retired due to mental health problems during the previous year, the highest ratio among all industries in Japan. This study found that WREC during non-working hours was associated with fatigue and depression when working mostly from the office, and continuous WREC during non-working hours may be associated with mental health problems. Therefore, WREC during non-working hours should be minimised in the information and communications industry and in all industries.

This study has its limitations. First, it focused on information technology workers who frequently conduct working from home.<sup>9</sup> They may frequently use ICT in their daily work and may be relatively familiar with using WREC with ICT. However, whether or not similar results can be obtained in other types of industry remains unclear. Second, in this study, 47% of the participants varied their work styles on a daily basis. Studies using a cross-over design or intervention studies are required to further clarify the effects of WREC. Third, in this study, PVT and self-reporting (work style, WREC and subjective ratings) were measured using participants' use of smartphones before bedtime. Although we used the short version of PVT (3 min), use of digital devices may have affected sleep variables. Fourth, this study did not calculate the target sample size before conducting screening; therefore, significant main effects and/or interactions may not be present due to lack of statistical power.

In conclusion, this study examined the effects of WREC during non-working hours on health after working from home or office. The results demonstrated that the longer the WREC, the worse the fatigue and depression and the lower the PVT lapse before bedtime after working mostly from office. Especially, longer telephone, video and email communication during non-working hours led to worse psychological detachment and fatigue and lower lapse before bedtime. Sleep provides recovery from fatigue, but high levels of fatigue, depression and alertness before bedtime may influence sleep quality and reduce the positive effects. Therefore, WREC during non-working hours, especially for those working mostly from office, should be minimised if possible.

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