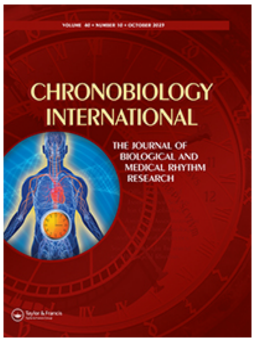

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Better alignment between circadian preference and sleep and work timings during COVID-19 did not benefit work engagement at home

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ABSTRACT

Modern society is structured around early routines which cause evening types to suffer from health and performance detriments associated with sleep times being misaligned with biological needs (circadian preference). Given that COVID-19 lockdowns were less constrained by social schedules, the current study explores whether temporal behaviours became better aligned with biological needs, and whether these changes benefited work engagement. 406 UK participants reported circadian preference and pre-lockdown and lockdown sleep times, work times, and work engagement. Results found that sleep health improved under lockdown measures in terms of increased sleep duration and reduced social jetlag, and sleep and work times became better aligned with circadian preferences. The most circadian-misaligned participants – students and young adults – exhibited the largest changes to sleep and work habits. However, work engagement decreased more in participants with improved social jetlag and delayed work habits, which is surprising given that these temporal changes reflect improved circadian alignment. We discuss potential moderators including poor sleep quality, non-engaging work-from-home environments, and mental health. These findings have implications for encouraging flexible educational and employment schedules post-COVID-19 to satisfy the common drive to improve circadian alignment, but future work must determine the moderating factors that impair work engagement during remote work.

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Sleep; circadian alignment; chronotype; entrainment; work engagement; COVID-19

Introduction

The World Health Organisation (WHO) declared the outbreak of the novel coronavirus disease (COVID-19) a global pandemic on 11th March 2020, and by April 2020, one-third of the global population was living under lockdown measures (The Lancet 2020). The stay-at-home orders caused individuals to experience reduced natural sunlight (Korman et al. 2020), reduced physical activity (Cheval et al. 2020), increased screen time (Cellini et al. 2020), increased financial, medical, and caregiving stressors associated with COVID-19 (Gao and Scullin 2020), and changes to employment, educational, and social routines (Korman et al. 2020). It is widely established that these factors (i.e., zeitgebers; Aschoff and Meyer-Lohmann 1954) affect the timing of sleep, and therefore the impact of COVID-19 lockdowns on temporal behaviour is of global interest. Here, for the first time, we seek to understand the consequences of changes to biological-societal clock entrainment for work and studying.

A mounting body of evidence has demonstrated that the timing of the sleep-wake cycle in relation to the solar day (phase of entrainment; Roenneberg 2015) shifts under lockdown measures. One study investigated sleep habits in 7517 participants from 40 countries and found that phase of entrainment (calculated from the midpoint of sleep; Roenneberg et al. 2015) was delayed by 34 minutes after one month of lockdown measures. The largest delay occurred on work days (+50 minutes) versus free days (+22 minutes). Consequently, social jetlag – the degree of misalignment between sleep times on work days and free days – was greatly reduced under lockdown measures. These results are consistent with longitudinal survey data, retrospective survey data, daily sleep log data, salivary melatonin, and crowdsourced smartphone databases (AMHSI Research Team 2021; Blume et al. 2020; Cellini et al. 2020; Lee et al. 2020; Leone et al. 2020; Liu et al. 2020; Marelli et al. 2021; Salehinejad et al. 2020; Wright et al. 2020; Yuksel et al. 2021; for review, see Richter et al. 2023). Given that the population consists of more evening chronotypes than morning chronotypes (Adan and Natale 2002; Roenneberg et al. 2007), but educational and employment start times are better suited to those who wake and sleep early, perhaps lockdown sleep delays and reduced

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social jetlag reflect sleep times becoming aligned with biological sleep needs rather than societal sleep needs.

In support, changes to sleep times during lockdown primarily affected work days, particularly wake times, whilst sleep times on free days showed smaller changes (Korman et al. 2020). This is suggestive of reduced social zeitgebers on work days driving lockdown sleep changes (Wittmann et al. 2006). In contrast, changes to environmental zeitgebers, such as light exposure, would be expected to affect sleep times on work and free days similarly. Korman et al. also found that those suffering the most from social jetlag before the lockdown experienced greater changes to sleep times during lockdown, further suggesting that a need to adjust to relaxed social schedules drove changes to sleep times during lockdown (Korman et al. 2020). In addition, younger adults exhibited greater sleep delays during lockdown compared to older adults (Korman et al. 2020; Lee et al. 2020; Leone et al. 2020; Marelli et al. 2021), which is unsurprising given that the biological preference for late sleep and wake times peaks in early adulthood (Roenneberg et al. 2004, 2007). In light of growing evidence that populations globally took advantage of the opportunity to improve circadian alignment during COVID-19 lockdowns, a critical question that is yet to be determined is whether this alignment benefitted aspects of work performance for those in employment and studying performance for those in education.

This suggestion has theoretical and practical implications because the importance of circadian alignment for studying and work performance is well established – the "synchrony effect" (May et al. 1993). Performance at work is difficult to measure objectively, but "work engagement", as assessed by the Utrecht Work Engagement Scale (UWES-9; Schaufeli et al. 2006), is gaining increased attention in organisational psychology as a measure of job success and is associated with several performance indices including employee attendance and retention, sales, and customer satisfaction (Bakker et al. 2014; Harter et al. 2003). Using this measure amongst 247 employees, it was found that the most circadian-misaligned employees (evening types), exhibited poorer work engagement as well as greater work burnout (the negative end of the work engagement continuum; Maslach et al. 2001; Waleriańczyk et al. 2019). Similarly, eveningness and increased social jetlag have been linked to lower job satisfaction (Tomaka 2015), lower self-reported work ability (Yong et al. 2016), and less favourable supervisor ratings (Yam et al. 2014). Moreover, intervention efforts have shown that when night shift workers' schedules are adjusted to align with individual circadian preferences, employees show improved social jetlag, sleep duration, sleep quality, and self-reported well-being on work days (Vetter et al. 2015), as well as reduced procrastination (Kühnel et al. 2015). Hence, circadian-misaligned employees are disadvantaged at work, and these findings highlight the need to determine whether work performance might have benefitted from adapting sleep and work habits to fit chronobiological needs during COVID-19 lockdowns.

The UWES-9 has also been validated for use in students for assessing academic engagement and is related to exam success (Carmona-Halty et al. 2019; Schaufeli et al. 2002). However, to the best of our knowledge, this scale is yet to be utilised in a student population in relation to circadian alignment. To demonstrate the synchrony effect within the educational sector, one study showed that when educational routines are delayed (start at 17:20 and finish at 21:40) to better match adolescent students' circadian preference for eveningness, students exhibit longer sleep durations, reduced social jetlag and a delay to the midpoint of sleep (Goldin et al. 2020). Increased alignment between chronotype and school start time was also associated with higher academic performance (Owens et al. 2010; Wheaton et al. 2016). Hence, when early educational routines are removed as a zeitgeber, sleep is adjusted to better align with chronobiological needs and cognitive performance benefits are seen. Similarly, another study analysed the 24-hour circadian profile of 190 undergraduate students and found that studying performance begins to peak 2–3 hours after (11:00–12:00) typical university start times and the optimal performance plateau continues until much later than university finish times (21:00–22:00; Evans et al. 2017). In fact, there is an ongoing debate urging policymakers to delay educational routines for these reasons (Adolescent Sleep Working Group 2014). Hence, similarly to work performance, research must determine whether the lack of structured educational routines during COVID-19 lockdowns enabled students to adapt sleep and studying times to better suit circadian preferences, and whether engagement with studying benefitted as a result.

The first UK COVID-19 lockdown presents a rare opportunity to investigate the effects of changes to sleep and work habits in a naturalistic setting that was less constrained by social zeitgebers. The current study aims to further current literature showing that individuals adapted sleep times under lockdown conditions to better align with circadian preferences and subsequently improve social jetlag. Beyond this, this study investigates for the first time whether work/studying times were similarly better aligned with circadian preferences during lockdown. This study also attempts to provide the first evidence for improved social jetlag and alignment between sleep/work times and circadian preferences benefiting work engagement. These findings will contribute to the small, but growing, body of evidence using the UWES-9 to exhibit synchrony effects, particularly for students. Demographic variables will be assessed to explore changes to sleep and work habits amongst different demographics (see supplementary materials) and we investigate whether these variables might moderate effects on work engagement (Collins et al. 2021; Feng and Savani 2020; Lee et al. 2020; Lin et al. 2021; Rubin et al. 2020).

Method

The target sample size and stopping rule rationale, hypotheses, data exclusion criteria, and analysis plans were all pre-registered and are available at https://osf.io/ue6jm. Any variations from pre-registration (e.g., exploratory analyses and data transformation) are indicated and justified in the text.

Participants

Participants were recruited through the Royal Holloway participant pool and word-of-mouth, and took part in exchange for course credits or the chance to win an Amazon voucher. The target sample size was determined in G*Power (Faul et al. 2009), using an effect size investigating whether phase of entrainment predicts work engagement (when $f^2 = 0.021$, $\alpha = 0.05$, power = 0.80; Waleriańczyk et al. 2019). This a priori power analysis showed that a sample size of 462 participants would meet the above statistical criteria. We planned to oversample because we had several exclusion criteria, but we also pre-registered a stopping rule of six weeks data collection due to the rapidly-changing nature of UK government restrictions.

Data were collected from 487 UK residents, but data from 81 participants had to be excluded: 57 who failed two or more attention checks, 7 who reported finding it extremely difficult to remember work or sleep habits before or during lockdown, 14 who had missing data for all analyses, and 3 who reported sleep durations of less than 3 hours or more than 14 hours. Therefore, data for 406 participants (mean age [SD] = 24.72 [9.56], age range 18–61, 21.9% males) is reported. See Table 1 for demographic information. All participants gave their informed consent, and the study was given ethical approval by the Research Ethics Committee at Royal Holloway, University of London.

Procedure

Participants completed an anonymous online questionnaire, lasting approximately 15 minutes, using the Qualtrics survey platform (Qualtrics 2014). The online questionnaire consisted of demographic information, the Morningness-Eveningness Questionnaire – Reduced (MEQr; Adan and Almirall 1991), the Munich ChronoType Questionnaire – Core (MCTQc Roenneberg et al. 2003), the Utrecht Work Engagement Scale – Shortened Version (UWES-9; Schaufeli et al. 2006), and questions to assess working habits as well as characterisation questions (described below). Given that the MEQr assesses circadian preference, which is a stable psychological trait (Roenneberg 2015), participants answered the MEQr and other demographic questions once. Participants answered all other questions twice; once referring to "before lockdown" and once referring to "during lockdown." "before lockdown" was described as "an average week before March 2020 when social and professional/educational routines were normal," whereas "during lockdown" was described as "an average week during March/April 2020, at the height of the first national UK lockdown, when individuals were not allowed to leave their homes except for essential shopping and exercise." Data were collected between 24th November 2020–5th January 2021, during the second and third UK COVID-19 lockdowns, therefore many social restrictions were in place during data collection. Participants were advised to refer to diaries and smart watches/sleep trackers if possible. Notably, the first UK COVID-19 lockdown began on 23rd March with restrictions easing towards late May 2020. During this time, a stay-at-home order was enforced which made it illegal for individuals to leave the house except for one hour of exercise per day, medical needs, work if work-from-home was impossible, and essential purchases.

Table 1. Demographic information for final sample of participants split by age.

	18–20 (*n* = 203)	21–30 (*n* = 143)	30+ (*n* = 60)	Overall (*n* = 406)
Gender				
Male	15%	30%	27%	22%
Female	85%	70%	73%	78%
MEQr Score				
Mean (*SD*)	11 (3.5)	14 (3.2)	16 (4.0)	13 (3.8)
Lockdown Employment				
Worker	11%	71%	88%	44%
Student	70%	23%	3%	44%
Not Working	18%	6%	8%	13%

Materials

Demographic information

Demographic variables that were expected to moderate changes to sleep and work habits during lockdown or the effect of circadian alignment on work engagement were assessed. Specifically, age, gender, primary employment status during lockdown, extent of caregiving and housework responsibilities during lockdown, and length of commute before lockdown were measured. Given the retrospective nature of this study, we also included characterisation questions to assess how difficult participants found it to remember, and make judgements about, sleep and work habits before or during lockdown. Answers to these questions formed the basis of one of our exclusion criteria. There was an additional characterisation question to determine participants' subjective assessment of how changes to temporal behaviour affected work engagement.

The Morningness-Evenigness Questionnaire – Reduced (MEQr)

Circadian preference was assessed using the Morningness-Eveningness Questionnaire – Reduced (MEQr; Adan and Almirall 1991) which consists of 5 items that determine preferred times for sleep and waking, morning and evening alertness, and "feeling best" rhythms. The MEQr is used to assess circadian preference because it measures chronotype as a stable psychological trait (Roenneberg 2015). The minimum score on MEQr is 4 and the maximum score is 25. Lower scores indicate a preference for eveningness and higher scores indicate a preference for morningness. MEQr scores correlate strongly ($r = 0.90$; Adan and Almirall 1991), with the original 19-item questionnaire which has been widely used (Horne and Östberg 1976), and the MEQr has been validated against sleep timings derived from actigraphy data such that lower MEQr scores (preference for eveningness) correlate with later sleep times ($r = -.34$; Natale et al. 2006).

The Munich ChronoType Questionnaire – Core (MCTQc)

The Munich ChronoType Questionnaire – Core (MCTQc; Roenneberg et al. 2003) uses 14 items to assess sleep behaviour on work days and free days. Specifically, the MCTQc determines the local time that defines the midpoint between an individual's sleep onset and sleep offset on free days, and this time (after correcting for sleep debt; Roenneberg et al. 2007) represents their phase of entrainment. Midpoint of sleep, as measured by the MCTQc, has high test-retest reliability ($r = .88$; Kühnle 2006), and has good external validity when compared to sleep timings measured from wrist actigraphy ($r = .73$; Santisteban et al. 2018) and dim light melatonin onset ($r = .68$; Kantermann et al. 2015).

The MCTQc also produces a social jetlag score which measures the difference in sleep times on work days and free days caused by a discrepancy between an individual's midpoint of sleep and their social clock (Wittmann et al. 2006). Social jetlag is computed using the difference between midpoint of sleep on work days and midpoint of sleep on free days after correcting for sleep debt (Jankowski 2017). The following sleep habits were also recorded using the MCTQc: work day sleep duration, free day sleep duration, midpoint of sleep on work days, midpoint of sleep on free days, work day sleep onset, free day sleep onset, work day sleep offset, and free day sleep offset (Roenneberg et al. 2012).

The Utrecht Work Engagement Scale – Shortened Version (UWES-9)

Work engagement was measured using the Utrecht Work Engagement Scale – Shortened Version (UWES-9; Schaufeli et al. 2006) which is a nine-item questionnaire assessing work engagement across 3 domains; vigour, dedication, and absorption. Vigour measures levels of energy and resilience towards work, dedication measures feelings of pride and inspiration towards work, and absorption measures the extent to which an individual is immersed in their work. The questions incorporated the wording of both the UWES-9 and the UWES Student Version (Schaufeli et al. 2002). All items are answered on a 7-point Likert scale ranging from *0 = never* to *6 = always*. Following recommendations (Schaufeli et al. 2006), a total work engagement factor score was computed rather than scores for each subscale. Total score was computed by summing scores from all items and dividing by the number of items. Therefore, the minimum score is 0 and the maximum is 6 with higher scores indicating higher work engagement. UWES-9 has excellent internal consistency ($\alpha = .93$; Schaufeli and Bakker 2003).

Working habits

To investigate typical working habits before and during lockdown, we included two additional questions to assess work start times and work finish times. We calculated the midpoint of the working day as the local time that defines the midpoint between work start and work finish times.

Statistical analyses

In line with the pre-registered exclusion criteria, 52 participants were excluded from all work analyses because they were unemployed before ($n = 4$) or during ($n = 9$) lockdown or they were furloughed during lockdown ($n = 39$). Data regarding work timings were excluded for 24 participants because they reported finding it extremely difficult to make judgements about work times before or during lockdown due to the fragmented nature of their working day. Sleep midpoint could not be calculated for 95 participants before lockdown and 85 participants during lockdown because they did not report sleep times on free days without the use of an alarm clock which is a requirement for using the MCTQc (Roenneberg et al. 2003). Although not pre-registered, participants were also excluded from work analyses if they reported working outside of the home during lockdown ($n = 38$) because the current study aims to investigate changes to work habits and work engagement in a work-from-home environment. There were missing responses, therefore, the n of each statistical analysis is reported.

To determine the magnitude of lockdown-related changes in temporal behaviours, deltas (Δ) were calculated as [lockdown – pre-lockdown] for each parameter. Hence, negative Δ indicate an earlier (e.g., midpoint of sleep) or reduced (e.g., social jetlag) parameter during lockdown compared to before lockdown, whereas a positive value indicates a later or greater parameter during lockdown. See supplementary materials for an explanation as to why deltas were not transformed as per the pre-registration for work engagement analyses.

As an exploratory analysis, we decided to statistically compare all sleep and work parameters (beyond the pre-registered analyses for social jetlag and sleep duration) before and during lockdown to characterise average lockdown-related changes in temporal behaviour. Given that within-participant changes to sleep and work habits did not always follow a normal distribution, Wilcoxon Matched-Pairs two-tailed tests were used, and the standardised Z statistics and effect sizes are reported. Effect sizes were calculated according to $r = Z/\sqrt{N}$ (Rosenthal 1994). Significance levels were Bonferroni corrected for multiple comparisons and corrected values are reported.

Linear regression models were used to investigate whether sleep and work habits changed according to circadian preference and whether this alignment predicted work engagement change. Key regression assumptions were satisfied in all models (Williams et al. 2013). ANOVAs were used for model comparison.

Statistical analyses were performed in R (R Core Team 2013), and p values were obtained using Satterthwaite approximations (package *lmerTest*; Kuznetsova et al. 2017). All figures were made using the *ggstatsplot* and *ggplot2* packages (Patil 2018; Wickham 2016). Data and analyses code can be accessed from https://osf.io/jnfrv/.

Results

How did sleep habits change during lockdown?

Compared to pre-lockdown, sleep duration did not change on lockdown free days, but there was a large, significant increase in work day sleep duration (Figures 1a,b; for sleep onset and offset times, see supplementary Figures S1 and S2). The midpoint of sleep delayed significantly (Figure 1c), and this was driven mostly by work days (supplementary Figure S3). Social jetlag (the difference between work day and free day sleep times) decreased significantly during lockdown (Figure 1d). Table 2 displays the descriptive and inferential data for each comparison of pre-lockdown versus lockdown sleep habit parameters.

How did work habits change during lockdown?

The length of the working day decreased significantly during lockdown (Figure 2a), and the timing of the working day (midpoint) was significantly delayed (Figure 2b) which was driven by a large delay in work start times (supplementary Figure S4). Work engagement also decreased significantly during lockdown (Figure 2c). Table 3 displays the descriptive and inferential data for each comparison of pre-lockdown versus lockdown work habit parameters.

Did changes to sleep and work habits represent better alignment with circadian preference?

Three linear regression models examined whether changes to sleep and work habits during lockdown represented better alignment with circadian preference. Circadian preference (MEQr score) was the predictor in all three models and the dependent variable was either Δ sleep midpoint, Δ social jetlag, or Δ working day midpoint. Later circadian preferences (lower MEQr scores) significantly predicted greater delays in lockdown sleep midpoint (Figure 3a) and working day midpoint (Figure 3c) as well as reduced social jetlag (Figure 3b) during lockdown. See Table 4 for model summary statistics. Of note, see the supplementary materials for analyses investigating whether demographic variables predicted changes to sleep and work habits during lockdown.

Does greater alignment between temporal behaviour and circadian preference predict improved work engagement?

Three regression analyses were performed to investigate whether increased alignment between sleep/work habits and circadian preference predicts better work engagement during lockdown compared to pre-lockdown. The dependent variable was Δ work engagement in all analyses and predictor variables were included in

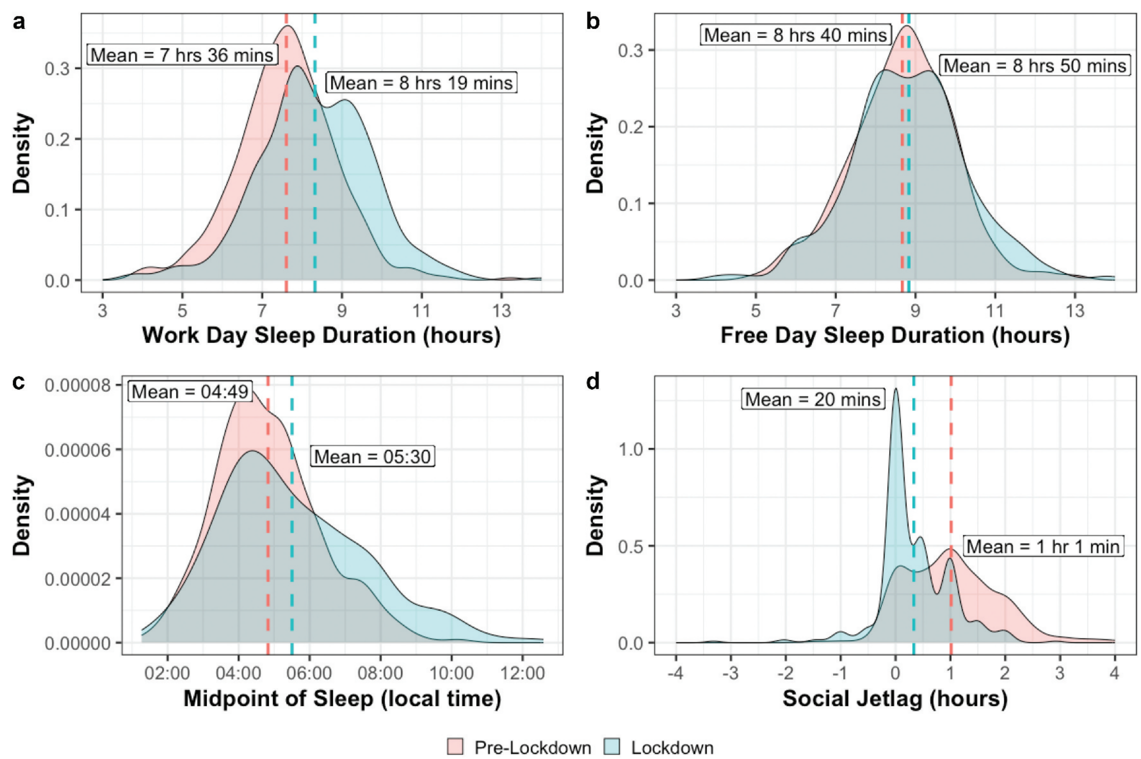

Figure 1. Distributions of (a) work day sleep duration, (b) free day sleep duration, (c) midpoint of sleep, and (d) social jetlag before (red) and during (blue) lockdown. Vertical dashed lines represent the means.

Table 2. Comparisons between pre-lockdown and lockdown for each sleep habit parameter. Means for sleep duration and social jetlag variables represent number of hours and minutes. Means of all other variables represent clock time (hh:mm). Standard deviations for all variables represent number of minutes. Z statistics, bonferroni-corrected *p* values, effect sizes (r), and number of observations for each wilcoxon matched-pairs test are also reported.

Sleep Habit	Pre-Lockdown Mean (*SD*)	Lockdown Mean (*SD*)	*Z*	*p*	*r*	*n*
Work Day Sleep Duration	7 hours 36 mins (±75 mins)	8 hours 19 mins (±85 mins)	−8.67	<0.001	0.43	406
Free Day Sleep Duration	8 hours 40 mins (±77 mins)	8 hours 50 mins (±88 mins)	−2.08	0.375	0.10	406
Work Day Sleep Onset	23:51 (±81 mins)	00:48 (±130 mins)	−10.55	<0.001	0.52	406
Free Day Sleep Onset	00:56 (±94 mins)	01:12 (±123 mins)	−3.52	0.004	0.17	406
Work Day Sleep Offset	07:27 (±89 mins)	09:08 (±139 mins)	−14.09	<0.001	0.70	406
Free Day Sleep Offset	09:36 (±100 mins)	10:02 (±125 mins)	−6.76	<0.001	0.34	406
Phase of Entrainment	04:50 (±89 mins)	05:30 (±122 mins)	−6.87	<0.001	0.40	288
Work Day Midpoint of Sleep	03:38 (±77 mins)	04:58 (±128 mins)	−13.79	<0.001	0.68	406
Free Day Midpoint of Sleep	05:15 (±89 mins)	05:37 (±116 mins)	−5.62	<0.001	0.28	406
Social Jetlag	61 mins (±51 mins)	20 mins (±39 mins)	−12.02	<0.001	0.60	406

three steps. Demographic variables were included in the first step, and Δ work day sleep duration was included in the second step. In the final step, either Δ sleep midpoint, Δ social jetlag, or Δ working day midpoint was included depending on the analysis. Predictors were kept in the model if they improved model fit as determined by model comparison. Three separate regression analyses were necessary because models with different numbers of observations cannot be statistically compared, and the number of observations that could be included for each of the main predictor variables varied.

Quadratic terms centred on the mean were included for the Δ sleep midpoint and Δ working day midpoint variables because it captures whether advances (alignment in morning types) *and* delays (alignment in evening types) predict Δ work engagement. A linear term was sufficient for the Δ social jetlag model since social jetlag is a measure of (mis)alignment in itself. In all three analyses, the demographics only model significantly predicted Δ work engagement (*ps* < .001) and the inclusion of Δ work day sleep duration did not significantly improve model fit (*ps* .180–.281). Results from the final step of each analysis are reported below.

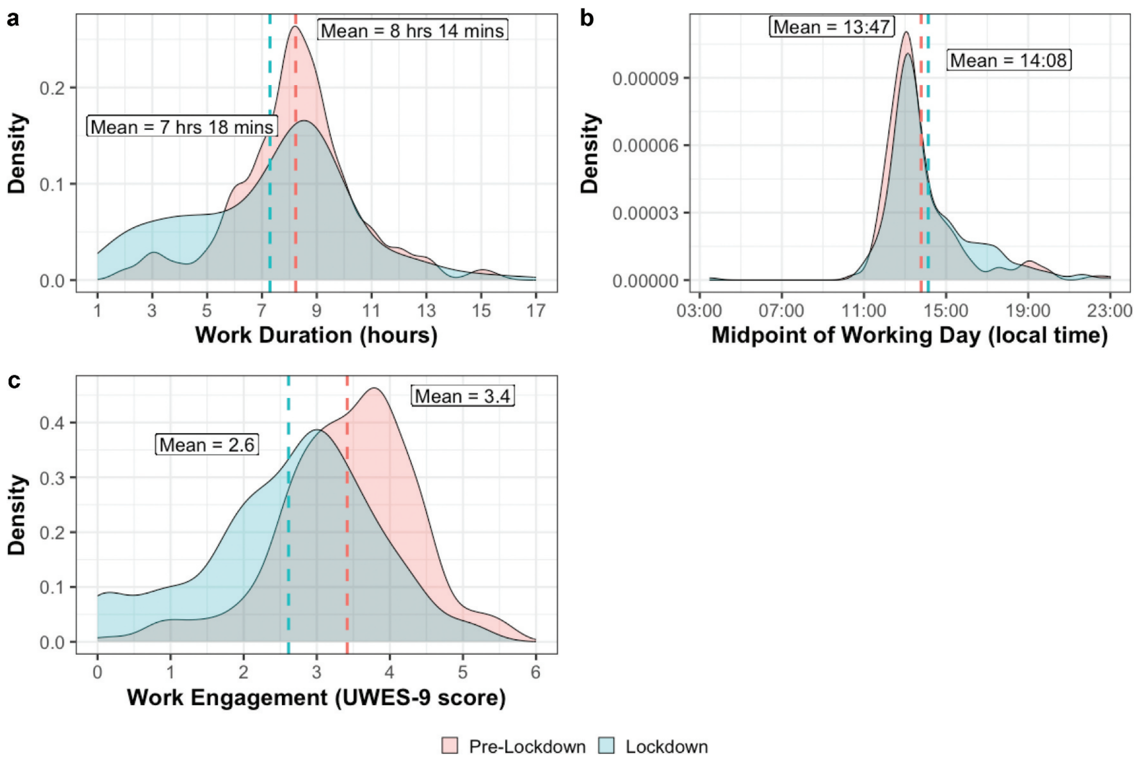

Figure 2. Distributions of **(a)** work duration, **(b)** the midpoint of the working day, and **(c)** work engagement before (red) and during (blue) lockdown. Higher UWES-9 scores indicate greater work engagement. Vertical dashed lines represent the means.

Table 3. Comparisons between pre-lockdown and lockdown for each work habit parameter. Means and standard deviations for the work duration variable represent number of hours and minutes. Means and standard deviations for the work engagement variable represents score on the UWES-9 scale where higher scores indicate better work engagement. Means of all other variables represent clock time (hh:mm) and standard deviations for all other variables represent number of minutes. Z statistics, bonferroni-corrected *p* values, effect sizes (r), and number of observations for each wilcoxon matched-pairs test are also reported.

Work Habit	Pre-Lockdown Mean (*SD*)	Lockdown Mean (*SD*)	*Z*	*p*	*r*	*n*
Work Duration	8 hours 14 mins (±133 mins)	7 hours 18 mins (±184 mins)	−4.97	<0.001	0.30	275
Midpoint of Working Day	13:47 (±119 mins)	14:08 (±131 mins)	−3.58	0.002	0.22	276
Work Start Time	09:40 (±142 mins)	10:34 (±177 mins)	−5.97	<0.001	0.36	276
Work Finish Time	17:54 (±129 mins)	17:52 (±147 mins)	−0.25	1.00	0.01	276
Work Engagement	3.42 (±0.93)	2.61 (±1.17)	−12.05	<0.001	0.68	310

Table 5 displays the model summary statistics for significant predictors in the final models of all three regression analyses (see supplementary Table S2 for summary statistics of all predictors).

In the Δ sleep midpoint model, linear and quadratic terms for Δ sleep midpoint did not significantly improve model fit ($p = 0.301$). Lockdown employment was the only significant predictor in the final model with students showing greater decreases in work engagement compared to workers.

For the Δ social jetlag model, inclusion of this predictor significantly improved model fit ($p < 0.001$). In contrast to our main hypothesis, decreased (improved) social jetlag during lockdown predicted greater decreases in work engagement during lockdown (Figure 4). These findings are in line with participants' subjective assessments. Specifically, a large proportion of participants believed that sleep habit changes negatively or very negatively affected their vigour (48.1% of participants), dedication (52.2%), and absorption (52.2%) with work during lockdown. Notably, students and females also showed greater decreases in work engagement during lockdown compared to workers and males.

For the Δ working day midpoint model, the inclusion of linear and quadratic terms for this predictor significantly improved model fit ($p = 0.005$). However, only the linear term was

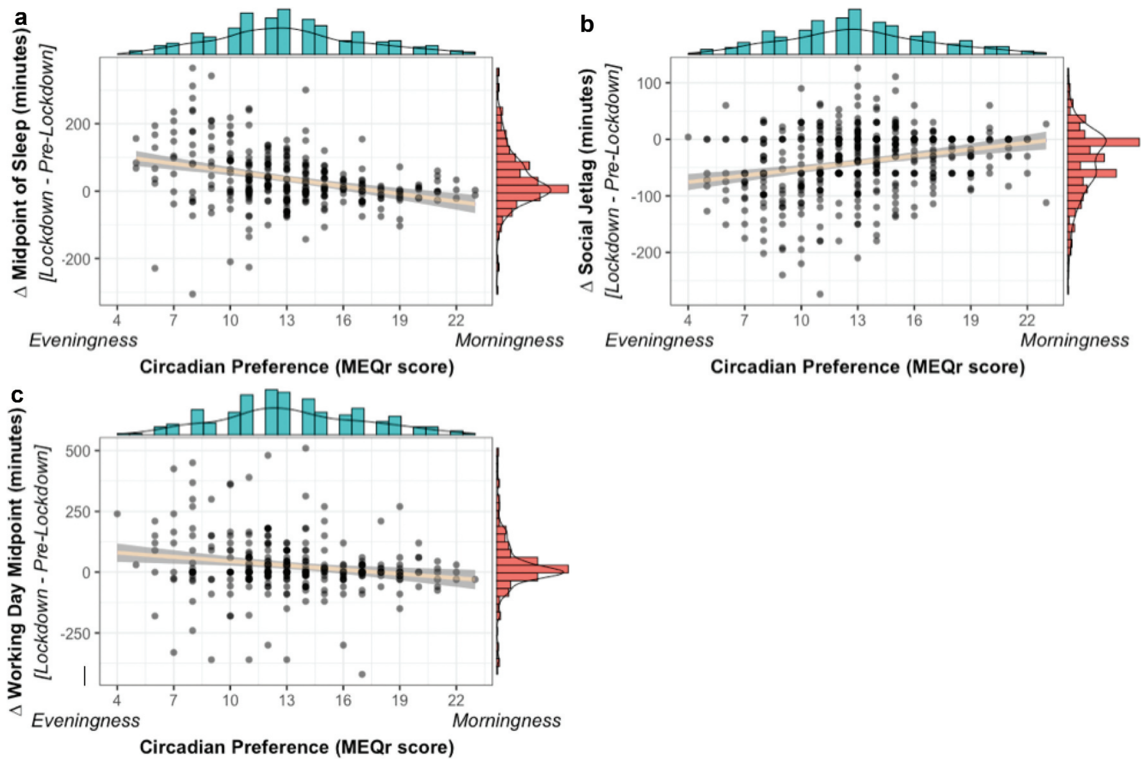

Figure 3. Scatterplots displaying circadian preference against **(a)** midpoint of sleep change, **(b)** social jetlag change, and **(c)** working day midpoint change. Positive values on the y axis indicate delayed lockdown sleep midpoint (3a) and working day midpoint (3c) compared to pre-lockdown, or increased social jetlag during lockdown compared to pre-lockdown. Densigram on the x axes (above the figures) displays the distribution of circadian preference (MEQr score). Densigram on the y axes (right of figures) displays the distribution of Δ midpoint of sleep (3a), Δ social jetlag (3b), and Δ working day midpoint (3c).

Table 4. Model summary statistics for the three linear regression models with circadian preference as the only predictor variable and Δ midpoint of sleep, Δ social jetlag, or Δ working day midpoint as the dependent variables (DVs).

Model DV	R^2	F	n	t	β	p
Δ Midpoint of Sleep	10.42%	34.39	288	−5.86	−7.49	<0.001
Δ Social Jetlag	6.1%	27.21	406	5.22	3.87	<0.001
Δ Working Day Midpoint	2.8%	9.03	276	−3.0	−5.79	0.003

Table 5. Model summary statistics for significant predictors in the final models of the three linear regression analyses with Δ work engagement as the dependent variable, and demographic variables and either Δ midpoint of sleep, Δ social jetlag, or Δ working day midpoint as the predictor variables (IVs). See supplementary table 2 for full model summary statistics of final models.

Key model IV	Contrast	R^2	F	p	n	t	β	p
Δ Midpoint of Sleep		**8.9%**	**3.68**	<0.001	**220**			
	Students v Workers					3.22	0.54	0.001
Δ Social Jetlag		**11.7%**	**6.85**	<0.001	**310**			
	Δ Social Jetlag					3.87	0.004	<0.001
	Males v Females					−2.01	−0.25	0.046
	Students v Workers					2.84	0.38	0.005
Δ Working Day Midpoint		**8.8%**	**4.32**	<0.001	**276**			
	Δ Working Day Midpoint – Linear Term					−2.63	−0.001	0.009

significant with greater delays in working day midpoint predicting greater decreases in work engagement during lockdown (Figure 5). Given that the results for social jetlag were also in the opposite direction to our hypothesis and aligned with participants' subjective assessments, we ran exploratory analyses to investigate this further. See the supplementary materials for an exploratory analysis investigating whether these results were driven by poor work engagement in evening types.

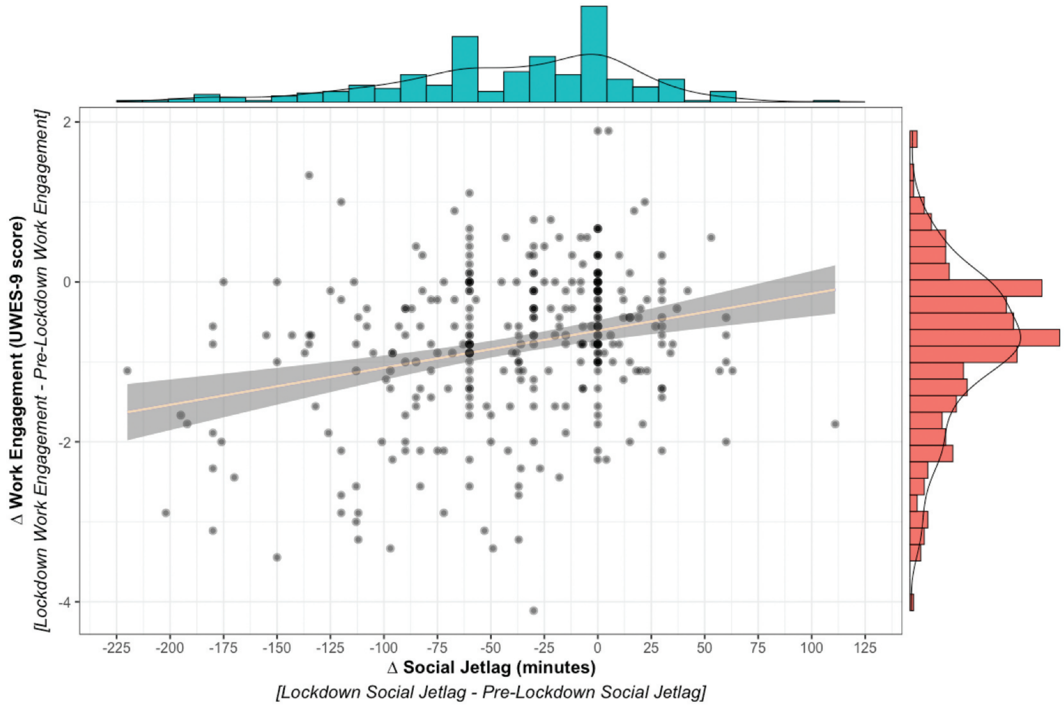

Figure 4. Scatterplot displaying social jetlag change against work engagement change. Positive values on the x axis indicate that social jetlag was greater during lockdown compared to pre-lockdown. Positive value on the y axis indicate that work engagement was greater during lockdown compared to pre-lockdown. Densigram on the x axis (above the figure) displays the distribution of Δ social jetlag. Densigram on the y axis (right of figure) displays the distribution of Δ work engagement.

Discussion

COVID-19 lockdowns presented populations globally with a unique circadian situation where there were fewer social zeitgebers, such as educational and employment schedules, constraining sleep and work times. The current study extends previous research by investigating whether sleep *and* work habits were adapted during the first UK COVID-19 lockdown to align better with individual circadian preferences, and to determine the effects of this alignment on work engagement.

Parallel to large-scale, international efforts (Korman et al. 2020; Leone et al. 2020; Richter et al. 2023; Yuksel et al. 2021), the current study found that individuals slept longer and later under lockdown measures. Daily sleep duration increased by over half an hour and the midpoint of sleep delayed from 04:49 to 05:30. Delays in sleep times were 3–4 times greater on work days compared to free days, therefore, social jetlag became close to absent during lockdown. For the first time, we also show that the midpoint of the working day delayed significantly, and this was driven by large delays in work start times. These findings support the suggestion that social zeitgebers are predominant sources of circadian misalignment (Korman et al. 2020; Skeldon et al. 2017).

The current study also adds to the literature by investigating whether the degree of lockdown-related changes to sleep and work habits is related to circadian preference. A recent study found that sleep times delayed consistently during lockdown irrespective of pre-lockdown chronotype (Korman et al. 2020). Crucially, though, Korman et al. measured chronotype using pre-lockdown midpoint of sleep, whereas the current study uses circadian preference which is a stable psychological trait and is thought to better reflect long-term sleep needs (Roenneberg 2015). Using this measure, we found that later circadian preferences predicted greater lockdown-related delays in sleep and work habits as well as greater reductions in social jetlag. Moreover, whilst the majority of evening (and intermediate) types exhibited some delay to sleep and work, only the most extreme morning types advanced sleep and work. Hence, the extent of temporal behaviour change reflected extremeness in circadian preference, and most circadian preferences would prefer delays to post-lockdown schedules.

It is well established that synchrony between circadian preferences and sleep and work/studying times benefits studying and work performance (Goldin et al. 2020; May et al. 1993; Tomaka 2015; Waleriańczyk et al. 2019; Yong et al. 2016). Surprisingly then, decreased social jetlag and greater delays in work habits here

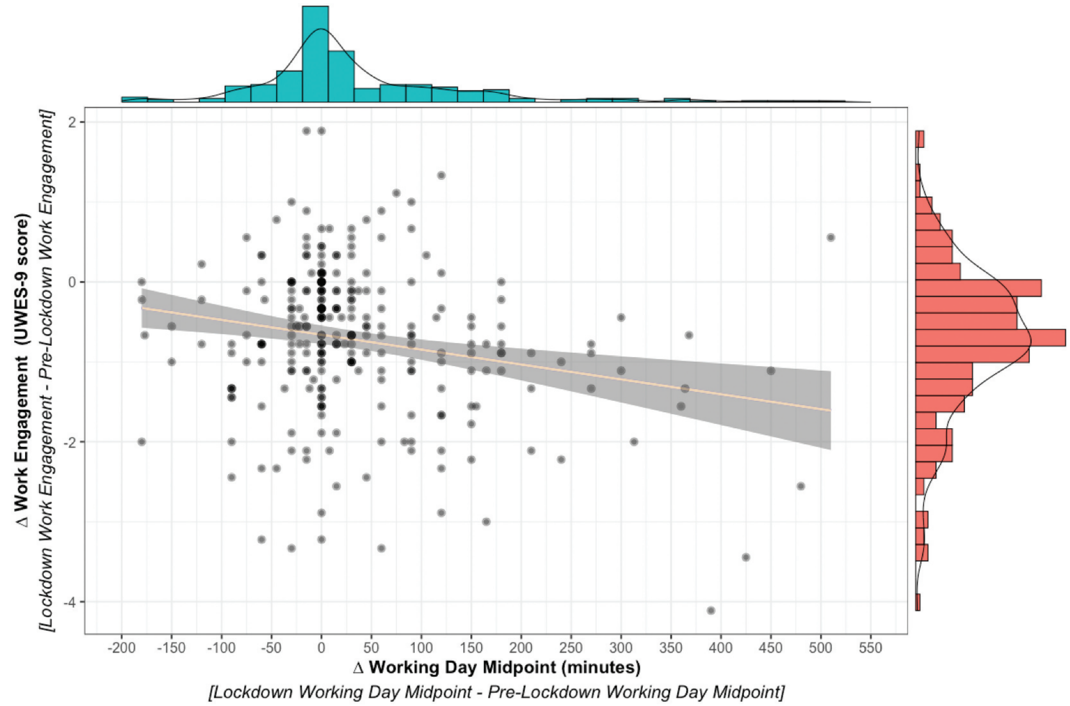

Figure 5. Scatterplot displaying working day midpoint change against work engagement. Positive values on the x axis indicate that the midpoint of the working day during lockdown was delayed (later) compared to pre-lockdown. Positive values on the y axis indicate that work engagement was greater during lockdown compared to pre-lockdown. Densigram on the x axis (above the figure) displays the distribution of Δ working day midpoint. Densigram on the y axis (right of figure) displays the distribution of Δ work engagement.

predicted poorer work engagement despite these changes representing increased circadian alignment. It was predicted post-hoc that circadian preference for eveningness might mediate this relationship. For example, evening types suffer most from sleep difficulties (Giannotti et al. 2002), which are exacerbated under lockdown (Beck et al. 2021; Cellini et al. 2020; Li et al. 2020; for reviews, see; Alimoradi et al. 2021; Jahrami et al. 2021, 2022), and had deleterious effects on resilience (Bazzani et al. 2021; Robillard et al. 2021; Yuksel et al. 2021) which directly impairs work engagement (Khan 2021; Ojo et al. 2021; Schaufeli et al. 2006; Schleupner and Kühnel 2021). Hence, despite improving their social jetlag, perhaps evening types suffered from impairments caused by poor sleep quality which in turn affected their work engagement and are perhaps reflected in their unwillingness to start work early. Crucially, though, exploratory analyses (see supplementary materials) revealed that this could not be the whole story because decreased social jetlag and greater delays in work habits predicted poor work engagement over and above circadian preference.

Instead, perhaps delayed work habits and similar sleep profiles between work and free days are indicators of factors that negatively affect work engagement but were not measured here, for example, non-engaging work environments and mental health. In support, individuals with housework responsibilities delayed work habits more than those without, likely because of an inability to work noninterrupted hours which in turn damages work performance (Collins et al. 2021). Similarly, family-work conflict, distracting work environments, and social isolation (related to "zoom fatigue;" Bailenson 2021) would cause individuals to delay work hours, and these factors predict poorer work engagement during lockdown (Galanti et al. 2021). In addition, improved social jetlag and later work times could reflect oversleeping across the week which is a symptom of mental health difficulties (Zhang et al. 2017). This suggestion is particularly plausible in light of evidence that young adult students were at high risk of poor mental health during COVID-19 (Holmes et al. 2020; Liu et al. 2020) and young adult students had the greatest improvements in social jetlag and delays in work times here. Future work should attempt to delineate this further.

The implications of the current results are far-reaching in terms of sleep health and work engagement at home. In the absence of strict social zeitgebers, sleep duration is lengthened, sleep and work times are delayed, and there is little difference between work and free day circadian profiles. In a post-COVID-19 world, flexible schedules should be more seriously considered so as to satisfy this common drive for improved circadian alignment. However, the current results show that the association between circadian alignment and work engagement, at least in a work-from-home environment, is not straightforward. There was no evidence here for benefits of circadian alignment on work engagement during lockdown. In fact, 80% of participants experienced declines in work engagement despite improved circadian alignment and the greatest work engagement decline was over two times larger than the greatest work engagement increase. Future research should establish which factors are detrimental to engagement in work-from-home environments in order for organisations to benefit most from remote work in the future.

There are limitations to the current study which should be acknowledged. Variables which may have affected work engagement were not obtained, such as sleep quality, work environment, and mental health, but possible roles for these variables are discussed. Responses to pre-lockdown temporal behaviour and work engagement were based on retrospective reports which raises the issue of reporting bias and recall, and the UWES-9 has not been validated for measuring retrospective work engagement. Participants were told to refer to diaries and smart watches/sleep trackers to aid recall, but we did not record the proportion of participants who did so. We did attempt to negate this issue by excluding data for participants who reported finding it extremely difficult to remember and make judgements about sleep and work habits. We also found statistically significant differences in pre-lockdown and lockdown UWES-9 scores suggesting that participants were able to discriminate, and participants' subjective assessments were in line with the quantitative data. In addition, evidence suggests that retrospective survey questions used in COVID-19 studies yield reliable data at the aggregate level, and recall is best for objective facts (e.g., sleep and work times) and when anchor points are used in the questions (e.g., defining the period of COVID-19 restrictions being referred to; Hipp et al. 2020).

Next, exclusion criteria for specific analyses resulted in less than desirable statistical power in some analyses. For this reason, conclusions should be treated tentatively, particularly for analyses where subsets of data were used. However, we recognise the importance of original science versus replication science here (Wilson et al. 2020). Original science serves a vital function in identifying potentially interesting effects, particularly for emerging research areas as is the case here, which then warrant further investigation under replication science. Given the nature of COVID-19 restriction in the UK during 2020, we pre-registered a six-week data collection window so as to prevent confusability during retrospective recall, but this clearly impacted statistical power. Future work should now further investigate the findings reported using better powered experimental designs.

The current sample consists of both students and workers which is potentially problematic given that changes to work characteristics may have varied between these populations during COVID-19 lockdowns. Employment status was included as a covariate throughout the analyses but, as previously mentioned, low statistical power may have rendered this insensitive. Future research should investigate factors affecting work engagement in these populations separately. We also acknowledge that the current sample consists of 78% females and 85% 18–30-year-olds which might raise concerns over the generalisability of the results beyond young adult females. However, the current results are in line with a recent large-scale, international effort (Korman et al. 2020) and several other studies using various methodologies (Cellini et al. 2020; Leone et al. 2020; Wright et al. 2020), which do not suggest that the current findings would be different in males or older age.

To conclude, this study provides novel evidence for individuals adapting their sleep and work habits to better align with circadian needs in a time that was less constrained by social zeitgebers. Hence, a preference for greater flexibility in social schedules can be expected beyond COVID-19. Unfortunately, recommendations as to how this alignment might benefit work engagement cannot be made as this effect was not found and widespread work engagement declines were evident. Future research should consider which factors associated with COVID-19 lockdowns may have diminished the expected effect, such as sleep difficulties, non-engaging work environments, and poor mental health. Future research might replicate the current study in a post-COVID-19 world when individuals who continue to work remotely are less impacted by COVID-related stressors. This work would have important theoretical implications for improving performance in education and employment.

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Data availability statement

The data and analysis scripts underlying this article are available on the Open Science Framework at https://osf.io/jnfrv/.

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