Solar cycles and time allocation of children and adolescents

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Research Summary

Why was the research done?

Understanding how children allocate their time in response to daily solar cycles is crucial within the realm of child development research. This study investigates the time allocation patterns of children and adolescents, with a specific focus on sleep patterns, in relation to variation in daily solar cycles. We contribute to a substantial body of literature examining the interplay between solar cycles and sleep, as well as the emerging research exploring the impact of solar cycles on time allocation among adults and children.

What were the key findings?

Utilizing a dataset of over 50,000 time-use diaries from two Australian cohorts spanning 16 years and employing an individual fixed effects estimator, we uncover a significant correlation between daylight duration and sleep patterns. Our findings reveal that days with longer daylight hours are associated with a decrease in total sleep duration, driven primarily by later sleep onset and earlier wake times. Additionally, longer daylight hours correspond to reduced time spent on personal care and media activities, with increased dedication to school and physical activities. Furthermore, we identify socio-demographic factors moderating these effects, such as older age and weekdays exerting a stronger influence on sleep duration, while children of mothers with lower education or unemployment exhibit a subtle impact.

What does this mean for policy and practice?

In terms of policy implications, our results underscore the importance of considering environmental factors, such as daylight duration, in designing interventions aimed at promoting healthy sleep habits and overall well-being among children and adolescents. Policymakers and educators may need to adjust school schedules or recreational programs to account for variation in daylight length, particularly in regions where these fluctuations are more pronounced. Furthermore, our findings highlight the potential need for targeted interventions tailored to specific demographic groups, such as older individuals or children from socioeconomically disadvantaged backgrounds, to mitigate the adverse effects of longer daylight durations on sleep duration.

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Acknowledgements/Funding Sources

Solar cycles and time allocation of children and adolescents

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This study explores the allocation of time, particularly to sleep, among children and adolescents in response to daily solar cycles. Utilizing a dataset of over 50,000 time-use diaries from two Australian cohorts spanning 16 years and employing an individual fixed effects estimator, we uncover a significant correlation between daylight duration and sleep patterns. Our findings reveal that days with longer daylight hours are associated with a decrease in total sleep duration, driven primarily by later sleep onset and earlier wake times. Additionally, longer daylight hours correspond to reduced time spent on personal care and media activities, with increased dedication to school and physical activities. Furthermore, we identify socio-demographic factors moderating these effects, such as older age and weekdays exerting a stronger influence on sleep duration, while children of mothers with lower education or unemployment exhibit a subtle impact. These insights contribute to our understanding of how environmental factors shape daily routines and offer implications for designing schedules that promote positive developmental outcomes in young individuals.

Keywords: Sleep; Time Allocation; Circadian Rhythms; Solar Cycles; Children.

JEL classifications: I00; I12; J22; J24

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# 1.	Introduction

Understanding how children allocate their time in response to daily solar cycles is crucial within the realm of child development research (Fiorini & Keane 2014; Matricciani *et al.* 2019; Nguyen *et al.* 2022). This study investigates the time allocation patterns of children and adolescents, with a specific focus on sleep patterns, in relation to variation in daily solar cycles. We contribute to a substantial body of literature examining the interplay between solar cycles and sleep (Harrison 2013; Mattingly *et al.* 2021), as well as the emerging research exploring the impact of solar cycles on time allocation among adults (Hamermesh *et al.* 2008; Gibson & Shrader 2018) and children (Jagnani 2022).

This paper advances the existing knowledge in three key aspects. Firstly, it is the first study, to our knowledge, to exclusively investigate the effects of daily solar cycles on the time allocation of young individuals in a developed country such as Australia.[1] While Jagnani (2022) provides early evidence on the impact of daily sunset time on Indian children's sleep and other time uses, such findings may not generalise well to other countries with different socio-economic contexts. Secondly, unlike previous studies employing cross-sectional data (Hamermesh *et al.* 2008; Gibson & Shrader 2018; Jagnani 2022), this paper utilises panel data and an individual fixed effects model to effectively control for time-invariant factors co-varying with daily solar cycles and time allocation. Thirdly, through extensive heterogeneous analysis, this study reveals novel insights into the differential impacts of daily solar cycles on the time allocation of children and adolescents.

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[1] This paper builds upon and distinguishes itself from previous Australian studies examining weather effects on children's time allocation (Nguyen *et al.* 2021), physical activity and sleep in child-parent pairs (Nguyen *et al.* 2023), and the impact of sleep on child development (Nguyen *et al.* 2024). While the latter study instrumentally used daily daylight duration to address sleep endogeneity, its focus remained on sleep's impact, with the effects of daylight treated as a first-stage result. Our study explores the comprehensive effects of not only daily daylight duration but also sunrise and sunset times, extending to both sleep duration and timing (onset and wakeup). Crucially, by leveraging high-quality data, we offer the first evidence of how solar cycles influence children's allocation of time to activities beyond sleep. Importantly, our heterogeneous effects analysis reveals novel insights into the moderating influence of socio-demographic factors – an aspect not addressed in previous studies.

Utilising a dataset comprising over 50,000 time-use diaries sourced from two cohorts within the Longitudinal Study of Australian Children (LSAC) survey spanning a 16-year period, and employing an individual fixed effects estimator, our findings reveal that among the three daily solar cycle variables analysed - daylight duration, sunrise time, and sunset time - the sleep duration of children and adolescents exhibits the most pronounced responsiveness to daily daylight duration. Notably, extended daylight duration correlates with a significant reduction in children's sleep duration, primarily attributed to later bedtimes and earlier waking times. Concurrently, these days witness a decrease in the time allocated to personal care or media activities, alongside an increase in time devoted to school or physical activities.

Furthermore, our study introduces novel evidence indicating that the impact of daily daylight duration on sleep duration is notably more pronounced among older individuals and during weekdays and slightly greater among children of mothers with lower educational attainment or unemployment status. These findings underscore the nuanced effects of daily solar cycles on the sleep patterns and activity allocation of children and adolescents, thereby contributing to a deeper understanding of the socio-environmental factors shaping their daily routines and behaviours.

The remainder of this paper is structured as follows. Section 2 provides an overview of the data utilised in this study, while Section 3 delineates the empirical models employed and presents the corresponding results. Additionally, Section 4 outlines the outcomes obtained from robustness checks conducted to ensure the validity and reliability of our findings. Moreover, Section 5 elucidates the findings derived from heterogeneous analysis and Section 6 encapsulates the paper's conclusions.

2. Data

2.1. Time-use diaries

Utilising time-use diaries (TUD) sourced from two cohorts of children surveyed as part of the Longitudinal Study of Australian Children (LSAC), we investigate the time allocation among children and adolescents. The LSAC, a biennial nationally representative survey, encompasses children born between March 2003 and February 2004 (Birth or B-Cohort, consisting of 5,107 infants aged 0–1 year in 2004) and those born between March 1999 and February 2000 (Kindergarten or K-Cohort, comprising 4,983 children aged 4–5 years in 2004). Commencing in 2004, the LSAC has undergone several survey waves, with the most recent being wave 9 conducted in 2020/21 (Mohal *et al.* 2021).

The TUDs, integrated within the LSAC, were collected biennially, with notable methodological modifications throughout the study duration. Initially, parents were provided with two TUDs per wave (one for a weekday and one for a weekend day) for completion regarding their child's activities in the first three waves. However, starting from wave 4, each family received one TUD per wave. Additionally, the reporting format transitioned from recording activities in 15-minute slots to utilising an "activity episode" diary from wave 4 onwards. Furthermore, from wave 4 onwards, children themselves were involved in completing the TUD via computer-assisted interviews. Lastly, Kindergarten cohort children completed TUDs in the first six waves, while Birth cohort children were not required to do so in waves 4, 5, and 9. These TUDs enable an examination of sleep allocation over a 16-year period, covering children and young individuals aged from birth (for B cohort) or 4/5 years old (for K cohort) up to 15/16 years old (for both cohorts).

2.2. Sleep variables

We utilise three variables to characterise the sleep patterns of children and adolescents. The primary variable, sleep duration, is derived by aggregating all time slots or episodes recorded

as sleep or napping during the diary date. Appendix Table B1 and Appendix Table B2 provide detailed activity classifications. Our sleep duration variable captures the actual time spent sleeping or napping, excluding periods of being awake in bed. We measure sleep duration in hours per day.

The second variable, sleep onset time,[2] is constructed from responses to a specific question regarding the time the study child went to sleep on the diary date. Similarly, we derive the third variable, wakeup time, from responses to a question about the time the study child woke up on the diary date. We measure both sleep onset time and wakeup time in hours, following the 24-hour clock. Unfortunately, the questions regarding the study child's bedtime or wakeup time were not included in the first three waves of the LSAC. For these waves, we designate the first time slot recorded with activities other than sleep from midnight as wakeup time. Additionally, we assign the first time slot recorded as sleep between the sunset and sunrise time calculated for the diary date as sleep onset time.

2.3. *Other time use variables*

In order to provide a comprehensive understanding of how children and adolescents allocate their time in response to daily solar cycles, beyond the three sleep-related variables outlined earlier, we utilise TUDs to construct additional grouped activities recorded during the same diary date. Drawing on methodologies established in prior research (Fiorini & Keane 2014; Nguyen *et al.* 2020; Nguyen *et al.* 2021; Nguyen *et al.* 2022), and to facilitate an informative and manageable analysis, we aggregate pre-coded activities into seven distinct activity groups, namely personal care, school, education, physical activity, chores, media and travel.[3] Personal

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[2] We employ the term "sleep onset time" instead of "bedtime" to accurately represent that our measure of sleep duration excludes time spent awake in bed. It's important to note that due to interruptions during nighttime sleep and instances of sleeping or napping outside of nighttime hours, the actual sleep duration may not correspond precisely to the difference between wakeup time and sleep onset time.

[3] Consistent with prior studies (Fiorini & Keane 2014; Nguyen *et al.* 2020; Nguyen *et al.* 2021; Nguyen *et al.* 2022), we focus on main activities to ensure that the total time allocated to all grouped activities does not exceed 24 hours per day. Beginning from wave 4 onwards, respondents were asked to identify the main activity

care consists of awaking in bed, eating/drinking, showering/bathing and undertaking non-physical non-educational activities. School includes time spent on day care centre/playgroup or organised school lessons. Education relates to educational activities outside of school, such as reading or being read to, doing homework and attending private lessons. Physical activities refer to time allocated to walking, cycling or attending organised sport activities while chores consists of time spent on household chores or work. Media activities include watching TV programs or movies/videos, playing video games, using computer and internet (unrelated to doing homework) and communicating via electronic devices. Travel refers to time spent on transit.

2.4. Sample

From an initial sample of approximately 55,000 TUDs collected across Waves 1 through 8, we systematically exclude TUDs with obvious inaccuracies or incomplete information. Additionally, TUDs lacking essential explanatory variables, which are controlled for in the regressions (as discussed in subsequent sections), are also omitted. Furthermore, due to our primary utilisation of an individual fixed effects model to estimate the effects of daily solar cycles, we must restrict the sample to individuals with a minimum of two observations during the study period. These sample restrictions culminate in a final dataset comprising 53,740 complete TUDs, derived from 8,708 unique children (including 4,356 unique children from the B cohort).

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undertaken, and we utilise this information to determine main activities. However, such data are not available in the initial three waves of the LSAC. Our examination of subsequent waves indicates that the most frequent secondary activities include eating, drinking, engaging in face-to-face conversations, and watching TV. Leveraging this observation, we arbitrarily classify which activity serves as the main one for time slots with multiple recorded activities.

3. Empirical model and results

3.1. Empirical model

We employ the following model to examine how children and adolescents adjust their time in response to variation in daily solar cycles:

$$T_{it} = \alpha + S_{i(p)t}\beta + X_{it}\gamma + \delta_i + \mu_{it} \tag{1}$$

Here T_{it} is a time allocation measure that individual i on diary date t, $S_{i(p)t}$ is a variable indicating daily solar cycles on that date in postcode p, X_{it} is a vector of individual and local level time-variant controls, δ_i is an individual time-invariant factor, and μ_{it} is an error term. α, β and γ are vectors of parameters to be estimated.

We include in X_{it} a rich set of characteristics which have been shown to be associated with children's time allocation (Nguyen *et al.* 2021; Nguyen *et al.* 2022). These include the individual's characteristics (e.g., age and its square, gender, Aboriginal status, low birthweight), the household's characteristics (e.g., maternal migration status, maternal education, number of siblings and two-parent households), and neighbourhood characteristics.[4] We additionally control for seasonal or spatial differences in time allocation by including TUD quarter, year and state/territory dummies in Equation (1). The inclusion of state/territory dummies additionally controls for different time zones across Australia. To capture likely variation in time use patterns throughout the week, we further include in X_{it} a series of day-of-week dummies and an indicator describing whether the diary was completed on holidays.

We employ three variables to represent daily solar cycles: daylight duration, sunrise time and sunset time. We measure daily daylight duration in hours per day and the other two variables

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[4] These include percentages of individuals having an Aboriginal/Torres Strait Islander origin, speaking English, being born in Australia or completing year 12 in linked areas, percentages of households with household income less than AU$1,000/week in linked areas, a metropolitan dummy. For completeness purposes, we describe some time-invariant variables, such as gender and migration status, which are included in the pooled cross-sectional regressions but are dropped from the individual FE regressions.

in hours, according to the 24-hour clock. These three variables are calculated using the diary date, geographic coordinates (i.e., longitude and latitude) of the child's residential postcode centroid, daylight saving adjusted time zone offsets and astronomical algorithms developed by Meeus (1999).[5] Because these variables are highly correlated, we introduce each of them separately in Equation (1). Moreover, we consider each of the 10 time-use variables described in Section 2 as a separate outcome in Equation (1).

We exploit the panel nature of the data to estimate Equation (1) using an individual fixed effects (FE) method. Standard errors are clustered at the individual child level to account for potential intertemporal correlations (Cameron & Miller 2015). The parameter of interest from this regression is β which captures the short-term[6] impact of daily solar cycles on time allocation. The identification source of β comes from changes in daily solar cycles recorded on multiple diary dates of the same individuals over time. Our empirical model improves on previously employed models in related literature (Gibson & Shrader 2018; Jagnani 2022) by effectively controlling for individual time-invariant factors that may be simultaneously correlated with the daily solar cycle variable and time allocation. As discussed by Gibson and Shrader (2018), one of such time-invariant unobservable factors would be residential sorting as individuals may self-select into different locations based on their responsiveness to solar cycles. Another potentially important time-invariant factor would be persistent reporting bias (Wooldridge 2010; Frazis & Stewart 2012).

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[5] Similar astronomical algorithms have been employed in previous studies (Giuntella *et al.* 2017; Gibson & Shrader 2018). We use a STATA command written by Gibson and Shrader (2018) to perform this task.

[6] We focus on "short-term" impact of daily solar cycles in this paper because any long-term impact would be absorbed in this individual FE model (Giuntella *et al.* 2017; Gibson & Shrader 2018).

3.2. Empirical results

1.1.1. Descriptive results

Summary statistics, detailed in Table 1 and Appendix Table A1, indicate that children and adolescents in our dataset typically spend approximately 10.5 hours per day sleeping, constituting the largest proportion of time allocated among all grouped activities within the 24-hour period. Moreover, the average bedtime is around 8 PM, with waking occurring at 7 AM. Table 1, presenting the means of key variables categorized by the median daylight duration, reveals that on days characterized by longer daylight periods, children and adolescents allocate less time to sleep, primarily due to later bedtime. Additionally, they dedicate less time to personal care and educational activities but allocate more time to school, physical activity, chores, and media activities.

The observed relationships between daylight duration and the three sleep-related variables are further elucidated visually in Figures 1 to 3. Specifically, Figure 1 which shows distributions of three sleep variables by daily daylight duration, represents that longer daylight durations shift the distribution of sleep duration or wakeup time leftward and the distribution of sleep onset time rightward. These movements are consistent with the view that longer daylight duration may decrease sleep duration, with individuals going to sleep later and waking up earlier. Consistent with this pattern, an earlier sunrise time may also decrease sleep duration by inducing individuals to rise earlier and go to sleep later[7] (see Figure 2). Moreover, we observe from Figure 3 that a later sunset time may also reduce sleep duration, primarily by causing individuals to go to sleep later.

However, as detailed in Section 3.1, these raw relationships between daily solar cycles and time allocation may not fully capture the true impacts of daily solar cycles on time usage, as

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[7] Early sunrise typically coincides with late sunset and this late sunset may induce individuals to go to sleep later.

they do not account for time-variant and invariant factors correlated with both solar cycles and time allocation. The subsequent section will directly address this issue.

1.1.2. Regression results

Table 2 presents FE estimates of each of the three daily solar cycle variables from regressions of ten time use indicators.[8] The first panel in Table 2 reports the results for daily daylight duration, suggesting that children and adolescents sleep statistically significantly less on days with longer daylight duration. Specifically, an increase of one hour in daylight duration is associated with a decrease of 0.07 hours (or 4.2 minutes) in sleep duration per day. This estimate is quite substantial in magnitude since an increase of 6 hours in daylight duration (i.e., the maximum variation of daylight duration observed in our data) can reduce sleep duration by 25 minutes per day (or 4% of sample mean). Moreover, the regression results on sleep onset time and wakeup time indicate that the reduction in sleep duration is partly explained by the pattern that on days with longer daylight duration, individuals go to sleep later and wake up earlier. Numerically, a one-hour-increase in daylight duration causes individuals to go to sleep 5.4 minutes later and wake up 2.4 minutes earlier.

The combined effect of daylight duration on sleep onset time and wakeup time suggests that if children had slept continuously at nighttime, a one-hour-increase in daylight duration would have decreased nighttime sleep duration by 7.8 minutes per day, a figure which is higher than the estimated effect of a similar increase in daylight duration on sleep duration of 4.2 minutes. Because our sleep duration measure excludes sleep interruptions but includes naps, this disparity suggests that children can partly compensate for the sleep loss due to longer daylight duration by taking naps during the day. Other estimates reported on the first panel of Table 2

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[8] Estimates for other variables, reported in Appendix Table A2, are as expected and in line with that in previous studies (Nguyen *et al.* 2021; Nguyen *et al.* 2022). For instance, time allocated to sleep, personal care and media decreases with age while time spent on school increases with age. Moreover, children's time allocations are statistically significantly affected by some household characteristics, including the number of siblings and living with both parents, days of the week or survey quarters.

describe that on days with longer daylight duration, children spend statistically significantly more time on school and physical activities and less time on personal care and media activities.

The second and third panel in Table 2 reports children's time allocation responses to sunrise time and sunset time, respectively. The results show that a later sunrise time increases sleep duration by 6.6 minutes, partly by inducing children to go to sleep earlier and wake up later. The estimates of sunrise time on non-sleep variables further suggest that this increase in sleep duration is collectively explained by a decrease in school or physically active time and an increase in personal care or media time. By contrast, and in line with that in a study of Indian children aged 6-14 years old by Jagnani (2022), our results indicate that a later sunset time statistically significantly decreases the time children spend on sleeping by 5.4 minutes, partly by influencing them to go to sleep later. Interestingly, despite clear differences in data, empirical methods and institutional contexts among studies, the pattern that wake-up time is less responsive to solar cues than sleep onset time is also observed in studies focusing on adults in the United States (Hamermesh *et al.* 2008; Giuntella & Mazzonna 2019). Our results further indicate that a later sunset time also causes children to reduce the time allocated to personal care or media activities and increase the time to school or physical activities.

The above results suggest that, in terms of the statistical significance level, sleep duration is more responsive to changes in daily daylight duration than to daily sunset time or daily sunrise time.[9] This pattern is in line with the fact that both daily sunrise and sunset time matters for children's sleep duration in Australia. It is also supported by the results from a t test for statistical significance of each of the three daily solar cycle variables which show that the F statistic is greatest for daily daylight duration. Because sleep duration is most sensitive to daily

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[9] In terms of the magnitude, the reverse appears to be true because the coefficients on sunset and sunrise time are greater (in absolute value) than the estimate on daylight duration. However, the estimates are not directly comparable in terms of the magnitude because these variables are measured differently (i.e., daylight duration is measured in hour/day while sunset and sunrise time is in 24-hour clock).

daylight duration among the three daily solar cycle variables considered here, to strengthen the statistical power of the analysis and for brevity purposes, we will focus on daily daylight duration in the remainder of this section.[10]

4.   Robustness checks

Appendix Table A3 presents results from several robustness checks for the estimated relationship between daylight duration and children's time allocation. Panel B reports the estimates of daylight duration from a pooled regression model where we do not control for individual fixed effects. In this pooled regression, we follow previous studies (Gibson & Shrader 2018; Jagnani 2022) to additionally control for postcode fixed effects so identification of the daylight duration impact on time allocation comes from daily variation in daylight duration across different individuals within a given postcode. We find that with some exceptions where pooled estimates of daylight duration are slightly more pronounced in terms of the statistical significance or magnitude than the baseline FE estimates (reported in Panel A), our results change little. The similarity between pooled and FE estimates suggests that in the absence of panel data as in the case for all prior studies, it would be suitable to use a pooled regression model to examine the relationship between daily solar cycles and sleep duration.

We next exclude all child and household level variables from the baseline FE regression model. The results, reported in Panel C of Appendix Table A3, show little sensitivity in the estimates of daylight duration on all time allocation variables. We reach a similar conclusion when using season dummies (Panel D) in place of quarter dummies. Finally, we experiment with including weather conditions[11] recorded on the TUD date as additional explanatory variables in the

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[10] Unreported results on daily sunrise and sunset time lead to similar conclusions and the results are available upon requests.

[11] Historical weather data from all monitoring stations in Australia were obtained from the Australian Bureau of Meteorology. As have been done previously (Nguyen *et al.* 2021; Nguyen *et al.* 2023), we assign daily weather elements from the three spatially closest weather stations to the individual's residential postcode centroid. Furthermore, we consider two weather elements which have been shown to affect children's time allocation: daily maximum temperature (and its square) and precipitation.

original FE regression model. The results, reported in Panel D of Appendix Table A3, indicate that with an exception that daily maximum temperatures may affect sleep duration (marginally statistically significant at 10% level), none of included weather variables statistically significantly explains sleep duration, sleep onset time or wakeup time. Moreover, including weather conditions, while not changing the estimate of daily daylight duration on sleep duration in any significant way, does render the estimate of daylight duration on sleep onset time to become statistically insignificant. We also note that additionally controlling for weather conditions decreases the magnitude and statistical level of estimates of daylight duration on some non-sleep variables such as personal care or physical activity. Lastly, consistent with prior evidence (Nguyen *et al.* 2021; Nguyen *et al.* 2023), our results show that on days with unfavourable weather conditions, as represented by cold or hot temperatures or rain, individuals spend statistically significantly less time on physical activities, mainly by allocating more time to media activities.

5. Heterogeneity

To shed light on the potential mechanisms through which daylight duration affects sleep, we next explore the heterogeneity in how individuals adjust their time in response to daily daylight duration variation with respect to: (i) child gender (i.e., male versus female), (ii) child age (young versus old, identified relative to the median age of all individuals in the whole sample), (iii) whether the diary was completed on weekends/holidays versus weekdays, and (iv) whether the child's mother was employed versus unemployed. We implement this heterogeneity analysis by separately running the regression equation (1) on two sub-samples of individuals identified by each of the above characteristics. For maternal employment status, sub-groups are defined using the value identified at its first appearance in the sample to address a concern that the children's time allocation or daylight duration may affect the way that we assign them to each sub-group.

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Figure 4 reports sample means of outcome variables (in bar below the horizontal axis) and daylight duration estimates by sub-group. It shows the differential impacts of daily daylight duration for some sub-group characteristics and outcomes. Particularly, the effects of daylight duration on study children's sleep duration tend to be greater for females, older study children, on weekends, or for children of employed mothers, because the estimates are always more negative (i.e., children are sleeping less on days with a longer daylight duration) or typically more statistically significant for them. Moreover, the sub-population estimates on non-sleep variables suggest some potential mechanisms for these heterogenous daylight duration impacts on sleep duration. For instance, the greater reduction in sleep duration for females is mainly explained by the fact that, when compared to males, females spend more time on physical activities but less time on school activities as daylight duration increases.

Likewise, the proportionally larger effect that increasing daylight duration has specifically on sleep duration for older individuals, is consistent with the finding that increasing daylight duration has a smaller effect on the time they spend on selected non-sleep activities such as personal care, physical and media activities for them. This age difference in the daily daylight duration impact on sleep duration corresponds well with the differential daily daylight duration effect on sleep onset time or wakeup time. In particular, older individuals adjust to longer daylight duration by waking up earlier (i.e., a one-hour increase in daylight duration decreases wake-up time by 6 minutes) without changing their sleep onset time. Younger individuals, by contrast, respond mainly by starting their sleep much later (i.e., a one-hour increase in daylight duration increases their sleep onset time by 7 minutes). Our finding of a greater daylight duration effect on sleep duration for older individuals is consistent with the premise that older individuals are more likely to be affected by social constraints, such as school schedules (Hamermesh *et al.* 2008; Groen & Pabilonia 2019; Ferrante & Leone 2023), and thus less able to compensate an earlier wakeup time with an earlier bedtime.

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Figure 4 further indicates that the differential daylight duration effects on time allocated to non-sleep activities help to explain the more apparent impact of increasing daylight duration on sleep duration on weekends. Specifically, increasing daylight duration has a statistically significant effect on study children's time allocations to personal care, school and chores activities on weekdays only. Moreover, the impact of daylight duration in increasing physically active time on weekends is twice as much as that on weekdays (i.e., a one-hour increase in daylight duration increases physically active time by 3 and 8 minutes per day on weekdays and weekends, respectively).

Figure 4 also shows that individuals adjust to longer daylight duration by going to sleep later on weekdays but by waking up earlier on weekends. Our finding of a more pronounced impact of daylight duration on sleep duration undertaken on weekends is in line with that in previous studies where children's time allocations to physical and media activities are more responsive to weather conditions on weekends (Nguyen *et al.* 2021; Nguyen *et al.* 2023). Like the previous findings, our finding is consistent with the view that individuals are more flexible on weekends, probabably because they are less socially constrained by their own school schedules or their parent's work commitments on weekends.

Sub-population results by maternal work status indicate that the daylight duration impact on sleep duration is more prominent for children of employed mothers because the estimate is statistically significant (at 1% level) for them only. This differential impact is consistent with a pattern that only children of employed mothers adjust to longer daylight duration partly by going to sleep later and waking up earlier. Our finding coupled with prior evidence showing that solar cycles affect sleep duration of employed adults only (Giuntella *et al.* 2017) suggest that employment status of parents influences the way that both parents and their offspring adjust their sleep patterns in response to daily solar cycle changes.

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Our results further reveal that children of employed mothers also spend signficantly more time at schools on days with longer daylight duration. This finding when observed with a pattern that, as compared to children of unemployed mothers, those of employed mothers spend less time on sleep (30 minutes per day, as can be seen from mean figures reported below the bars in Figure 4) but more time at schools (41 minutes per day) suggest the following: Work arrangements of mothers affect how their children allocate their time during the day as well as how the children adjust their time in response to daily solar cycle variation.

6.   Conclusion

This study leverages variation in local daily daylight duration recorded on diary dates across the same individuals to evaluate the causal impacts of daily solar cycles on the time allocation of children and adolescents. Our findings indicate that longer daylight durations significantly decrease sleep duration in children and adolescents, prompting later bedtime and earlier wake-up times. Additionally, extended daylight periods reduce children's time allocated to personal care or media activities while increasing their engagement in school or physical activities. Notably, we offer novel evidence suggesting that the effects of daylight length on sleep duration are notably amplified for older individuals or on weekdays, with a slight elevation observed for children of mothers with lower educational attainment or employment status.

In terms of policy implications, our results underscore the importance of considering environmental factors, such as daylight duration, in designing interventions aimed at promoting healthy sleep habits and overall well-being among children and adolescents. Policymakers and educators may need to adjust school schedules or recreational programs to account for variation in daylight length, particularly in regions where these fluctuations are more pronounced. Furthermore, our findings highlight the potential need for targeted interventions tailored to specific demographic groups, such as older individuals or children from socioeconomically

disadvantaged backgrounds, to mitigate the adverse effects of longer daylight durations on sleep duration.

For future research, there is a need for longitudinal studies that explore the long-term effects of daily solar cycles on various aspects of child development beyond sleep patterns. Additionally, further investigation into the mechanisms underlying the observed associations, such as the role of parental influences and societal norms, could provide valuable insights for designing more effective interventions. Moreover, incorporating objective measures of sleep quality, such as polysomnography or actigraphy (Lehrer *et al.* 2022), could enhance our understanding of the nuanced relationships between daily solar cycles and sleep patterns in children and adolescents. Overall, continued research in this area can inform evidence-based strategies to optimize the daily routines and promote positive developmental outcomes in this population.

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Table 1: Summary statistics by daylight duration

Variable	Longer daylight	Shorter daylight	Longer daylight - Shorter daylight
	(1)	(2)	(3)
Child age	7.30	6.39	0.91***
Male	0.51	0.51	0.00
Indigenous	0.03	0.02	0.01***
Low birth weight	0.06	0.06	0.00
Mother has a certificate or diploma	0.39	0.38	0.01***
Mother has a graduate degree	0.36	0.38	-0.03***
Mother ESB migrant	0.09	0.10	0.00
Mother NESB migrant	0.17	0.15	0.02***
Number of siblings	1.44	1.38	0.06***
Lived with both parents	0.83	0.86	-0.03***
Sleep duration (hour/day)	10.42	10.67	-0.25***
Sleep onset time (hour, 24-hour clock)	20.30	20.10	0.19***
Wakeup time (hour, 24-hour clock)	6.93	6.95	-0.02
Personal care duration (hour/day)	4.12	4.19	-0.07***
School duration (hour/day)	1.91	1.82	0.08***
Educational activity duration (hour/day)	0.96	1.03	-0.07***
Physical activity duration (hour/day)	2.62	2.51	0.10***
Chores duration (hour/day)	0.38	0.30	0.08***
Media activity duration (hour/day)	2.25	2.14	0.11***
Travel duration (hour/day)	1.34	1.33	0.01
Sunrise time (hour, 24-hour clock)	6.37	7.09	-0.71***
Sunset time (hour, 24-hour clock)	18.10	17.23	0.87***
Number of observations	26,870	26,870	

Notes: Figures are sample means. Tests are performed on the significance of the difference between the sample mean for "Shorter daylight duration" individuals (identified as those with daylight duration < median of daylight duration among individuals included in the final sample) and "Longer daylight duration" individuals (daylight duration >=median). The symbol *denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Table 2: Impact of daylight duration, sunrise time and sunset time on children's time allocation

	Sleep duration (hour/day)	Sleep onset time (24-hour clock)	Wakeup time (24-hour clock)	Personal care (hour/day)	School (hour/day)	Educational (hour/day)	Physical (hour/day)	Chores (hour/day)	Media (hour/day)	Travel (hour/day)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Daylight duration (hour/day)	-0.06***	0.07**	-0.02	-0.05***	0.08***	0.01	0.09***	0.00	-0.07***	0.01
	[0.01]	[0.03]	[0.01]	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]
Observations	53,740	53,713	53,739	53,740	53,740	53,740	53,740	53,740	53,740	53,740
No of unique children	8,708	8,708	8,708	8,708	8,708	8,708	8,708	8,708	8,708	8,708
Sample mean	10.55	20.20	6.94	4.15	1.86	1.00	2.56	0.34	2.19	1.34
R-squared	0.228	0.035	0.131	0.034	0.387	0.052	0.205	0.152	0.244	0.059
F-test	21.81	4.81	2.48	8.62	21.17	0.45	31.28	0.08	17.87	0.43
Sunrise time (24-hour clock)	0.10***	-0.12**	0.07***	0.09***	-0.09***	0.00	-0.13***	-0.02*	0.07**	-0.03
	[0.02]	[0.06]	[0.02]	[0.03]	[0.03]	[0.02]	[0.03]	[0.01]	[0.03]	[0.02]
R-squared	0.227	0.035	0.131	0.034	0.387	0.052	0.205	0.152	0.244	0.059
F-test	17.87	4.44	8.10	7.54	8.73	0.05	18.54	2.81	5.00	2.09
Sunset time (24-hour clock)	-0.08***	0.10*	-0.00	-0.07**	0.13***	0.02	0.15***	-0.01	-0.13***	-0.00
	[0.02]	[0.06]	[0.02]	[0.03]	[0.03]	[0.02]	[0.03]	[0.01]	[0.03]	[0.02]
R-squared	0.227	0.035	0.131	0.034	0.387	0.052	0.205	0.152	0.244	0.059
F-test	13.73	3.14	0.00	5.52	23.64	1.48	28.24	1.08	24.67	0.06

Notes: Estimates for each column and panel are from a separate regression model (1). F test refers to the statistic from a t test for statistical significance of the respective independent variable (i.e., daylight duration, sunrise time or sunset time). Other variables include child age (and its square), maternal completed qualification, living with both parents, number of siblings; local socio-economic background variables, state/territory dummies, TUD year dummies, TUD quarter dummies, TUD day-of-week dummies, and a holiday indicator. Summary statistics such as sample size and sample mean are not reported for the last two panels since they are identical to those reported in the first panel. Robust standard errors clustered at the individual level are in squared brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Figure 1: Distributions of sleep duration, sleep onset time and wakeup time by daylight duration
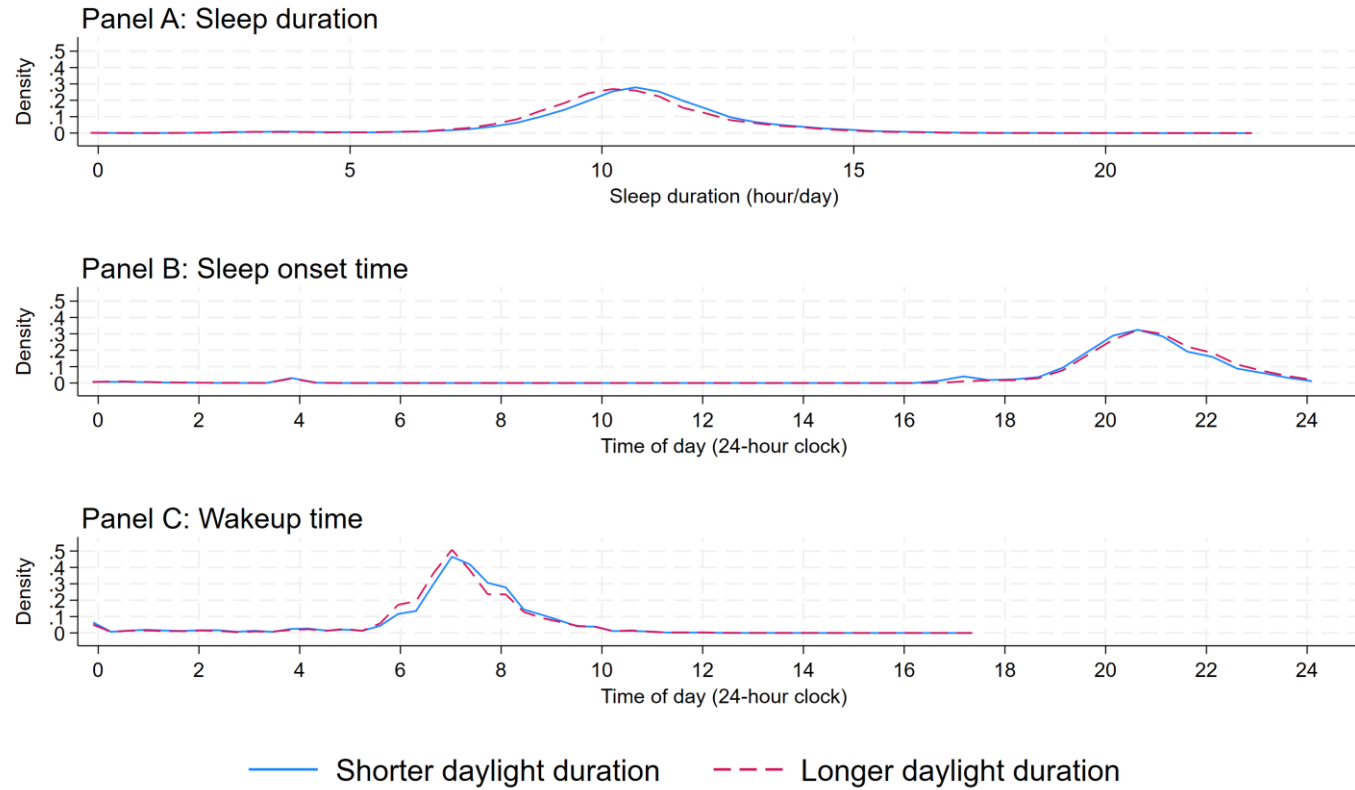
Panel A: Sleep duration

Panel B: Sleep onset time

Panel C: Wakeup time

——— Shorter daylight duration   – – – Longer daylight duration

Notes: This figure reports univariate kernel density estimation of sleep duration (in hours per day), sleep onset time (in hour according to a 24-hour clock) and wakeup time (in hour according to a 24-hour clock) for a pooled sample of LSAC children with a valid TUD. "Longer daylight duration" indicates all TUDs recorded on dates with daylight duration at or above the median while "Shorter daylight duration" refers to those under the median.

Figure 2: Distributions of sleep duration, sleep onset time and wakeup time by sunrise time
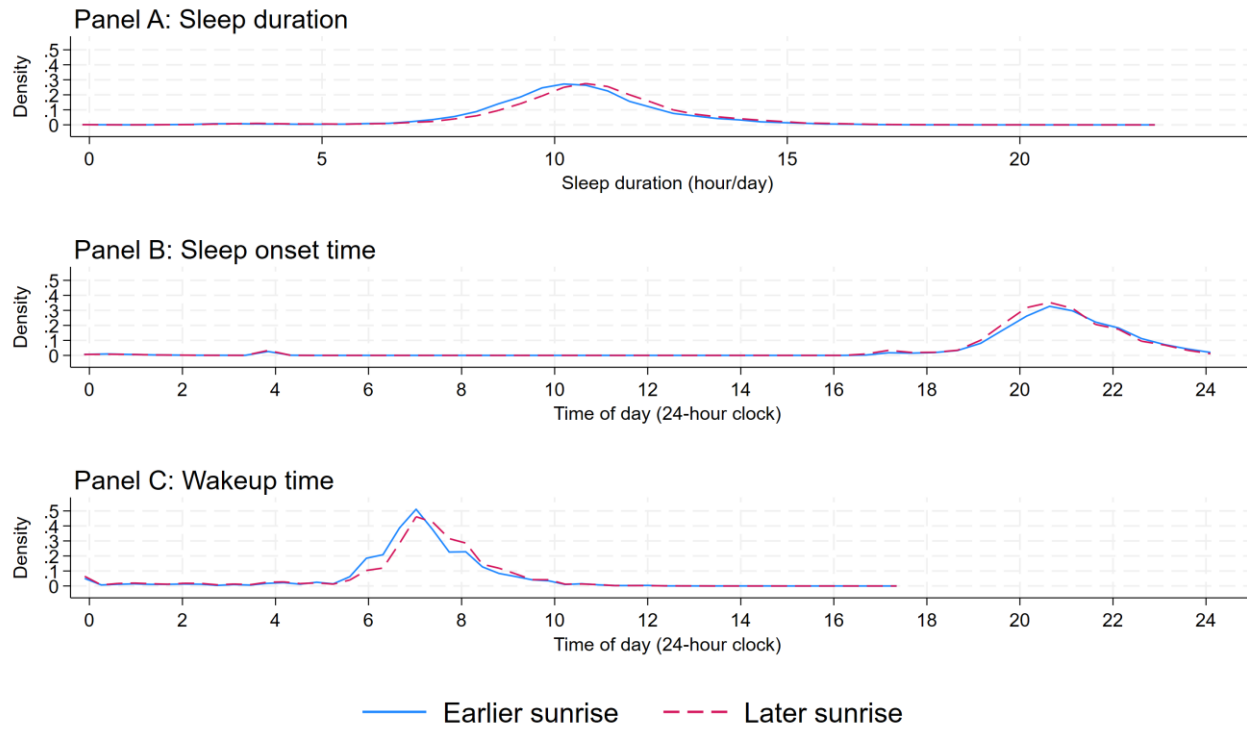
Notes: This figure reports univariate kernel density estimation of sleep duration (in hours per day), sleep onset time (in hour according to a 24-hour clock) and wakeup time (in hour according to a 24-hour clock) for a pooled sample of LSAC children with a valid TUD. "Earlier sunrise" indicates all TUDs recorded on dates with sunrise time at or above the median while "Later sunrise" refers to those under the median.

Figure 3: Distributions of sleep duration, sleep onset time and wakeup time by sunset time
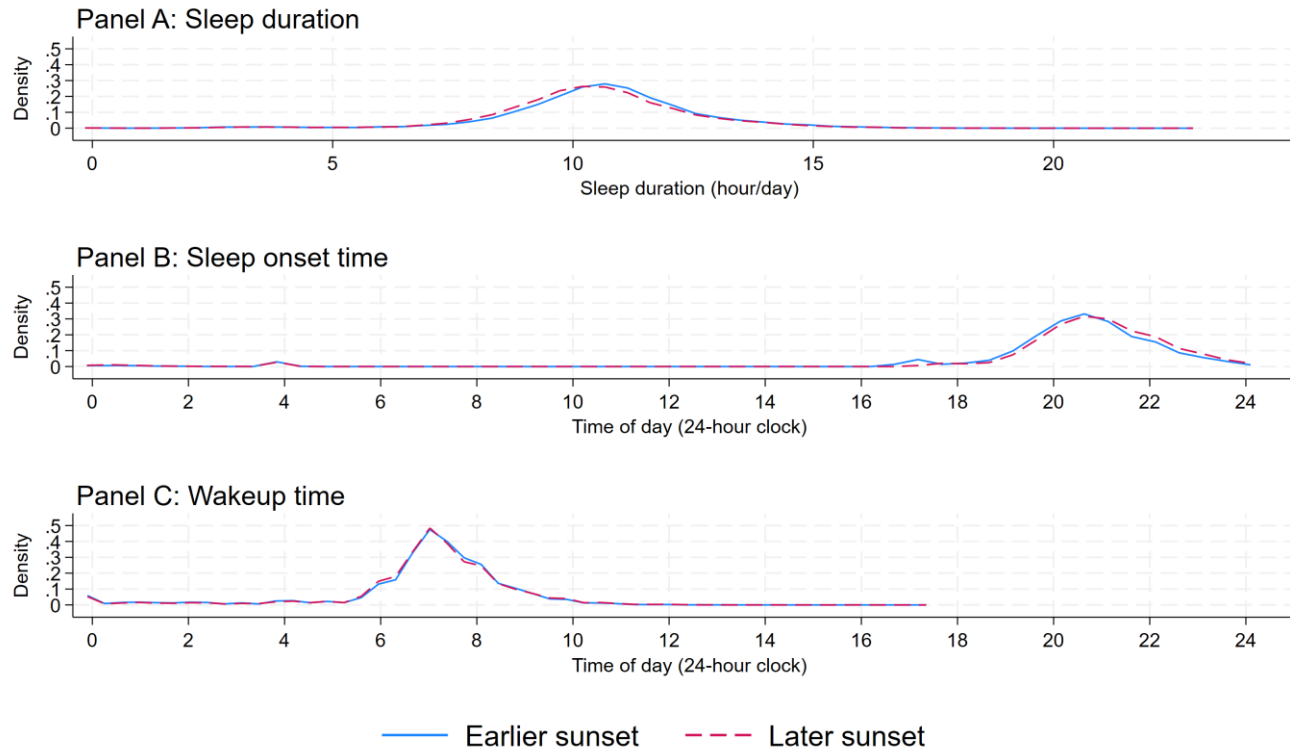
Panel A: Sleep duration

Panel B: Sleep onset time

Panel C: Wakeup time

——— Earlier sunset   – – – Later sunset

Notes: This figure reports univariate kernel density estimation of sleep duration (in hours per day), sleep onset time (in hour according to a 24-hour clock) and wakeup time (in hour according to a 24-hour clock) for a pooled sample of LSAC children with a valid TUD. "Earlier sunset" indicates all TUDs recorded on dates with sunset time at or above the median while "Later sunset" refers to those under the median.

Figure 4: Heterogenous impacts of daylight duration on study children's time allocation
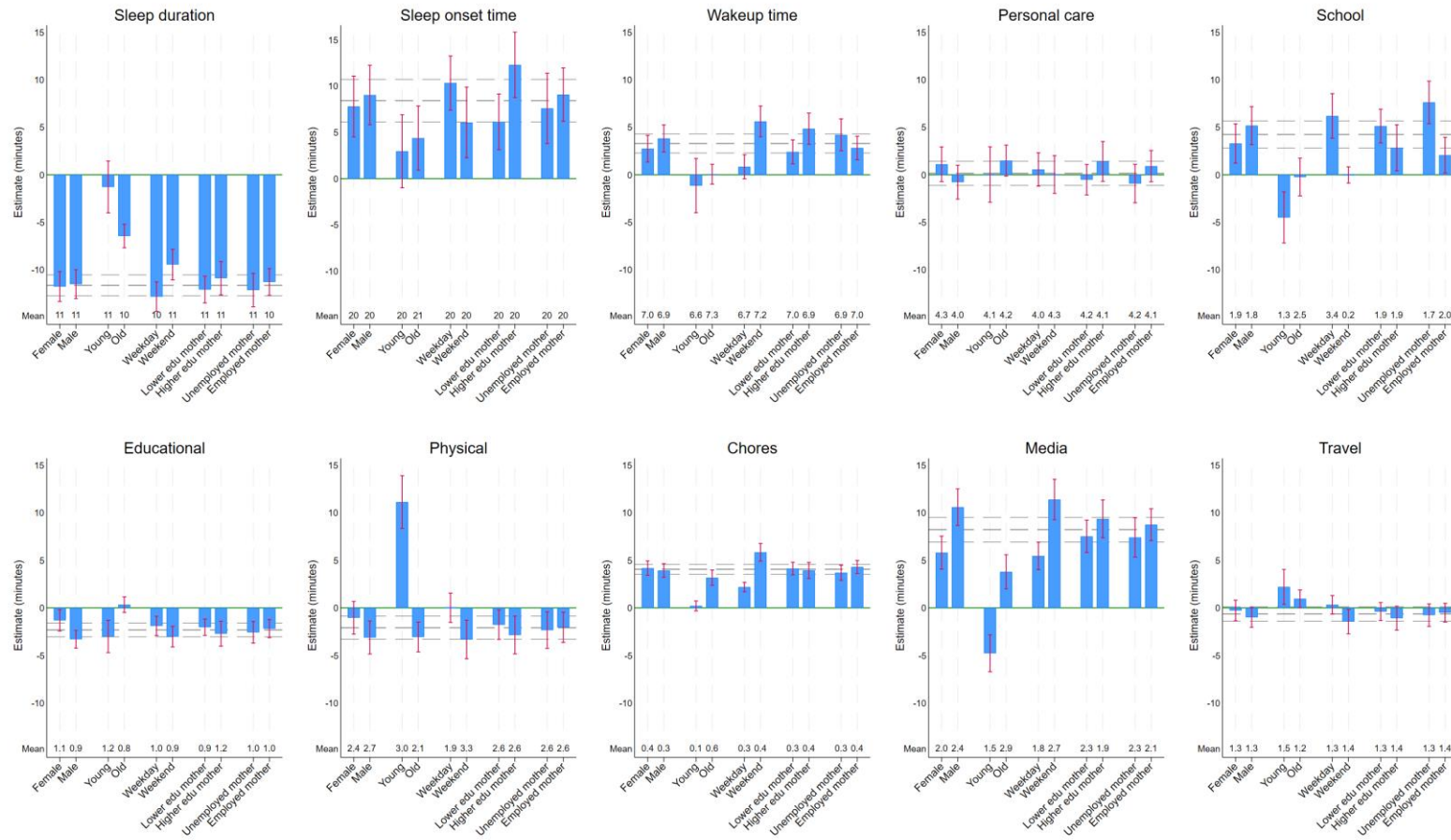
Notes: Results (coefficient estimates and 95% confidence intervals which are multiplied by 60 for aesthetic purposes so the coefficient estimates can be interpreted in minutes) for different sub-populations are obtained from separate FE regressions using Equation (1). The solid (dash) horizontal line shows the daylight duration coefficient (95% confidence interval) estimates for the whole population. The sample mean of the dependent variable, represented in hours, for each sub-population is printed below the bars. Detailed regression results are reported in Appendix Table A4.

Online Appendixes

for refereeing purposes and to be published online

Appendix A reports additional results.

Appendix B describes coding rules for activities.

Appendix Table A1: Variable description and summary statistics

Variable	Description	Mean	Min	Max	Standard deviations		
					Overall	Between	Within
Child age	Study child age at the survey time (years)	6.84	0.00	16.00	4.51	2.67	3.94
Male	Dummy = 1 if study child is a male, = 0 if female	0.51	0.00	1.00	0.50	0.50	0.00
Indigenous	Dummy: = 1 if study child has Aboriginal/Torres Strait Islander origin, = 0 otherwise	0.02	0.00	1.00	0.15	0.17	0.00
Low birth weight	Dummy: = 1 if study child's birth weight is 2500 grams or less, = 0 otherwise	0.06	0.00	1.00	0.24	0.25	0.00
Mother has a certificate	Dummy: = 1 if study child's mother has advanced diploma/diploma, = 0 otherwise	0.39	0.00	1.00	0.49	0.46	0.17
Mother has a graduate degree	Dummy: = 1 if study child's mother has a bachelor degree or higher, = 0 otherwise	0.37	0.00	1.00	0.48	0.46	0.13
Mother ESB migrant	Dummy: = 1 if study child's mother was born overseas in an English-Speaking Background (ESB) country, = 0 otherwise	0.10	0.00	1.00	0.30	0.29	0.02
Mother NESB migrant	Dummy: = 1 if study child's mother was born overseas in a Non-ESB (NESB) country, = 0 otherwise	0.16	0.00	1.00	0.36	0.33	0.19
Number of siblings	Number of siblings	1.41	0.00	11.00	1.00	0.96	0.44
Lived with both parents	Dummy: = 1 if study child lived with both parents at the survey time, = 0 otherwise	0.85	0.00	1.00	0.36	0.34	0.18
Sleep onset time	Time the study child went to sleep on the diary date (hour, 24-hour clock)	20.20	0.00	23.98	3.48	1.73	3.14
Wakeup time	Time the study child woke up on the diary date (hour, 24-hour clock)	6.94	0.00	17.25	1.89	1.15	1.60
Sleep duration	Total time spent on sleeping and napping per TUD day (hour/day)	10.55	0.00	22.75	2.03	1.16	1.75
Personal care	Total time spent on personal care per TUD day (hour/day)	4.15	0.00	20.00	2.28	1.24	1.99
School	Total time spent on school related activities per TUD day (hour/day)	1.86	0.00	19.75	2.81	1.23	2.58
Educational activity	Total time spent on sleeping and napping per TUD day (hour/day)	1.00	0.00	14.42	1.33	0.74	1.14
Physical activity	Total time spent on sleeping and napping per TUD day (hour/day)	2.56	0.00	23.75	2.29	1.12	2.06
Chores	Total time spent on sleeping and napping per TUD day (hour/day)	0.34	0.00	11.50	0.77	0.38	0.69
Media activity	Total time spent on sleeping and napping per TUD day (hour/day)	2.19	0.00	18.75	2.12	1.24	1.81
Travel	Total time spent on sleeping and napping per TUD day (hour/day)	1.34	0.00	18.50	1.40	0.71	1.25
Sunrise time	Sunrise time on the TUD date (hour, 24-hour clock)	6.73	4.69	7.81	0.54	0.40	0.39
Sunset time	Sunset time on the TUD date (hour, 24-hour clock)	17.66	16.68	20.95	0.73	0.48	0.60
Daylight duration	Daylight duration on the TUD date (hour/day)	10.93	8.98	15.01	1.07	0.66	0.90

Notes: Sample size: 53,740 observations. English-Speaking Background (ESB) countries include UK, Ireland, Canada, New Zealand, South Africa and USA.

Appendix Table A2: Time allocation responses to daylight duration – Remaining results

	Sleep duration (hour/day)	Sleep onset time (24-hour clock)	Wakeup time (24-hour clock)	Personal care (hour/day)	School (hour/day)	Educational (hour/day)	Physical (hour/day)	Chores (hour/day)	Media (hour/day)	Travel (hour/day)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Child age	-7.25***	23.19***	17.96***	-12.20***	18.00***	9.35***	-5.20**	-4.04***	6.40***	-5.06***
	[2.05]	[4.48]	[2.02]	[2.68]	[2.41]	[1.61]	[2.42]	[0.96]	[2.39]	[1.63]
Child age squared	0.65***	-1.27***	-0.98***	0.81***	-0.83***	-0.60***	-0.19***	0.20***	-0.29***	0.25***
	[0.04]	[0.10]	[0.04]	[0.05]	[0.04]	[0.03]	[0.05]	[0.02]	[0.05]	[0.03]
Mother education: Certificate [a]	2.21	-1.30	-2.47	-8.81**	1.17	-3.76	-0.29	-2.12	6.70*	4.89**
	[3.35]	[7.87]	[3.32]	[4.42]	[3.86]	[2.71]	[3.94]	[1.63]	[4.07]	[2.35]
Mother education: Graduate [a]	1.04	9.99	1.20	-8.75	10.14**	0.02	-4.38	0.96	-1.59	2.56
	[4.49]	[10.59]	[4.54]	[5.83]	[5.15]	[3.56]	[5.05]	[2.30]	[5.35]	[3.24]
Number of siblings	-3.03**	-5.93**	-4.14***	6.59***	-1.74	2.07**	-0.35	1.46**	-4.22***	-0.78
	[1.21]	[2.43]	[1.28]	[1.53]	[1.28]	[0.89]	[1.35]	[0.59]	[1.38]	[0.90]
Living with both parents	-0.39	14.69**	-5.04*	7.71**	-0.47	10.56***	-0.37	3.23**	-13.35***	-6.92***
	[2.91]	[6.38]	[2.97]	[3.80]	[3.16]	[2.18]	[3.26]	[1.27]	[3.40]	[2.06]
Second quarter [b]	1.51	-1.29	-6.67*	-6.77	27.28***	1.60	-8.29**	-2.94**	-12.31***	-0.09
	[3.76]	[6.81]	[3.76]	[4.55]	[4.01]	[2.99]	[4.12]	[1.39]	[3.53]	[2.74]
Third quarter [b]	2.02	-7.25	2.80	-4.73	16.45***	1.74	-11.17***	-1.11	-3.35	0.15
	[3.73]	[7.11]	[3.76]	[4.58]	[4.05]	[2.97]	[4.12]	[1.46]	[3.63]	[2.78]
Fourth quarter [b]	-0.35	-12.58	-0.29	-1.69	11.95***	0.07	-13.11***	1.73	0.35	1.06
	[3.92]	[9.02]	[3.82]	[4.94]	[4.26]	[2.96]	[4.45]	[1.86]	[4.21]	[2.92]

Notes: Results are from the FE regression. Coefficient estimates and standard errors are multiplied by 60 for aesthetic purposes. [a], [b], and [c] denotes having year 12 or below qualification, first quarter and Sunday as the base group, respectively. Other variables include local socio-economic background variables, state/territory dummies, and TUD year dummies. Robust standard errors clustered at the individual level are in squared brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A2: Time allocation responses to daylight duration – Remaining results (continued)

	Sleep duration (hour/day)	Sleep onset time (24-hour clock)	Wakeup time (24-hour clock)	Personal care (hour/day)	School (hour/day)	Educational (hour/day)	Physical (hour/day)	Chores (hour/day)	Media (hour/day)	Travel (hour/day)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Monday [c]	-17.61***	-2.25	-16.43***	-18.39***	151.83***	2.32**	-73.44***	-6.11***	-28.78***	-9.82***
	[1.64]	[3.08]	[1.59]	[2.09]	[2.21]	[1.16]	[1.94]	[0.68]	[1.72]	[1.30]
Tuesday [c]	-22.06***	-1.97	-21.34***	-25.12***	173.65***	4.96***	-80.56***	-7.23***	-34.74***	-8.91***
	[1.61]	[3.17]	[1.59]	[2.11]	[2.31]	[1.15]	[1.90]	[0.68]	[1.75]	[1.25]
Wednesday [c]	-22.00***	-4.95	-20.75***	-25.90***	174.72***	6.34***	-84.13***	-6.89***	-33.70***	-8.45***
	[1.56]	[3.16]	[1.55]	[2.10]	[2.29]	[1.21]	[1.87]	[0.71]	[1.69]	[1.28]
Thursday [c]	-25.00***	-1.19	-21.23***	-23.99***	173.76***	4.56***	-82.12***	-6.90***	-35.92***	-4.39***
	[1.67]	[3.13]	[1.57]	[2.14]	[2.44]	[1.19]	[1.93]	[0.67]	[1.71]	[1.32]
Friday [c]	-44.80***	-3.85	-24.44***	-21.43***	168.68***	-3.46***	-70.38***	-8.28***	-23.03***	2.71*
	[1.75]	[3.62]	[1.66]	[2.21]	[2.42]	[1.23]	[1.99]	[0.69]	[1.73]	[1.41]
Saturday [c]	-28.41***	-0.95	-8.83***	1.39	-3.13**	-0.48	12.48***	-0.91	4.37***	14.69***
	[1.65]	[3.10]	[1.66]	[2.03]	[1.55]	[1.11]	[2.09]	[0.62]	[1.57]	[1.37]
Holidays	1.34	-13.17***	29.01***	0.85	-137.30***	-11.09***	64.72***	11.73***	54.10***	15.65***
	[1.45]	[3.36]	[1.33]	[1.82]	[1.60]	[1.01]	[1.92]	[0.79]	[1.76]	[1.26]
Observations	53,741	53,714	53,740	53,741	53,741	53,741	53,741	53,741	53,741	53,741
No of unique children	8,708	8,708	8,708	8,708	8,708	8,708	8,708	8,708	8,708	8,708
Sample mean	10.55	20.20	6.94	4.15	1.86	1.00	2.56	0.34	2.19	1.34
R-squared	0.228	0.036	0.132	0.035	0.387	0.052	0.205	0.152	0.245	0.059
F-test	25.83	8.29	8.75	8.27	27.12	0.85	32.25	0.05	25.88	1.79

Notes: Results are from the FE regression. Coefficient estimates and standard errors are multiplied by 60 for aesthetic purposes. [a], [b], and [c] denotes having year 12 or below qualification, first quarter and Sunday as the base group, respectively. Other variables include local socio-economic background variables, state/territory dummies, and TUD year dummies. Robust standard errors clustered at the individual level are in squared brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A3: Time allocation responses to daylight duration - Robustness checks

	Sleep duration (hour/day)	Sleep onset time (24-hour clock)	Wakeup time (24-hour clock)	Personal care (hour/day)	School (hour/day)	Educational (hour/day)	Physical (hour/day)	Chores (hour/day)	Media (hour/day)	Travel (hour/day)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A: Baseline (Number of observations: 53740, Number of individuals: 8708)										
Daylight duration (hour/day)	-0.06***	0.07**	-0.02	-0.05***	0.08***	0.01	0.09***	0.00	-0.07***	0.01
	[0.01]	[0.03]	[0.01]	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]
Panel B: Using a pooled OLS regression model										
Daylight duration (hour/day)	-0.07***	0.07**	-0.01	-0.05***	0.08***	0.00	0.10***	0.00	-0.07***	0.01
	[0.01]	[0.03]	[0.01]	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]
Panel C: Excluding child or household level variables										
Daylight duration (hour/day)	-0.07***	0.08**	-0.02	-0.06***	0.08***	0.01	0.09***	0.00	-0.07***	0.01
	[0.01]	[0.03]	[0.01]	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]
Panel E: Including season dummies instead of quarter dummies										
Daylight duration (hour/day)	-0.07***	0.03	0.00	-0.05***	0.07***	0.01	0.10***	0.01	-0.07***	0.01
	[0.02]	[0.03]	[0.02]	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]
Panel D: Including local weather conditions on TUD date										
Daylight duration (hour/day)	-0.06***	0.02	-0.01	-0.04**	0.09***	0.02	0.03	0.01	-0.05***	0.01
	[0.02]	[0.04]	[0.02]	[0.02]	[0.02]	[0.01]	[0.02]	[0.01]	[0.02]	[0.01]
Daily maximum temperature (^{o}F)	0.02*	0.03	-0.01	-0.03**	0.03***	-0.02**	0.04***	-0.01*	-0.06***	0.01*
	[0.01]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.01]	[0.01]
Daily maximum temperature squared	-0.00*	-0.00	0.00	0.00*	-0.00***	0.00**	-0.00***	0.00	0.00***	-0.00*
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Daily precipitation (inch)	0.00	0.00	0.00	0.00	-0.00	0.01***	-0.01***	-0.00	0.01***	-0.00
	[0.00]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]

Notes: Estimates for each column and panel are from a separate regression. Unless indicated otherwise, results are from an individual FE regression. Unless stated otherwise, other variables include child age (and its square), maternal completed qualification, living with both parents, number of siblings; local socio-economic background variables, state/territory dummies, TUD year dummies, TUD quarter dummies, TUD day-of-week dummies, and a holiday indicator. For OLS regressions, we also control for child gender, Aboriginal status, low birthweight status, cohort dummy, maternal migration statuses and postcode dummies. Robust standard errors clustered at the individual level are in squared brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A4: Heterogeneity in the impact of daylight duration on time allocation

Separate by:	Gender		Age		Weekend		Mother's education level		Mother's employment status	
	Female	Male	Young	Old	Weekday	Weekend	Lower education	Higher education	Unemployed	Employed
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Outcome:	Sleep duration (hour/day)									
Daylight duration (hour/day)	-11.76***	-11.50***	-1.28	-6.44***	-12.82***	-9.45***	-12.07***	-10.88***	-12.13***	-11.27***
	[0.80]	[0.78]	[1.39]	[0.63]	[0.79]	[0.82]	[0.72]	[0.90]	[0.90]	[0.72]
Observations	26,679	27,833	27,840	26,240	28,252	26,260	34,358	19,585	21,914	31,872
Number of individuals	4,481	4,698	7,796	7,750	8,847	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	10.55	10.54	11.27	9.77	10.40	10.69	10.55	10.53	10.62	10.50
Outcome:	Sleep onset time (24-hour clock)									
Daylight duration (hour/day)	7.79***	9.03***	2.96	4.38**	10.33***	6.07***	6.14***	12.29***	7.59***	9.07***
	[1.68]	[1.64]	[2.01]	[1.77]	[1.49]	[1.95]	[1.53]	[1.80]	[1.94]	[1.47]
Observations	26,662	27,823	27,820	26,233	28,238	26,247	34,339	19,577	21,901	31,858
Number of individuals	4,481	4,698	7,795	7,750	8,846	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	20.20	20.21	19.74	20.69	20.25	20.15	20.18	20.24	20.13	20.26
Outcome:	Wakeup time (24-hour clock)									
Daylight duration (hour/day)	2.74***	3.82***	-1.14	0.06	0.84	5.61***	2.41***	4.85***	4.20***	2.82***
	[0.72]	[0.73]	[1.45]	[0.53]	[0.64]	[0.82]	[0.65]	[0.84]	[0.85]	[0.63]
Observations	26,678	27,833	27,839	26,240	28,251	26,260	34,357	19,585	21,914	31,871
Number of individuals	4,481	4,698	7,796	7,750	8,847	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	6.99	6.90	6.56	7.35	6.71	7.20	6.99	6.86	6.89	6.98

Notes: Estimates for each column and panel are from a separate individual FE regression. Other variables include child age (and its square), maternal completed qualification, living with both parents, number of siblings; local socio-economic background variables, state/territory dummies, TUD year dummies, TUD quarter dummies, TUD day-of-week dummies, and a holiday indicator. Robust standard errors clustered at the individual level are in squared brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A4: Heterogeneity in the impact of daylight duration on time allocation (continued)

Separate by:	Gender		Age		Weekend		Mother's education level		Mother's employment status	
	Female	Male	Young	Old	Weekday	Weekend	Lower education	Higher education	Unemployed	Employed
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Outcome:	Personal care (hour/day)									
Daylight duration (hour/day)	1.10	-0.78	0.03	1.49*	0.55	0.02	-0.51	1.40	-0.92	0.91
	[0.93]	[0.91]	[1.49]	[0.83]	[0.89]	[1.01]	[0.82]	[1.07]	[1.03]	[0.84]
Observations	26,679	27,833	27,840	26,240	28,252	26,260	34,358	19,585	21,914	31,872
Number of individuals	4,481	4,698	7,796	7,750	8,847	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	4.30	4.01	4.12	4.19	3.98	4.34	4.16	4.14	4.23	4.10
Outcome:	School (hour/day)									
Daylight duration (hour/day)	3.29***	5.17***	-4.49***	-0.24	6.19***	-0.01	5.12***	2.83**	7.62***	2.07**
	[1.05]	[1.02]	[1.37]	[1.01]	[1.20]	[0.43]	[0.91]	[1.23]	[1.14]	[0.96]
Observations	26,679	27,833	27,840	26,240	28,252	26,260	34,358	19,585	21,914	31,872
Number of individuals	4,481	4,698	7,796	7,750	8,847	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	1.88	1.85	1.29	2.48	3.41	0.21	1.85	1.89	1.67	2.00
Outcome:	Educational (hour/day)									
Daylight duration (hour/day)	-1.31**	-3.30***	-3.01***	0.33	-1.90***	-3.03***	-2.04***	-2.72***	-2.57***	-2.19***
	[0.57]	[0.47]	[0.87]	[0.42]	[0.51]	[0.55]	[0.44]	[0.67]	[0.58]	[0.48]
Observations	26,679	27,833	27,840	26,240	28,252	26,260	34,358	19,585	21,914	31,872
Number of individuals	4,481	4,698	7,796	7,750	8,847	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	1.10	0.89	1.23	0.75	1.04	0.95	0.89	1.19	1.01	0.98

Notes: Estimates for each column and panel are from a separate individual FE regression. Other variables include child age (and its square), maternal completed qualification, living with both parents, number of siblings; local socio-economic background variables, state/territory dummies, TUD year dummies, TUD quarter dummies, TUD day-of-week dummies, and a holiday indicator. Robust standard errors clustered at the individual level are in squared brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table A4: Heterogeneity in the impact of daylight duration on time allocation (continued)

Separate by:	Gender		Age		Weekend		Mother's education level		Mother's employment status	
	Female	Male	Young	Old	Weekday	Weekend	Lower education	Higher education	Unemployed	Employed
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Outcome:	Physical (hour/day)									
Daylight duration	-1.04	-3.12***	11.13***	-3.06***	0.01	-3.32***	-1.77**	-2.86***	-2.34**	-2.05**
(hour/day)	[0.88]	[0.89]	[1.42]	[0.80]	[0.79]	[1.03]	[0.79]	[1.01]	[0.98]	[0.81]
Observations	26,679	27,833	27,840	26,240	28,252	26,260	34,358	19,585	21,914	31,872
Number of individuals	4,481	4,698	7,796	7,750	8,847	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	2.44	2.67	2.97	2.13	1.90	3.27	2.55	2.57	2.57	2.56
Outcome:	Chores (hour/day)									
Daylight duration	4.18***	3.93***	0.21	3.17***	2.19***	5.84***	4.14***	3.94***	3.70***	4.29***
(hour/day)	[0.39]	[0.36]	[0.27]	[0.41]	[0.25]	[0.47]	[0.34]	[0.43]	[0.41]	[0.35]
Observations	26,679	27,833	27,840	26,240	28,252	26,260	34,358	19,585	21,914	31,872
Number of individuals	4,481	4,698	7,796	7,750	8,847	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	0.38	0.31	0.12	0.58	0.25	0.44	0.34	0.35	0.32	0.36
Outcome:	Media (hour/day)									
Daylight duration	5.81***	10.59***	-4.78***	3.79***	5.46***	11.40***	7.52***	9.36***	7.41***	8.75***
(hour/day)	[0.88]	[0.98]	[0.99]	[0.91]	[0.73]	[1.08]	[0.87]	[1.02]	[1.06]	[0.85]
Observations	26,679	27,833	27,840	26,240	28,252	26,260	34,358	19,585	21,914	31,872
Number of individuals	4,481	4,698	7,796	7,750	8,847	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	2.00	2.40	1.50	2.94	1.76	2.68	2.34	1.95	2.27	2.15
Outcome:	Travel (hour/day)									
Daylight duration	-0.27	-0.99*	2.20**	0.96**	0.32	-1.45**	-0.38	-1.08*	-0.76	-0.51
(hour/day)	[0.55]	[0.53]	[0.94]	[0.47]	[0.50]	[0.65]	[0.48]	[0.64]	[0.60]	[0.50]
Observations	26,679	27,833	27,840	26,240	28,252	26,260	34,358	19,585	21,914	31,872
Number of individuals	4,481	4,698	7,796	7,750	8,847	8,587	5,813	2,906	3,626	5,061
Mean of dep. variable	1.34	1.33	1.50	1.16	1.26	1.43	1.32	1.38	1.31	1.36

Notes: Estimates for each column and panel are from a separate individual FE regression. Other variables include child age (and its square), maternal completed qualification, living with both parents, number of siblings; local socio-economic background variables, state/territory dummies, TUD year dummies, TUD quarter dummies, TUD day-of-week dummies, and a holiday indicator. Robust standard errors clustered at the individual level are in squared brackets. The symbol *denotes significance at the 10% level, **at the 5% level, and ***at the 1% level.

Appendix Table B1: Coding rules for activities by B cohort children

Grouping	Wave 1	Wave 2	Wave 3	Waves 6, 7 and 8
Sleep	Sleeping, napping	Sleeping, napping	Sleeping, napping	Sleeping/napping (not end of the day bed-time); Time between sleep (from response to the question "what time did you go to sleep?") and wake-up (next day, from response to the question "What time did you wake up?")
Personal care	Awake in bed / cot; Looking around, doing nothing; Bathe / nappy change, dress / hair care; Breastfeeding; Other eating, drinking, being fed; Crying, upset; Destroy things, create mess; Held, cuddled, comforted, soothed; Not sure what child was doing	Awake in bed; Eating, drinking, being fed; Bathing, dressing, hair care, health care; Doing nothing, bored/restless; Crying, upset, tantrum; Arguing, fighting; Destroy things, create mess; Being reprimanded; Being held, cuddled, comforted, soothed; Quiet free play; Not sure what child was doing;	Awake in bed; Eating, drinking, being fed; Bathing, dressing, hair care, health care; Doing nothing, bored/restless; Crying, upset, tantrum; Arguing, fighting; destroying things, creating mess; Being reprimanded; Being held, comforted, soothed; Quiet free play; Not sure what child was doing	Eating/drinking; Cleaning teeth; Showering/bathing; Getting dressed / getting ready; Personal care nec.; Doctor; Dentist/Orthodontist; Physiotherapist / Chiropractor; Medical/Health care; Personal care/Medical/Health Care nec.; Listening to music; Playing musical instruments or singing for leisure; Chess, card, paper and board games / crosswords; Games of chance / gambling; Hobbies, collections; Handwork crafts (excl. clothes making); Arts; Unstructured non-active play nec; Clubs; Religious groups; Doing nothing; Non-active activities nec.; Talking face-to-face; Talking on a landline phone; Non-verbal interaction; Negative face-to-face communication; Communication nec.; Illegal activities; Filling out the diary; Other; Uncodeable activity
School	Responses "Day care centre / playgroup" to the question "where was the child?"	Responses "Day care centre / playgroup" to the question "where was the child?"	Responses "Day care centre / playgroup" to the question "where was the child?"	School lessons, excluding Recess and Lunch

Grouping	Wave 1	Wave 2	Wave 3	Waves 6, 7 and 8
Education	Read a story, talked / sung to, sing / talk; Colour / draw, look at book, puzzles; Organised activities / playgroup	Read a story, told a story, sung to; Colour/draw, look at book, educational game; Organised lessons/activities	Read a story, talk/sing, talked/sung to; drawing/colouring, looking at book, etc.; organised lessons/activity	Private music lessons/practice, academic tutoring; Reading or being read to for leisure; Doing homework (not via electronic devices); Doing homework (electronic device); Attend courses (excluding school /university)
Physical	Crawl, climb, swing arms or legs; Other play, other activities; Visiting people, special event, party	Active free play; Visiting people, special event, party; Walking; Ride bicycle/trike	Active free play; visiting people, special event, outing; walking; travel in pusher/bicycle seat; ride bicycle, trike, etc.	Archery / Shooting sports; Athletics / Gymnastics; Fitness / Gym / Exercise; Ball Sports; Martial arts / Dancing; Motor Sports / Roller Sports / Cycling; Water/Ice/Snow Sports; Organised team sports and training other; Archery / Shooting sports (individual); Athletics / Gymnastics (individual); Fitness / Gym / Exercise (individual); Martial arts / Dancing (individual); Motor Sports / Roller Sports / Cycling (individual); Ball Sports (individual); Water/Ice/Snow Sports (individual); Organised individual sport and training other; Archery / Shooting sports (unstructured); Athletics / Gymnastics (unstructured); Fitness / Gym / Exercise (unstructured); Ball Sports (unstructured); Martial arts / Dancing (unstructured); Motor Sports / Roller Sports / Cycling (unstructured); Water/Ice/Snow Sports (unstructured); Unstructured active play Other; Walking pets/playing with pets; Active club activities; Shopping; Shopping; Purchasing consumer goods; Purchasing durable goods; Window shopping; Purchasing repair services; Purchasing administrative services; Purchasing personal care services; Purchasing other services; Attendance at movies / cinema; Attendance at concert/theatre; Attendance at museum / exhibition / art gallery; Attendance at zoo / animal park / botanic garden; Attendance at other mass events; Going out nec; Religious practice; Weddings, funerals, rites of passage; Religious activities / ritual ceremonies nec; Attending live sporting events; Active activities nec
Chores		Being taught to do chores	Being taught to do chores	Retailing; Hospitality (including fast food); Clerical/office; Labourers and related workers; Gardening / lawn mowing; Babysitting; Apprenticeships/trades persons; Working in a family business or farm; Work Other; Umpiring (work); Car washing (work); Animal care (work); Volunteering (work); Cleaning/tidying; Laundry/clothes care; Clothes making; Food/drink preparation; Food/drink clean up; Gardening (maintenance chores); Cleaning grounds/garage/shed/outside of house (chores); Pool care (chores); Animal care; Home maintenance; Design/Home Improvement; Heat/water/power upkeep; Car/boat/bike care; Selling/disposing of household assets; Rubbish/Recycling; Packing; Household management Other; Taking care of siblings (chores); Chores nec
Media	Watching TV, video or DVD; Listening to tapes, CD's, radio, music	Watching TV, video, DVD, movie; Listening to tapes, CDs, radio, music; Using computer, computer game	Watching TV, video, DVD, movie; listening to tapes, CDs, radio, music; using computer, computer game	Playing games (electronic device); Playing games (Electronic device) nfd; Watching TV programs or movies/videos; Spending time on social networking sites; Downloading/posting media; Internet shopping; General Internet browsing; Creating/maintaining websites; General application use; Electronic device use nec.; Talking on a mobile phone; Video chatting; Texting/emailing; Online chatting / Instant messaging

Grouping	Wave 1	Wave 2	Wave 3	Waves 6, 7 and 8
Travel	Taken places with adult (e.g. shopping); Taken out in pram or bicycle seat; Travel in car / other household vehicle; Travel on public transport, ferry, plane	Travel in car; Travel in a pusher/bicycle seat; Travel on public transport; Taken places with adult (e.g. Shopping)	Travel in car; travel on public transport; taken places with adult	Travel by foot; by bike, scooter, skateboard etc.; by private motor vehicle/bike; by public/chartered transport; Travel nec.

Appendix Table B2: Coding rules for activities by K cohort children

Grouping	Wave 1	Waves 2 and 3	Wave 4	Wave 5	Wave 6
Sleep	Sleeping, napping	Sleeping, napping	Sleeping/napping; Time between sleep (from response to the question "what time did you go to sleep?") and wake-up (next day, from response to the question "What time did you wake up?")	Sleeping/napping (not end of the day bed-time); Time between sleep (from response to the question "what time did you go to sleep?") and wake-up (next day, from response to the question "What time did you wake up?")	Sleeping/napping (not end of the day bed-time); Time between sleep (from response to the question "what time did you go to sleep?") and wake-up (next day, from response to the question "What time did you wake up?")
Personal care	Awake in bed; Eating and drinking; Bathe, dress, hair care, health care; Do nothing, bored/restless; Crying, upset, tantrum; Arguing, fighting, destroy things; Held, cuddled, comforted, soothed; Being reprimanded, corrected; Not sure what child was doing	Awake in bed; Eating and drinking; Bathe, dress, hair care, health care; Do nothing, bored/restless; Crying, upset, tantrum; Arguing, fighting, destroy things; Held, cuddled, comforted, soothed; Being reprimanded, corrected; Quiet free play; Not sure what child was doing	Eating/drinking; Bathing, dressing, toileting, teeth brushing, hair care; Dentist, Doctor, Chiropractor, Physio, Optometrist; Listening to music, CDs, playing music; Board or card games, puzzles, toys, art; Non-Active Club Activities i.e. Chess C; Doing nothing; Talking face to face; Other	Eating/drinking; Cleaning teeth; Showering/bathing; Getting dressed / getting ready; Personal care nec.; Doctor; Dentist; Physiotherapist / Chiropractor; Medical/Health care nec.; Listening to music, playing musical instruments or singing for leisure; Unstructured non-active play; Non-active club activities; Doing nothing; Non-active activities nec.; Talking face-to-face (in person not via electronic devices); Non-verbal interaction (e.g. cuddles); Negative face-to-face communication; Communication nec.; Filling out the diary; Other	Eating/drinking; Cleaning teeth; Showering/bathing; Getting dressed / getting ready; Personal care nec; Doctor; Dentist/Orthodontist; Physiotherapist / Chiropractor; Medical/Health care; Personal care/Medical/Health Care nec.; Listening to music; Playing musical instruments or singing for leisure; Chess, card, paper and board games / crosswords; Games of chance / gambling; Hobbies, collections; Handwork crafts (excl. clothes making); Arts; Unstructured non-active play nec; Clubs; Religious groups; Doing nothing; Non-active activities nec; Talking face-to-face; Talking on a landline phone; Non-verbal interaction; Negative face-to-face communication; Communication nec; Illegal activities; Filling out the diary; Other; Uncodeable activity
School	Responses "Day care centre / playgroup" to the question "where was the child?"	Responses "School, after/; before school; care" to the question "where was the child?"	School Lessons, excluding Recess and Lunch	School Lessons, excluding Recess and Lunch	School Lessons, excluding Recess and Lunch

Grouping	Wave 1	Waves 2 and 3	Wave 4	Wave 5	Wave 6
Education	Read a story, talk/sing, talked/sung to; colour, look at book, educational game; being taught to do chores, read, etc.; organised lessons / activities	Use computer/computer games (if this activity done for or as part of homework); Read a story, talk/sing, talked/sung to; Reading looking at book by self; Other organised lessons / activities	Private music, language, religion lessons, tutoring; Reading or being read to for leisure; Homework (not on computer) including music practice; Computer for homework - internet; Computer for homework - not internet	Private music lessons/practice, academic tutoring; Reading or being read to for leisure; Doing homework (not via electronic devices); Doing homework	Private music lessons/practice, academic tutoring; Reading or being read to for leisure; Doing homework (not via electronic devices); Doing homework (electronic device); Attend courses (excluding school /university)
Physical	Walk for travel or for fun; ride bicycle, trike etc. (travel or fun); other exercise - swim / dance/ run about; visiting people, special event, party; other play, other activities	Walk for travel or for fun; Ride bicycle, trike etc. (travel for fun); Visiting people, special event, party; Organised sport/physical activity; Other organised lessons / activities	Organised team sports and training i.e.; Organised individual sport i.e. swimming; Ball games, riding a bike, scooter, ska; Taking Pet for a walk; Scouts, girl guides, etc.; Shopping; Going out to museums, cultural events,; Cinema; Live Sporting Events	Organised team sports and training; Organised individual sport and training; Unstructured active play; Walking pets / playing with pets; Active club activities; Shopping; Going out to a concert, play, museum, art gallery, community or school event , an amusement park etc.; Religious activities / ritual ceremonies; Attending live sporting events; Active activities nec.	Archery / Shooting sports; Athletics / Gymnastics; Fitness / Gym / Exercise; Ball Sports; Martial arts / Dancing; Motor Sports / Roller Sports / Cycling; Water/Ice/Snow Sports; Organised team sports and training other; Archery / Shooting sports (individual); Athletics / Gymnastics (individual); Fitness / Gym / Exercise (individual); Martial arts / Dancing (individual); Motor Sports / Roller Sports / Cycling (individual); Ball Sports (individual); Water/Ice/Snow Sports (individual); Organised individual sport and training other; Archery / Shooting sports (unstructured); Athletics / Gymnastics (unstructured); Fitness / Gym / Exercise (unstructured); Ball Sports (unstructured); Martial arts / Dancing (unstructured); Motor Sports / Roller Sports / Cycling (unstructured); Water/Ice/Snow Sports (unstructured); Unstructured active play Other; Walking pets/playing with pets; Active club activities; Shopping; Shopping; Purchasing consumer goods; Purchasing durable goods; Window shopping; Purchasing repair services; Purchasing administrative services; Purchasing personal care services; Purchasing other services; Attendance at movies / cinema; Attendance at concert/theatre;

Grouping	Wave 1	Waves 2 and 3	Wave 4	Wave 5	Wave 6
					Attendance at museum / exhibition / art gallery; Attendance at zoo / animal park / botanic garden; Attendance at other mass events; Going out nec; Religious practice; Weddings, funerals, rites of passage; Religious activities / ritual ceremonies nec; Attending live sporting events; Active activities nec.
Chores		Helping with chores/jobs	Making own bed, tidying own room; Making, preparing own food; Getting self ready, packing own school; Cleaning, tidying other rooms; Cooking, meal preparation, making lunch; Washing dishes, stacking and emptying d; Gardening, putting out the bin; Taking care of siblings, other children; Taking care of pets (excluding Walking pets)	Retailing (including fast food); Pamphlet delivering; Umpiring/refereeing; Car washing; Gardening / lawn mowing; Babysitting; Animal care; Working in a family business or farm; Work nec.; Volunteering; Cleaning/tidying; Laundry/clothes care; Food/drink preparation; Food/drink clean up; Gardening / lawn mowing; Animal care (excluding active play); Home maintenance; Taking care of siblings; Chores nec	Retailing; Hospitality (including fast food); Clerical/office; Labourers and related workers; Gardening / lawn mowing; Babysitting; Apprenticeships/trades persons; Working in a family business or farm; Work Other; Umpiring (work); Car washing (work); Animal care (work); Volunteering (work); Cleaning/tidying; Laundry/clothes care; Clothes making; Food/drink preparation; Food/drink clean up; Gardening (maintenance chores); Cleaning grounds/garage/shed/outside of house (chores); Pool care (chores); Animal care; Home maintenance; Design/Home Improvement; Heat/water/power upkeep; Car/boat/bike care; Selling/disposing of household assets; Rubbish/Recycling; Packing; Household management Other; Taking care of siblings (chores); Chores nec
Media	Watching TV, video, DVD, movie; Listening to tapes, CD's, radio, music; Use computer/computer games	Watching TV, video, DVD, movie; Listening to tapes, CD's, radio, music; Use computer/computer games (if this activity done NOT for or NOT as part of homework)	Electronic media, games, computer use; Computer games - internet; Computer games - not internet; Xbox, Playstation, Nintendo, WII etc.; Internet not covered elsewhere; TV/DVD; Talking on a landline phone; Talking on a mobile phone; Texting, email, social networking	Playing games; Watching TV programs or movies/videos; Spending time on social networking sites; Downloading/posting media (e.g. music, videos, applications); Internet shopping (excluding downloading/posting media); General Internet browsing (excluding homework); Creating/maintaining websites (excluding social networking profile); General application use (e.g. Microsoft Office; excluding homework); Electronic device use	Playing games (electronic device); Playing games (Electronic device) nfd.; Watching TV programs or movies/videos; Spending time on social networking sites; Downloading/posting media; Internet shopping; General Internet browsing; Creating/maintaining websites; General application use; Electronic device use nec; Talking on a mobile phone; Video chatting; Texting/emailing; Online chatting / Instant messaging

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Grouping	Wave 1	Waves 2 and 3	Wave 4	Wave 5	Wave 6
			- facebook/twitter; Skype or Webcam	nec.; Talking on a landline phone (not video chat); Talking on a mobile phone (not video chat); Video chatting (e.g. Skype); Texting/emailing; Online chatting / Instant messaging	
Travel	Travel in pusher or on bicycle seat; travel in car / other household vehicle; travel on public transport, ferry, plane; taken places with adult (e.g. shopping)	Travel in car; Travel on public transport; Taken places with adult (e.g. Shopping)	Travel by foot; by bike, scooter, skateboard etc.; by private car; Travel by public transport such as bus	Travel by foot; by bike, scooter, skateboard etc.; by private motor vehicle/bike; by public/chartered transport such as bus, taxi or aeroplane; Travel nec.	Travel by foot; by bike, scooter, skateboard etc.; by private motor vehicle/bike; by public/chartered transport; Travel nec.