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Changes in early adolescents' time use after acquiring their first mobile phone. An empirical test of the displacement hypothesis.

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Abstract: This study empirically tests the displacement hypothesis, examining whether adolescents' mobile phone use displaces time spent on activities that benefit cognitive development and academic performance. Longitudinal time-use data from a sample of Australian early adolescents (ages 10-13) and a difference-in-differences design are used to model the effect of first mobile phone acquisition on allocation of time to various activities. The results challenge the displacement hypothesis, providing no evidence that mobile phone acquisition displaces enrichment, physical activity or sleep time in early adolescence. However, acquiring a mobile phone is associated with a significant reduction in time spent watching TV, movies, or videos. This suggests the rise in adolescent mobile phone use may partly represent shifting away from traditional screen activities rather than displacing cognitively beneficial activities. Guidelines for parents recommending later ages of mobile phone acquisition are unlikely to affect early adolescents' time spent on non-screen activities.

Keywords: Academic performance, early adolescents, difference-in-differences, displacement hypothesis, educational outcomes, enrichment activities, longitudinal data, mobile phones, parental mediation, time use.

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Introduction

The rapid rise of smartphones has allowed adolescents to spend more time on screens outside of school than ever before (Fomby et al., 2021; Radesky et al., 2023). Recent estimates across different contexts indicate that adolescents spend an average of four hours per day engaged with their mobile devices (Radesky et al., 2023; Tkaczyk et al., 2024; Tomczyk & Lizde, 2023).[i] This massive increase in adolescents' mobile phone use has caused concerns among educators, parents and researchers regarding its effects on critical areas of adolescent development (George & Odgers, 2015). Of particular worry are potential detrimental effects on academic performance, as the dawn of the smartphone era correlates with the historic decline in adolescents' academic performance across many countries (Schleicher, 2023). Fueling these debates, empirical studies consistently report that higher phone use is associated with decreased academic performance – though causal evidence remains limited (Amez & Baert, 2020; Kates et al., 2018). In response, schools around the world have implemented mobile phone bans on school grounds to cope with their potential to distract students from participation in class, despite inconclusive evidence of the effectiveness of such bans (Kessel et al., 2020; Selwyn & Aagaard, 2021). As public discourse intensifies around protecting youth from supposed harms of mobile devices, research on the effects of mobile phone use on educational outcomes is still underdeveloped (Amez & Baert, 2020; Gerosa & Gui, 2023).

Most studies in this research area rely on correlational evidence, suggesting that the reported negative associations may stem at least partly from unobserved confounding (Amez & Baert, 2020). While a recent study based on longitudinal data found negative effects of smartphone use on the academic performance of university students (Amez et al., 2023), similarly robust evidence for effects on adolescents is still lacking. A handful of studies has investigated the effects of the age of first mobile phone acquisition on early adolescents' educational outcomes. Earlier acquisition of a mobile phone has been found to be related to lower academic performance (Dempsey et al., 2019), and to lower language proficiency, but only among those who already spend more than two hours daily on television and video games (Gerosa & Gui, 2023). Another study on children from low-income neighborhoods in the US found no effect of mobile phone acquisition on school grades (Sun et al., 2023).

Previous research has proposed three mechanisms which might cause negative effects of mobile phone use on adolescents' cognitive development and academic performance. First, frequent mobile phone use may negatively affect cognitive functioning, e.g., by distracting students or by affecting their ability to focus their attention (Glass & Kang, 2019; Ward et al., 2017; Wilmer et al., 2017); second, mobile phone use may indirectly affect educational outcomes by harming adolescents' health and wellbeing (Dempsey et al., 2019); and third, mobile phone use may displace time spent on other non-media activities which can affect academic performance (Kushlev & Leitao, 2020; Marciano & Camerini, 2021; Neuman, 1988).

The present study is focused on the third argument, the displacement hypothesis. The basic idea of displacement is that people possess a fixed time budget. Hence, if they want to increase the time spent on a certain activity, e.g., using new technology like the mobile phone, they have to reduce the time spent on other activities (Bryant & Fondren, 2009). The net effect of such shifts in time use on the outcome of interest depends on the effects of both the displacing and the displaced activity (Fiorini & Keane, 2014). Despite being frequently used as one of the main explanations for hypothesized negative effects of mobile phone use on adolescents' academic performance (e.g., Dempsey et al., 2019; Gerosa & Gui, 2023; Marciano & Camerini, 2021), the empirical evidence for displacement effects of mobile phone use is limited.

This study presents a comprehensive and rigorous empirical test of the displacement hypothesis regarding adolescents' mobile phone use. Analyses are based on a large panel dataset of Australian early adolescents (aged 10-13 years) which provides comparable, self-reported 24-hour time use diaries for a large cohort of early adolescents at two time points (at ages 10/11, and 12/13). Many previous studies on the effects of mobile phone use on adolescents' educational outcomes have relied on the mostly implausible assumption that adolescents with different levels of mobile phone use are similar except for the properties captured by the models' control variables (Amez & Baert, 2020). The present study diminishes this problem by employing a specific identification strategy: A weighted difference-in-differences analysis is used to model the effect of early adolescents' first mobile phone acquisition on the time they allocate to different cognitively and academically beneficial activities. Mobile phone acquisition serves as a proxy for increased phone use time. As explained further in the methods section, this design is well-suited to capture displacement effects of mobile phone use during the first two years after early adolescents acquired their first own mobile phone.

Effects of new media on adolescents' time use

This section reviews previous literature on time displacement in childhood and adolescence and develops the research questions to be addressed in the empirical part of the paper. It starts by reviewing the empirical literature on how adolescents' allocation of time relates to cognitive development and academic outcomes, identifying the most relevant types of activities. It then discusses previous empirical findings on displacement effects of media and technology use, before outlining theoretical principles from media displacement research. Based on this theoretical and empirical background, three research questions are derived to examine whether mobile phone use displaces cognitively and academically beneficial time use among early adolescents.

Cognitively and academically beneficial time use in adolescence

The allocation of adolescents' time outside of school has long been known to affect their cognitive skills and academic performance (e.g., G. Caetano et al., 2019; Del Boca et al., 2017; Jürges & Khanam, 2021) and, ultimately, their future educational and occupational success (Hernæs et al., 2019). Three types of time use have particularly well-documented links to cognitive development and academic performance: Enrichment activities, physical activity, and sleep. Enrichment activities are activities adolescents can perform in their free time, which are intended to foster their cognitive or noncognitive skills (C. Caetano et al., 2020). This includes activities like reading, homework, extracurricular lessons, and cultural activities like making music or arts or going to a museum. Several studies have reported positive effects of enrichment time on adolescents' cognitive skills (e.g., Cabane et al., 2016; Covay & Carbonaro, 2010; Jürges & Khanam, 2021). Similarly, physical activity is generally considered to benefit cognitive development and academic performance, although studies mostly report rather small effects (Barbosa et al., 2020). The evidence for causal effects on educational outcomes is strongest for the third of the outcomes, sleep. A lack of sleep has detrimental effects on academic performance (Curcio et al., 2006).

Previous empirical findings

Since the advent of the television era, researchers have extensively studied the question of which activities are displaced by the introduction of new media (e.g., Putnam, 2000). A particularly large strand of research has investigated the displacement effects of television on children's and adolescents' reading time (Koolstra & van der Voort, 1996; Neuman, 1995). Other studies have investigated the displacement of homework by television viewing (Vandewater et al., 2006). Most previous studies investigating displacement effects of children's and adolescents' technology engagement in general (screen time) have focused on physical activity (e.g., Gebremariam et al., 2013; Lizandra et al., 2019) and on sleep (Fomby et al., 2021; Hale & Guan, 2015; Przybylski, 2019). These studies tend to report moderate negative correlations between physical activity or sleep and screen time. However, these studies mostly rely on correlational designs. It is therefore unclear whether displacement effects have caused the reported negative correlations or whether the latter result from unobserved differences between heavier and less heavy screen users (Robinson, 2011).

The very few studies that specifically focus on displacement effects of mobile phones have mostly investigated the displacement of sleep, because the portability of mobile phones facilitates their use in bed, which in turn might affect sleep patterns and sleep quality (Grover et al., 2016; Lemola et al., 2015; Schweizer et al., 2017). For enrichment activities, available evidence is limited to studies investigating mobile phone use in the classroom, which can negatively affect students' learning (Sunday et al., 2021). For physical activity, some studies report negative correlations between mobile phone use and physical activity levels (Lepp et al., 2013). Again, studies with longitudinal or experimental designs are still lacking, questioning whether mobile phones actually displace cognitively beneficial activities.

Principles of time displacement

Why should mobile phone use affect the time adolescents spend on enrichment, physical activity, or sleep? Among others, media displacement research has developed two general principles: the principal of marginal fringe activities and the principle of functional similarity (Bryant & Fondren, 2009). The principle of marginal fringe activities postulates that new media tend to displace less structured activities or unstructured free time, over which individuals tend to have more control. Hence, new media are likely to displace less structured leisure activities like leisure reading, leaving highly structured activities like structured sports practice unaffected.

The idea of functional similarity is that new media displaces activities that previously served the same function for the consumers, but yielded comparatively lower satisfaction (e.g., radio as a source of evening entertainment before the introduction of television in the 1950s). Applying this theoretical principle can be difficult particularly when a medium is used for multiple purposes (Koolstra & van der Voort, 1996). Finally, some studies on the effects of television on children's reading habits have discussed other theoretical mechanisms explaining negative effects. Koolstra and van der Voort (1996) found that television watching affected children's attitudes towards reading negatively and it also had detrimental effects on their ability to concentrate on reading.

Research questions

In sum, the review of the displacement literature suggests that mobile phones should be more likely to displace leisure reading and sleep rather than time spent on highly structured activities such as sports practice or extracurricular lessons. Similar mechanisms like the one described by Koolstra and van der Voort (1996) could induce negative effects of mobile phone use on reading and doing homework, which require high degrees of concentration and self-regulation (Kushlev & Leitao, 2020). The distraction potential of the mobile phone regarding homework and studying has been demonstrated in a range of studies (David et al., 2015; Mrazek et al., 2021; Ward et al., 2017). Whether distraction and interference lead to permanently lower net time spent on reading, homework, or other high-focus activities, has hardly been investigated empirically. It nevertheless seems plausible, especially for activities over which adolescents possess much control (e.g., leisure reading).

The case of mobile phones is also special in another regard: They can be used during almost any other given activity. Since the introduction of smartphones and tablet computers, children's use of screens as a secondary activity increased (Goode et al., 2020). It may therefore be expected that mobile phones do not necessarily displace any time spent on enrichment, physical activity, or sleep, but rather increase the amount of “divided” time that is spent simultaneously on multiple activities. However, because use times among adolescents accumulate to multiple hours a day (Radesky et al., 2023), it is very likely that some displacement occurs when mobile phones enter early adolescents’ lives. This leads to the first, largely explorative research question:

RQ1: *Does mobile phone use negatively affect the time adolescents spend on enrichment activities, physical activity, and sleep?*

Displacement effects may differ by sociodemographic groups, because mobile phones can be used for different purposes, and with varying intensity. Given the effects of enrichment activities on educational outcomes, the social stratification of enrichment activities (Covay & Carbonaro, 2010), and their symbolic status function (Choi, 2017), it could be expected that displacement processes of mobile phone acquisition differ between adolescents with different socioeconomic backgrounds. The parenting style literature suggests that socioeconomically more advantaged parents are both more invested in fostering their children’s talents by structuring their leisure activities (Lareau, 2011) and in actively mediating their ICT use, e.g., by enforcing technology bans in bedrooms (Koch et al., 2024). This would make it less likely for socioeconomically more advantaged adolescents to displace enrichment, physical activity, or sleep time. Such an effect would be in line with the “third-level digital divide” (van Deursen & Helsper, 2015), which states that socioeconomically advantaged adolescents can derive more desirable outcomes from their ICT use due to their higher possession of certain resources such as digital competencies or parental support (Bohnert & Gracia, 2023). However, regarding displacement, it may also be the other way around: Because more advantaged adolescents spend on average more time on enrichment activities, these adolescents have “more to lose” in terms of absolute enrichment or physical activity time. Hence, the second research question states:

RQ2: *Does the effect of mobile phone use on the time adolescents spend on enrichment, physical activity, and sleep differ between by adolescents' socioeconomic background?*

Applying the principle of functional similarity is difficult for a multi-purpose medium like the modern mobile phone. However, one may still argue that other recreational screen activities (watching television or videos, electronic games) are more functionally similar to mobile phone use than enrichment activities and should therefore rather be displaced instead. In line with pediatric guidelines (e.g., World Health Organization, 2019), parents frequently impose limits on children's and young adolescents' overall screen time (Mollborn et al., 2022). Such restrictions may necessitate trade-offs between early adolescents' screen activities, potentially leading to displacement effects. This yields the final research question:

RQ3: *Does mobile phone use negatively affect the time adolescents spend on other electronic media activities?*

Method

The core idea of the research design is to use early adolescents' acquisition of their first mobile phone as the independent (treatment) variable instead of a direct measure of mobile phone use time. This idea is based on two assumptions. First, mobile phone acquisition is assumed to be a robust proxy for an increase in early adolescents' daily mobile phone use time during the period of observation (up to two years after the initial acquisition). Second, the relationship between mobile phone acquisition and the outcome variables is assumed to be much less affected by unobserved confounding (third variables affecting both the independent and the dependent variables) than the relationship between the time spent using the mobile phone and the outcome variables. At which point in time adolescents acquire their first mobile phone is mostly decided by their parents, and parental criteria on the right timing should depend on factors largely unrelated to adolescents' current time allocation (Perowne

& Gutman, 2023). Under these assumptions, analyzing the effects of mobile phone acquisition comes much closer to a natural experiment than directly analyzing the effects of changes in time spent using a mobile phone. The first assumption can be tested empirically using the present data (see below), while the second assumption cannot. Potential violations of these assumptions are discussed in the final section of this article.

Data

Analyses are based on two panel waves from the Longitudinal Study of Australian Children (LSAC; Department of Social Services et al., 2021) collected in 2014 and 2016. The early adolescents under study were born between 2003 and 2004 (the "B cohort"). The LSAC is one of the very few large-scale survey datasets worldwide that includes repeated measures of adolescents' time use based on 24h-diaries, the current gold standard in time use research. The data analyzed in this study stems from time use diaries filled out by the adolescents themselves and from parent interviews. 3,775 adolescents provided a time use diary for at least one of the waves. After removing inconsistent or implausible diaries and adolescents which provided a valid diary only for one of the panel waves, 2,511 adolescents remain in the sample. Listwise deletion of adolescents with missing values in one of the control variables yields an initial analysis sample of 2,206 adolescents. All results presented in the following account for the sampling design and for selective panel attrition by applying a longitudinal survey weight and by calculating cluster-robust standard errors.

Measures

Treatment

Mobile phone acquisition is measured based on the following question in the parent questionnaire: "Does [your] child own or use a mobile phone? Exclude mobile phones that are only used for playing games or do not contain a SIM card." Response categories are "0

No”; “1 Yes, [the child] has [its] own phone”; “2 Yes, [the child] uses someone else's phone”; “3 Yes, [the child] has [its] own phone and uses someone else's phone”. For this study, acquisition is defined as adolescents receiving their own phone, which includes categories 1 and 3. Adolescents who exclusively use someone else’s phone are treated as not owning their own phone.

Figure 1 shows the distribution of the phone ownership variable in the initial analysis sample. A large share of early adolescents received their first mobile phone between the panel waves at age 10/11 and age 12/13 (1,319 individuals). This “treated” group represents 58.8% of the cohort[ii]. At the same time, 25.4% of early adolescents (538 individuals) did not acquire their own mobile phone up to the second measurement (age 12/13). This group serves as the control group (“untreated”) in the following analyses.[iii] The 15.8% of early adolescents who already had their own mobile phone at age 10/11 are removed from the analysis sample because they do not represent a meaningful comparison group in the analytical framework of this study. The resulting final sample consists of 1,857 early adolescents.

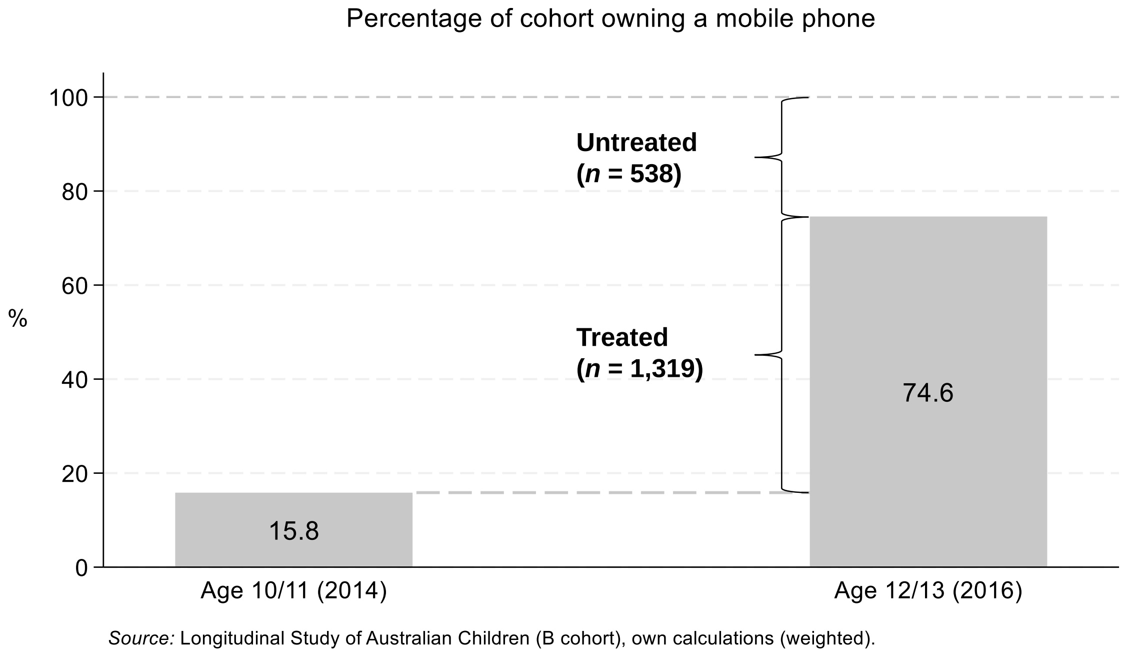

Figure 1. Adolescents’ mobile phone ownership status by panel wave (*n* = 2,206).

Dependent variables

The detailed records of adolescents’ time use diaries provided by the LSAC include information on one random day of the week for each adolescent, with standardized codes indicating the start and end time of one main activity and up to three parallel secondary activities. For the main analyses, daily time spent on an activity is calculated by summing up the duration of all intervals in which the activity was performed, including primary and up to three secondary activities. For some variables, several codes are combined. This calculation acknowledges the fact that mobile devices may facilitate multitasking. Other studies analyzing the same time use dataset have used a different calculation, dividing the duration of time intervals by the number of parallel activities (Cano & Gracia, 2022). Results from a robustness test using this alternative calculation are presented at the end of the results section.

Enrichment activities are measured separately, using three different types of enrichment: “Reading for pleasure”, “homework”, and “cultural activities and other enrichment". The latter category includes a diverse range of activities, from creative activities like playing musical instruments, over structured after-school activities such as going to clubs or tutoring, to highbrow cultural activities like going to the museum. Physical activity is measured based on "structured sports" activities. Sleep is measured focusing on nighttime sleep, calculated as the difference between the wake-up time and the time adolescents went to bed on the day the diary was filled out. "Watching TV, movies, or videos" and "playing games on an electronic device" indicate the two most common electronic media activities that are available as pre-coded categories in the data. Table A1 (Supplementary Material) presents the original codes used to generate the dependent variables.

Control variables

In addition, certain time-varying variables are included as controls. As a developmental milestone which is often associated with changes in commute distance and longer school hours, the change to secondary school may also motivate parents to purchase their child a mobile phone (Perowne & Gutman, 2023). The variable indicating early adolescents' current school type differentiates between primary, secondary, combined, and special schools. Parent-reported household income is included as a control variable because children's time allocation can be affected by periods of financial hardship (Arnup et al., 2022). Changes in household income may also affect the purchase of a mobile phone. Parental separation can affect children's time allocation (Cano & Gracia, 2022), and it may also affect mobile phone acquisition because of the increased coordination required in families after parental separation. The number of parents living in the household is measured using a binary variable indicating the presence of either one or two parents in the household.

Table 1. Summary statistics of dependent variables and controls variables, by panel wave (age). Standard deviation in parentheses for continuous variables.

	Age 10/11	Age 12/13
Enrichment activities (daily minutes)		
Reading for pleasure	21.9 (45.9)	19.6 (48.5)
Homework	14.3 (34.5)	28.2 (58.0)
Cultural activities and other enrichment	27.5 (56.6)	17.2 (47.3)
Physical activity (daily minutes)		
Structured sports	26.3 (54.8)	28.3 (58.8)
Sleep (daily minutes)		
Nighttime sleep	589.3 (69.7)	569.1 (81.0)
Electronic media activities (daily minutes)		
TV, movies, or videos	143.4 (123.3)	142.2 (125.4)
Electronic games	71.8 (106.6)	64.7 (105.9)
Type of school (%)		
Primary	83.3	8.4
Secondary	0.2	62.9
Combined / special	16.5	28.7
Number of parents living in the household (%)		
One	11.9	13.4
Two	88.1	86.6
Household income (in 1,000 Australian Dollars, imputed)	2.4 (1.6)	2.6 (1.8)
N (adolescents)	1,857	1,857

Statistical modeling

Difference-in-differences

This study applies a weighted difference-in-differences (DID) method, which is a very popular econometric method to study treatment effects in observational settings. DID compares the change in the outcome between treated and untreated units across measurements. The resulting coefficients can be interpreted as an average treatment effect on the treated (ATT) under the assumption of parallel trends (Chaisemartin & D'Haultfœuille, 2023). The parallel trends assumption states that in the hypothetical case of an absence of the treatment (here: mobile phone acquisition), the treated individuals (here: early adolescents who acquired their first mobile phone between the two measurements) would have had the same trend in the outcome variable as the untreated individuals (here: early adolescents who did not acquire their first mobile phone during the same period). A main advantage of the DID design is that unobserved time-constant differences between treated and untreated units do not affect the estimate as long as they are unrelated to future trends in the outcome (their association with the outcome is assumed to be constant over time). This assumption is much weaker than the exogeneity assumption typically made in studies reporting cross-sectional correlations.

For this study, the DID is estimated using a two-way fixed effects regression model (TWFE), which allows controlling for time-varying confounders. The latter are events which affect both the timing of mobile phone acquisition and time spent on enrichment, physical activity, sleep, or electronic activities subsection on control variables). The applied statistical model can be noted as follows:

Eq. 1: $$y_{ijt} = \beta_j x_{it} + \mu_{jt} + \alpha_{ij} + \varepsilon_{ijt}$$

where y_{ijt} is the time spent by adolescent *i* on an activity *j* at timepoint *t* and x_{it} is the vector of time-varying predictors including the phone ownership status and the control variables. β_j stands for the vector of regression coefficients. μ_{jt} denotes period dummies for both time points. α_{ij} denotes the unit-fixed effects, and ε_{ijt} the idiosyncratic error tern.

Matching procedure

In addition, matching on pre-treatment covariates is combined with the DID approach. This technique can effectively reduce bias in DID analyses resulting from violations of the parallel trends assumption (Ham & Miratrix, 2022). Adolescents who receive a mobile phone earlier may differ systematically from those who do later, e.g., regarding their sex (Gerosa & Gui, 2023). Such differences can affect not only the levels, but also the trends in the outcome variables. For instance, as girls and boys at this age develop specific interests, sex differences in time use are likely to become larger over time. To account for such violations of the parallel trends assumption of the DID, multivariate distance matching (MDM) based on a Epanechnikov Kernel matching algorithm with automatic bandwidth selection is applied prior to the DID analysis (using the package “kmatch” in Stata 18.0: Jann, 2017).

MDM is performed based on the following variables suspected to be related to both mobile phone acquisition and time trends in the outcome variables: sex, family socioeconomic position (SEP), parental perception of school performance at age 10/11, and remoteness of place of residence. Family SEP is measured using a composite measure provided by the LSAC (Baker et al., 2017). The original variable is divided into quartiles for the matching to achieve a good balance across the whole spectrum of family SEP. Adolescents’ school performance may affect their time allocation, and their parents may consider school performance in their assessment of the child’s readiness to possess a mobile phone (Perowne & Gutman, 2023). The parental perception of the child’s current school achievement in comparison to classmates at age 10/11 is measured based on a four-point scale from “[well] below average” to “excellent”. Table 2 displays the covariate balance before and after performing MDM. For variables like remoteness of place of residence or sex, the matching minimizes a previously large imbalance (indicated by the standardized mean difference [SMD]) between treated and untreated early adolescents. Overall, MDM achieves almost perfect covariate balance between both groups.

Table 2. Covariate balancing before and after MDM.

	Before matching			After matching		
	Treated	Untreated	SMD	Treated	Untreated	SMD
Family SEP quartile (%)						
First (low SEP)	27.2	28.8	−.04	27.2	27.2	.00
Second	26.2	25.9	.01	26.2	26.2	.00
Third	23.7	25.4	−.04	23.7	23.7	.00
Fourth (high SEP)	22.9	19.9	.07	22.9	22.9	.00
Sex (%)						
Male	47.6	59.0	−.23	47.6	47.6	.00
Remoteness of place of residence (%)						
Major city	68.1	49.4	.39	68.1	68.1	.00
Inner regional Australia	22.0	32.6	−.24	22.0	22.0	.00
Outer regional / remote Australia	10.0	18.0	−.23	10.0	10.0	.00
Parental perception of school performance (scale 1−4)	2.7	2.7	.02	2.7	2.7	−.01
N (adolescents)	1,319	538		1,319	538	

Model validation

To validate the data and the statistical model employed in this study, a preliminary analysis examines the effect of mobile phone acquisition on the time spent using a mobile phone. This analysis aims to ensure the data and research design are capable of capturing displacement effects of mobile phone use on the outcome activities in the first place. To this end, an additional variable is created which captures all time intervals explicitly spent using a mobile phone. Table A2 (Supplementary Material) presents the categories and detailed labels of the time use intervals which are used to code this variable. Only intervals which unambiguously refer to mobile phones are included. The resulting variable captures only a subset of the relevant time intervals because many of the detailed activity labels are still too generic in nature (e.g., "video (watch)") and can therefore not be related to a certain device. In addition, secondary activities cannot be included (except "talking on a mobile phone") because detailed labels for these activities are unavailable. It is generally difficult to capture time spent using mobile devices based on time use diaries (Barr et al., 2020; große Deters & Schoedel, 2023). For these reasons, the resulting variable most likely underestimates adolescents' actual phone use (mean = 2.3 minutes at age 10/11; 15.0 minutes at age 12/13), but it is sufficient to conduct the intended test.

The test based on the model as specified in Eq. 1 (with MDM) shows a 16.7 minute increase ($p < .01$) in daily mobile phone time associated with early adolescents' first mobile phone acquisition between age 10/11 and age 12/13. Hence, changes in adolescents' time allocation caused by mobile phone acquisition can in principle be captured by the data and research design of this study. A visualization of the (unadjusted) trends in all outcome variables (including mobile phone time) by treatment status is provided in Figure A1 in the Supplementary Material.

Results

Effects on enrichment, physical activity, and sleep

Figure 2 presents the main results from five separate, weighted DID models. Addressing RQ1, the coefficients refer to the change in the time spent on enrichment activities (reading for pleasure, homework, and cultural activities and other enrichment), physical activity, and sleep associated with early adolescents' first acquisition of a mobile phone (net of the trend in the control group and the time-varying controls). The marker (dot) indicates the estimated change in adolescents' daily minutes spent on each activity between age 10/11 and age 12/13. According to Figure 2, there are no statistically significant effects (at the 5% level) of mobile phone acquisition on early adolescents' daily time spent regarding any of the outcome activities. The DID analysis identifies a negative effect of mobile phone acquisition on early adolescents' daily time spent on cultural activities and other enrichment by −10.1 daily minutes, which is however only marginally significant ($p < .10$).

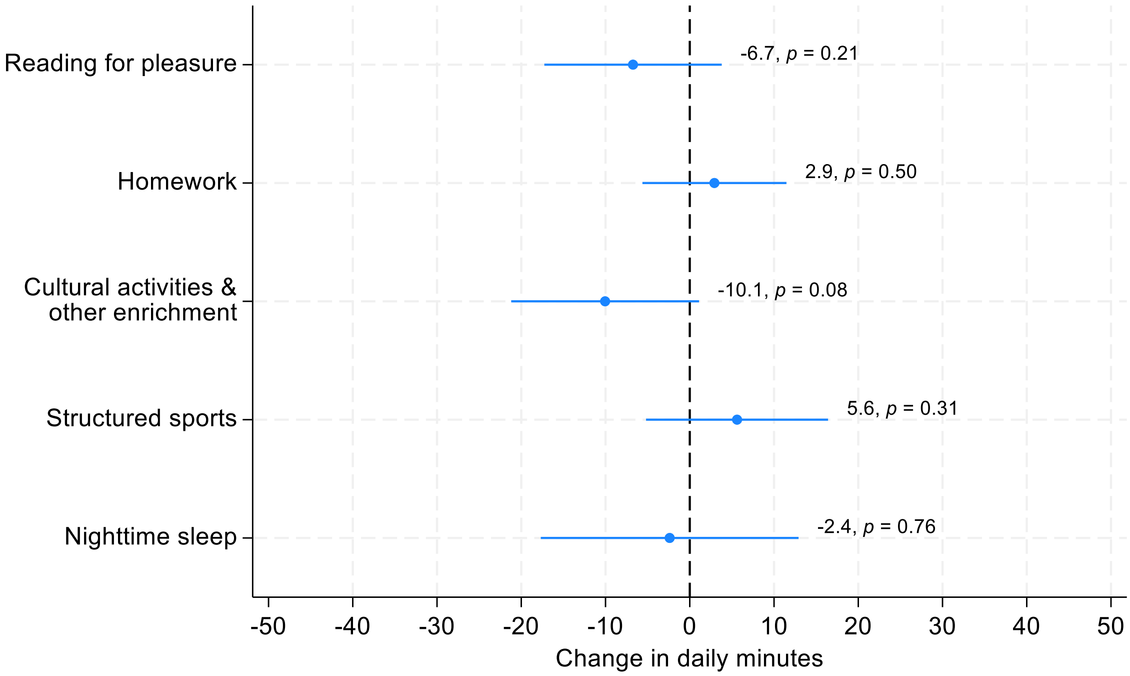

Figure 2. Estimated changes in early adolescents' enrichment, physical activity, and sleep time after acquiring their first mobile phone (coefficients with 95%-confidence intervals). *N* = 1,857.

Moderation by family socioeconomic position

Does the effect of mobile phone acquisition on enrichment, physical activity, and sleep differ by family SEP (RQ2)? Figure 3 displays average marginal effects of first mobile phone acquisition separately for early adolescents with higher and lower family SEP (based on the same statistical model as Figure 2, extended by a moderation term). None of the differences between the coefficients by family SEP are significant at the 5%-level. There are no statistically significant negative coefficients for both subgroups, either. Hence, there is no evidence for displacement effects among the subgroups of early adolescents with either higher or lower SEP. For early adolescents with higher family SEP, there is a positive effect on the time spent on structured sports (+16.9 daily minutes), which is statistically significant ($p < .05$). For early adolescents with lower family SEP, the coefficient for structured sports is slightly negative, but not statistically significant.

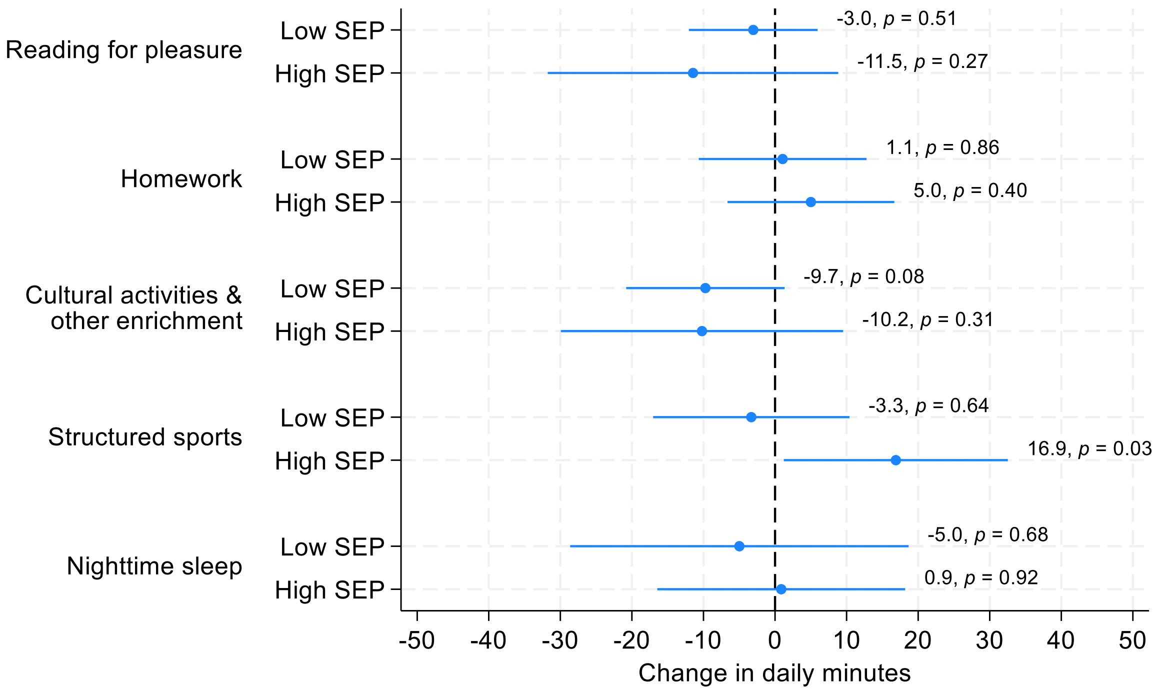

Figure 3. Estimated changes in early adolescents' daily minutes spent on enrichment, physical activity, and sleep, after acquiring their first mobile phone (average marginal effects derived from TWFE regression models with 95%-confidence intervals), by family SEP. *N* = 1,857.

Effects on electronic media activities

Figure 4 reports the effects of mobile phone acquisition on the time early adolescents spend on TV, movies, or videos, and on electronic games (RQ3). Adolescents' first mobile phone acquisition between age 10/11 to age 12/13 is associated with a decrease of −27.6 minutes per day of watching TV, movies, or videos ($p < .05$). For electronic games, the coefficient is also negative, but not statistically significant ($p > .10$). This result implies a considerable displacement effect of mobile phone acquisition on early adolescents' screen-related activities with regard to watching TV, movies, or videos[iv]. The average daily time early adolescents aged 10/11 spend on watching TV, movies, or videos is 143.4 minutes, according to Table 1. Hence, the reported effect corresponds to a 19.2% decrease.

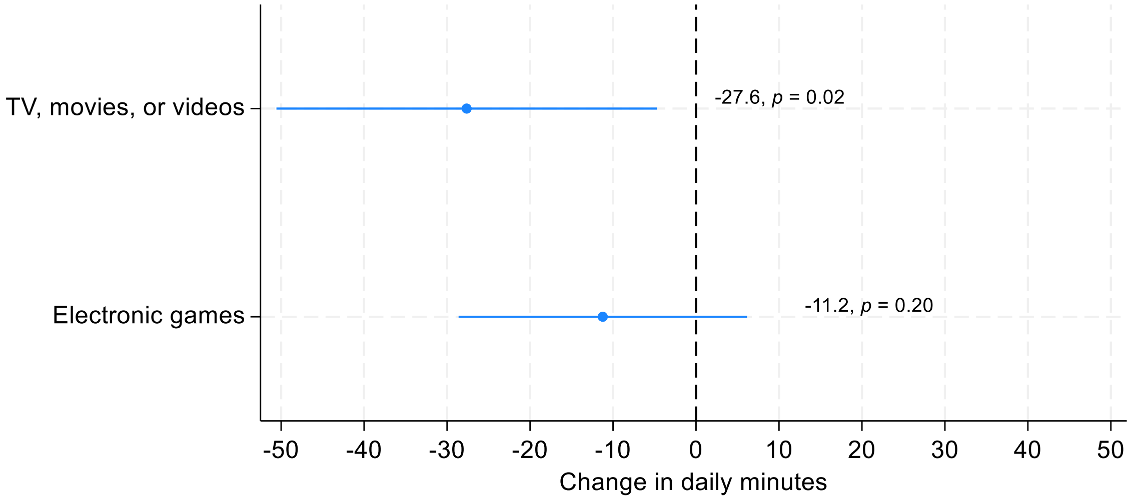

Figure 4. Estimated changes in early adolescents' daily minutes spent on electronic activities after acquiring their first mobile phone (regression coefficients with 95%-confidence intervals). N = 1,857.

Robustness tests

For the main analyses presented in this study, the dependent variables are calculated as the sum of all daily time intervals, irrespective of whether they refer to the primary or to (up to three) secondary activities. An alternative way of dealing with secondary activities is dividing the time spent on each of the parallel activities by the number of parallel activities (e.g., as in Cano & Gracia, 2022), so the total of daily activities sums up to exactly 24 hours. Repeating the main analysis from Figure 2 with dependent variables based on this alternative calculation (except nighttime sleep because no parallel secondary activities are recorded during sleep) yields the same substantial conclusions (see Figure A2, Supplementary Material). In addition, Figure A3 (Supplementary Material) displays estimates from a DID model without prior matching on pre-treatment covariates (MDM). While the negative effect on cultural activities and other enrichment is similar in magnitude to the result with MDM, it is statistically significant in the model without matching. The remaining coefficients are largely similar, except the effect on “TV, movies, or videos”, which is still negative, but only marginally significant (-19.9 daily minutes; $p = .07$) in the DID model without matching.

Discussion

Based on longitudinal time use data and difference-in-differences modeling, this study tests the displacement hypothesis regarding early adolescents’ mobile phone use. It investigates the effects of early adolescents’ acquisition of their first mobile phone on the daily time spent on enrichment activities, physical activity, and sleep. These activities are generally assumed to be beneficial for adolescents’ cognitive development and academic performance. Results show no evidence for displacement effects of adolescents’ mobile phone acquisition on cognitively or academically beneficial activities. Moreover, there are no significant displacement effects for adolescents with higher or lower family SEP, and the model coefficients do not differ significantly between these two groups. However, the results show a large displacement effect of first mobile phone acquisition between the ages of 10/11 and 12/13 on the time early adolescents spend watching television, movies, or videos.

Overall, the results challenge the displacement hypothesis regarding mobile phones, that is, the notion that the extensive daily mobile phone use of contemporary adolescents (Radesky et al., 2023) displaces time the adolescents would have spent on activities which are beneficial for their cognitive development and academic performance (Gerosa & Gui, 2023). This finding might help explain why studies on the direct effects of adolescents’ mobile phone use on educational outcomes tend to find only small or null effects when applying more rigorous causal inference designs (e.g., Gerosa & Gui, 2023): One of the mostly used theoretical explanations for negative media effects on children and adolescents, the displacement hypothesis, may in fact be unfounded in relation to mobile phones.

Instead of displacing cognitively beneficial activities, early adolescents appear to displace time spent on traditional electronic media activities such as watching television or movies. The increase in mobile phone use among adolescents appears to be part of "ongoing changes in media and device preference" (Hall & Liu, 2022: 3). The results of this study are therefore in line with the principle of functional similarity. Similar to the rise of television in the 1950s, the rise of mobile phones may represent yet another shift in adolescent media behaviors without severe consequences for time allocation to educationally relevant non-media activities (Himmelweit et al., 1958).

Parental restrictions on early adolescents' screen time may be an additional reason for the link between mobile phone use and other screen time like television, which could enforce trade-offs in early adolescents' time allocation. Parental mediation in this age group may be successful in protecting the time early adolescents spend on enrichment, physical activity, and sleep (Mascheroni, 2014). Another potential explanation is that adolescents displace marginal fringe activities (Bryant & Fondren, 2009) or increase multitasking during other activities than those investigated in this study. However, this second explanation could not be further investigated due to data limitations and may therefore inspire future research.

Limitations

Despite its advantages for causal identification, the research design of this study has several limitations: First, it captures effects only during the first two years after adolescents' first mobile phone acquisition. Because the extent of adolescents' mobile phone use and the types of activities performed with mobile phones is strongly linked to increasing age (Mascheroni & Ólafsson, 2016), it is possible that significant phone-induced changes in adolescents' daily time allocation occur more than two years after phone acquisition. Such delayed effects would not have been captured by the presented statistical model. Delayed effects are particularly likely because parental mediation becomes less strict with increasing age of adolescents (Suárez-Álvarez et al., 2022). Second, the variable used in this study to identify mobile phone acquisition did not distinguish between phones of different types (e.g., smartphones vs. flip phones or phones with limited capabilities). Because fully functioning smartphones have a much broader range of possible applications than other types of mobile phones, their acquisition is likely to lead to a stronger increase in use times than, e.g., a flip phone acquired mainly to facilitate communication with other family members. This means that the effects of acquisition may differ for the subgroup of smartphone owners, with potentially larger (negative) effects than reported in this study. Third, the reported effects in this study represent only a population average. Studies on media effects often report negative effects only for particular subgroups of the population (Gerosa & Gui, 2023; Odgers, 2018). While the moderation analysis of family SEP aims to capture heterogeneity of this type, it may be that other subgroups display significant displacement effects.

Fourth, although DID is one of the most powerful methods for causal identification based on observational data, the interpretation of the model coefficients as causal effects still relies on assumptions. The determinants of earlier or later mobile phone acquisition are not well understood and may vary across time and regional context. There may be other relevant unobserved factors which could violate the parallel trends assumption and which were not considered in the presented analysis (e.g., changes regarding the behavior of important peers). Finally, the study is based on data from a single country, Australia. Because there are no studies with comparable designs published yet, it remains unclear whether the results are generalizable to other countries. For example, the relatively high daily time that early adolescents in the study sample spend on television, movies, or videos (more than two daily hours) may be lower in other countries, potentially leading to differing results.

Further implications

The results have practical relevance because children's or early adolescents' acquisition of the mobile phone (in particular, of the smartphone) is considered an important developmental milestone (Moreno et al., 2019) and its use by adolescents is an important source of tension and conflict in many families (Matthes et al., 2021). Parents differ in their decision when to grant their children the permission to acquire their first mobile phone and have different concerns regarding the potential consequences of this milestone (Moreno et al., 2019; Perowne & Gutman, 2023; Vaterlaus et al., 2021). Many parents around the globe therefore ask for scientific evidence regarding the effects of mobile phones on their children and discussions on appropriate age recommendations for first mobile phone acquisition are often controversial (Gerosa & Gui, 2023). The findings of this study offer no further evidence supporting recommendations for restricting mobile phone access in early adolescence, at least not on the societal level.

Mobile phones are being discussed as one of the driving forces behind the decline in adolescents' cognitive skills across many countries (Thompson, 2023). The presented results are to some extent reassuring: Mobile phone use in early adolescence is unlikely to displace cognitively beneficial activities pursued outside of the classroom. Most of the time early adolescents spend on mobile phones may be used in ways that are not "productive" regarding cognitive development (Radesky et al., 2023). Still, the presented results suggest that adolescents most likely would not have spent a significant amount of this time on "productive" activities anyway (Jorge et al., 2022). This conclusion is in line with recent experimental research showing that displacement effects of social media use are largely limited to activities which have no positive effect on affective well-being either (Hall et al., 2019). However, the question where adolescents take all that time to use their mobile phones remains partly unresolved. Recent advances in collecting accurate data on mobile technology use in the family context (e.g., Barr et al., 2020) might help to shed light on this question in the future.

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[i] Yet, obtaining reliable estimates of adolescents' phone use times is challenging, as data collection methods are complex and use times vary by context and age ((große Deters & Schoedel), 2023).
[ii] Minor inconsistencies between the percentages and the number of cases result from the application of survey weights.
[iii] In principle, the same analysis could be conducted for the change from age 12/13 to the next panel wave (age 14/15), because the same variables are available in the LSAC for this wave. However, because approximately 95% of early adolescents in the dataset acquired a mobile phone up to age 14/15, this analysis would have to rely on a very small control group, yielding insufficient statistical power.
[iv] An additional analysis (not reported) based on detailed activity labels shows that the identified decrease in "Watching TV, movies or videos" associated with mobile phone acquisition is mostly based on a decrease in watching television programs, and, to a lesser extent, on a decrease in watching movies. Daily minutes of watching videos (e.g., YouTube), are not significantly reduced.

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Supplementary Material

Table A1. Coding of enrichment activities, physical activity, and electronic media activities.

Activity	LSAC-provided codes aggregated for the analyses
Reading for pleasure	"Reading for pleasure"
Homework	"Doing homework (not via electronic devices)" and "Doing homework (electronic device)"
Cultural activities and other enrichment	"Arts" (e.g., drawing), "Attend courses (excluding school /university)", "Attendance at concert/theatre", "Attendance at museum / exhibition / art gallery", "Attendance at zoo / animal park / botanic garden", "Clubs", "Going out not further specified" (e.g., going to the library), "Handwork crafts (excl. clothes making)", "Hobbies, collections", "Playing musical instruments or singing for leisure" and "Private music lessons/practice, academic tutoring".
Structured sports (team and individual sports activities)	"Archery / Shooting sports", "Athletics / Gymnastics", "Fitness / Gym / Exercise" "Ball Sports", "Martial arts / Dancing", "Motor Sports / Roller Sports / Cycling", "Water/Ice/Snow Sports", and "Organized team sports and training other".
Nighttime sleep	[Difference between wake-up time and bedtime]
TV, movies, or videos	"Watching TV programs or movies/videos"
Electronic games	"Playing games (electronic device)", "Playing games (electronic device) not further defined"

Table A2. Detailed labels used to code mobile phone time

Main activity code	**Detailed activity label**
Playing games (electronic device)	*Smart phone (gaming)*
	iphone (gaming)
	Mobile (gaming)
Watching TV programs or movies/videos	*Phone (smart watch movie/tv)*
	iphone (watch movie/tv)
	Mobile (watch movie/tv)
General application use	*Phone (read)*
	iphone (read)
	Mobile (read)
Texting/emailing	*Texting*
	Messaging
	SMS
	iMessage
Online chatting / Instant messaging	*Messenger*
Listening to music	*iphone (listen music)*
Talking on a mobile phone	*[all labels, both main and secondary activities]*

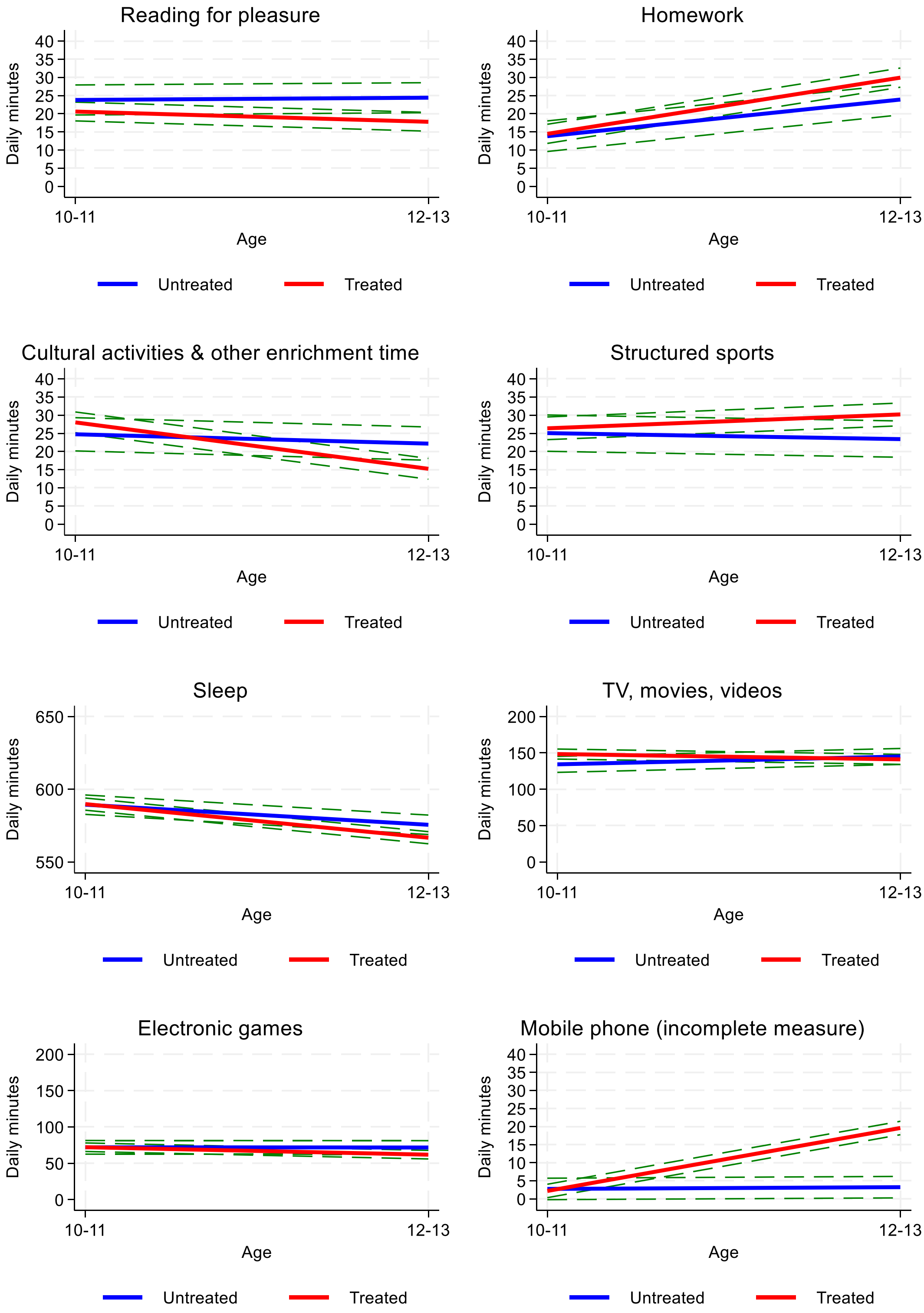

Figure A1. Development of adolescents' daily time spent with enrichment, physical activity, sleep, and electronic media activities between panel waves, by treatment group (Untreated vs. treated adolescents). Estimates from linear growth curve models obtained from random-effects models (weighted, no matching or control variable adjustment). *N* = 1,857.

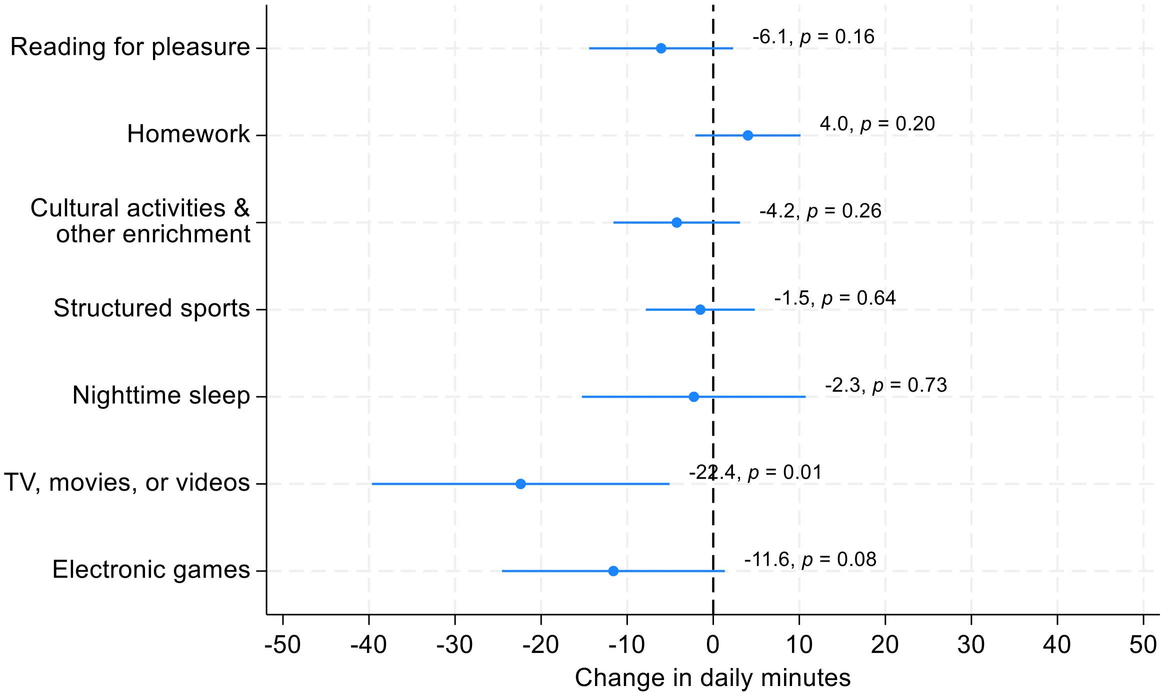

Figure A2. Estimated changes in adolescents' daily enrichment, physical activity, and electronic activity time after children acquire their first mobile phone based on an alternative calculation of the dependent variables with time intervals divided by the number of parallel activities (with matching). *N* = 1,857.

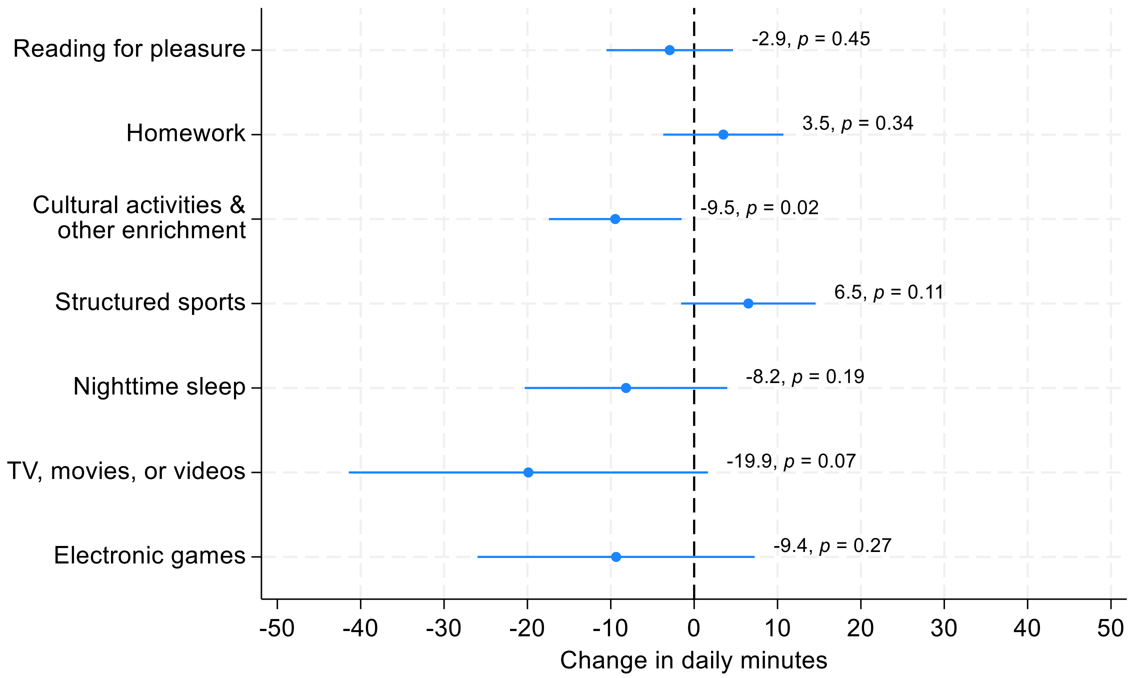

Figure A3. Estimated changes in adolescents' daily enrichment, physical activity, and electronic activity time after children acquire their first mobile phone based a DID analysis without matching on pre-treatment covariates (MDM). $N = 1{,}857$.