Screen-based Behaviors in Australian Adolescents: Longitudinal Trends from a 4-Year Follow-up Study

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ABSTRACT

The longitudinal trends of screen time, a highly prevalent behaviour in adolescents, are relatively unknown. This study examined longitudinal trends in screen time among a large sample of Australian primary school-aged children transitioning into secondary school-aged adolescence. Data were derived from the Longitudinal Study of Australian Children (LSAC). In 2010, 2,179 children (49.7% boys; 10.3±1.1 years) completed a time-use diary, recording their main activities during waking hours. This was repeated with the same sample in 2012 (12.4±0.5 years) and 2014 (14.4±0.5 years). Data were analyzed for time spent in TV viewing, computer use, electronic gaming, and social networking and online communication. Repeated-measures MANCOVA tests were performed to analyze trends in screen time. Trends were also analyzed by sex. Total screen time significantly increased (+85.9 min/day) over four years ($\eta_p^2 = .010$, $P < .001$), but differed by sex, with a larger increase in boys (boys: +41.6, girls: +22.7 min/day). Electronic gaming increased in boys (+43.2 min/day) and decreased in girls (−16.8 min/day). In contrast, girls reported larger increases in TV viewing (boys: +0.4, girls: +29.1 min/day), computer use (boys: +24.8, girls: +34.3 min/day) and time communicating online and social networking (boys: +4.3, girls: +15.2 min/day). To conclude, screen time among adolescents increases between the ages of 10 and 14 years, but differs by sex and screen time domain. Future screen time reduction interventions may choose to focus on recreational computer use and electronic gaming in boys and TV viewing and time spent communicating online and social networking for girls.

Keywords: Screen time; Australia; Longitudinal; Trends

INTRODUCTION

Screen time refers to time spent on screen-based devices including, but not limited to, TV viewing, recreational computer use, video-gaming and, smartphone- and computer tablet-use [1]. Higher levels of screen time are associated with multiple adverse physical and mental health indicators among children and adolescents, and such associations often remain when adjusted for time spent in moderate-to-vigorous intensity physical activity [2]. These include unfavourable cardiometabolic risk factors, such as increased adiposity [3], as well as mental health issues such as higher levels of depression, hyperactivity and internalising problems [4]. Others have argued the effect of screen time on psychological well-being may be negligible [5] and, in some cases, may even be beneficial [6]. Collectively, however, the evidence suggests there are more known harmful effects of high levels of screen time than potential benefits [7].

The *Australian 24-Hour Movement Guidelines for Children and Young People* (5-17 years) recommend that recreational screen time should be limited to ≤2 h/day [8]. However, in adolescents aged 12-17-years, only 13% of boys and 17% of girls are meeting the guidelines [9]. Public health concerns may rise given that electronic screens are now a ubiquitous part of the adolescent landscape [7], occupying an increasing part of their daily time, and likely to be largely used sitting [10].

Despite an increased quantity of research on screen time, most studies were cross-sectional and have the limitation of only assessing screen time at a single-time point [11]. Therefore, the longitudinal trends of screen time in adolescents is relatively unknown, especially in Australia. Data from the Longitudinal Study of Australian Children (LSAC) showed that screen time increased by 64 min/day, measured between 2004 (4-5-years) to 2012 (11-12-

years) [12]. However, evidence shows that screen time in childhood may track into adolescence [13]. The trends of screen time during the transition of childhood to adolescence are important because in this period, more changes in lifestyle will arise due to the transition from primary to secondary school [14]. If reductions in screen time are important for health, we need to know more about the behaviour and whether it persists over time. Therefore, the aim of this study is to examine longitudinal trends in screen time among a nationally-representative sample of Australian primary school-aged transitioning into secondary school-aged adolescence.

METHODS

Sample

Data were obtained from the Kindergarten (K) cohort of the LSAC, a longitudinal cross-sequential survey in a nationally-representative sample of Australian adolescents aged between 10-11 and 14-15-years. Full details of the LSAC methodology are published elsewhere [14]. In brief, from an initial mail-out to 9,893 children, 50.4% were successfully recruited; 37.5% chose to opt-out and 15.2% were uncontactable. Excluding the latter, the overall response rate was 59.4% [16]. Data collection, including face-to-face interviews with the adolescent's parents and other caregivers (e.g., teachers), census-linked data, and time-use diaries from the adolescent, commenced in 2004; and, was repeated with the same adolescent every two-years. The LSAC was approved by the Australian Institute of Family Studies Ethics Committee and all participants provided written informed consent.

Participants

The present study utilised the latest available longitudinal data from the time-use diary derived from the K-cohort adolescents when they were aged 10-11 (Wave 4, 2010), 12-13

(Wave 5, 2012) and 14-15-years (Wave 6, 2014). The response rates for the diary component were 96% (n = 3,994), 92% (n = 3,646) and 87% (n = 3,074) at Waves 4, 5 and 6, respectively [16]. Participants with diary-data were excluded where the start times were out-of-order or incorrectly entered (n = 604; 19.6%) or, if they had missing diary-data on screen time (n = 291; 9.5%). The final sample size was 2,179 (Figure 1).

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Procedures

Time-use diaries were used to assess adolescent's activities (e.g., screen time) over the course of a single randomly-allocated day. Adolescents recorded their main activities and the commencement time, in sequence, from awake to bed-(sleep)-time [16]. The day after diary completion, a trained interviewer went through the diaries with the adolescent to check the quality of data collected and to record additional contextual information.

A pre-established coding framework was used to code the adolescent's activities [16], hence making diaries comparable across adolescents and across waves [17]. Details of the harmonisation are available in Supplemental Table 1. In brief, the present study assessed TV viewing, computer use (excluding games), electronic gaming, and online communication and social networking. Total screen time was calculated by summing all screen-based activities mentioned above.

Covariates

In Wave 4, parents provided sociodemographic (sex, household income) characteristics using standardised questionnaire items. These characteristics were included in the analyses as covariates, based on being associated with screen time [18].

Given that weight status is a potential correlate and determinant of screen time [19,20], waist circumference—measured twice by the interviewer to the nearest 0.1cm using a portable stadiometer (Invicta, Code IP0955) and a tape measure—was used as covariate (average of Wave 4 measures).

Last, maturational status was included as covariate, as it is an identified correlate of sedentary behavior [21]. Pubic hair development is a commonly used marker for maturational status in both boys [22] and girls [23]. In Wave 4, parents were asked to rate the amount of change their child experienced with respect to body hair (armpits and/or dark pubic hair) development. Using a standardised scale of 1-4, parents rated body hair development with 1 meaning 'has not yet started'; 2 'has barely started'; 3 'has definitely started'; and 4 meaning 'seems complete'.

Statistical analysis

Analyses were conducted using SPSS version 25 (SPSS Inc., Chicago, IL, USA). Alpha levels of $P < 0.05$ were considered as significant. For each respondent, longitudinal sample-weights were produced to reduce the effect of bias in sample selection and participant non-response [24]. Little's MCAR test was not significant ($\chi^2 = 264.583$, df = 289, p = .846), indicating that missing values were randomly distributed and therefore listwise deletion was employed. Descriptive statistics were used to describe the profile of the sample across each time-point. Repeated-measures analyses of covariance (MANCOVA), adjusting for all covariates, were used to examine differences in screen time across time-points (within-subjects factor=time). As part of the MANCOVA procedure, tests of within-subject contrasts were used to identify the pattern and significance of change in screen time.

Mauchly's test was used to indicate whether assumptions of sphericity were violated [25], therefore degrees of freedom were corrected using Huynh-Feldt estimates of sphericity [26]. Partial eta-squared (η_p^2) was used as an effect size measure, using the following conventions: small ($\eta_p^2 \geq 0.01$), medium ($\eta_p^2 \geq 0.06$), and large-effect ($\eta_p^2 \geq 0.14$) [27]. Post-hoc tests compared time-points two-by-two, using Bonferroni correction. Given evidence that screen time differs by sex among adolescents [28], time-by-sex interactions were examined and in case of significance, time change was analyzed by sex and reported separately.

Before conducting our analytical models, we tested for multicollinearity among potential covariates using tests variance inflation factor (VIF), with no VIFs indicating multicollinearity (VIF ≥2) [29]. The assumption for normality was checked graphically using QQ-Plots and histograms.

RESULTS

Participants' characteristics and unadjusted means for screen-based activities are presented in Table 1. Of 2,179 participants, 49.7% (*n* = 1083) were boys. Participants were, on average, 10.3 years (± 1.1) old at Wave 4; 12.4 years (± 0.5) old at Wave 5; and, 14.4 years (± 0.5) old at Wave 6. Participants spent, on average, 176.8 minutes (± 141.8) on screen-based activities on the sampled day at 10-11-years (Wave 4); 209.9 minutes (± 149.8) at 12-13-years (Wave 5); and, 261.4 minutes (± 182.7) at 14-15-years (Wave 6).

>>>PLEASE INSERT TABLE 1 HERE<<<

Trends over time in total screen time

As shown in Figure 2, after adjusting for sex, household income, waist circumference and maturational status, total screen time significantly changed between the ages of 10 and 14

(F_{time} = 11.1, P < .001, η_p^2 = .010), including a significant trend (F = 19.7, P < .001, η_p^2 = .012). Post-hoc tests identified that total screen time significantly increased from the age of 10 (175.6 min/day) to the age of 12 (207.7 min/day) and again at the age of 14 (261.5 min/day; all P < .001).

Sex differences in total screen time

The change in total screen time between the ages of 10 and 14 differed by sex ($F_{timexsex}$ = 3.2, P = .041, η_p^2 = .002) (Figure 2). The 'time-by-sex' interaction was significant from age 10 to age 12 ($F_{timexsex}$ = 4.9, P = .028, η_p^2 = .003). There was a significant increase in total screen time among girls (+22.7 min/day, P < .001), with a larger increase among boys (+41.6 min/day, P = < .001). The increase in total screen time between the ages of 12 and 14 did not significantly differ by sex ($F_{timexsex}$ = 0.1, P = .761, η_p^2 = .000).

>>>PLEASE INSERT FIGURE 2 HERE<<<

TV viewing

TV viewing (Figure 3, A) significantly changed between the ages 10 and 14 (F_{time} = 9.6, P < .001, η_p^2 = .010), including a significant trend (F = 16.6, P < .001, η_p^2 = .010). Post-hoc tests revealed that television viewing did not significantly differ between the age of 10 (116.3 min/day) and the age of 12 (118.7 min/day; P = .999). However, TV viewing increased at the age of 14 (133.5 min/day), which was statistically different from the ages 10 and 12 (all P < .001).

Sex differences in TV viewing

The change in television viewing over four years differed by sex ($F_{timexsex}$ = 6.1, P = .002, η_p^2 = .004) (Figure 3, A). The 'time-by-sex' interaction was significant between the ages 12 and 14 ($F_{timexsex}$ = 11.7, P = .001, η_p^2 = .010). There was a significant increase in TV viewing among girls (+29.1 min/day, P < .001), while TV viewing did not significantly change in boys (+0.4 min/day, P = .936). The increase in TV viewing between the ages of 10 and 12 did not significantly differ by sex ($F_{timexsex}$ = 2.2, P = .138, η_p^2 = .001).

Computer use (excluding games)

Computer use (excluding games) (Figure 3, B) significantly changed between the ages of 10 and 14 (F_{time} = 7.8, P = .001, η_p^2 = .010), including a significant trend (F = 10.3, P = .001, η_p^2 = .010). Post-hoc tests revealed that computer use (excluding games) significantly increased from the age of 10 (8.4 min/day) to the age of 12 (38.0 min/day) and again at the age of 14 (64.0 min/day; all P < .001).

Sex differences in computer use (excluding games)

The change in computer use (excluding games) over four years differed by sex ($F_{timexsex}$ = 9.3, P < .001, η_p^2 = .010) (Figure 3, B). The 'time-by-sex' interaction was significant between the ages of 10 and 12 ($F_{timexsex}$ = 8.6, P = .003, η_p^2 = .010), showing a significant increase in computer use (excluding games) among girls (+34.3 min/day, P < .001), and a slightly smaller increase in boys (+24.8 min/day, P < .001). The increase in computer use (excluding games) between the ages of 12 and 14 did not significantly differ by sex ($F_{timexsex}$ = 3.1, P = .076, η_p^2 = .002).

Electronic gaming

Electronic gaming (Figure 3, C) did not significantly change between the ages of 10 and 14 (F_{time} = 0.8, P = .436, η_p^2 = .001).

Sex differences in electronic-games

The change in electronic gaming over four years differed by sex ($F_{timexsex}$ = 49.5, P < .001, η_p^2 = .030) (Figure 3, C). The 'time-by-sex' interaction was significant between the ages of 10 and 12 ($F_{timexsex}$ = 12.3, P < .001, ηp^2 = .010). There was a significant decrease in electronic gaming among girls (−9.4 min/day, P = .001), while there was a significant increase in boys (+9.7 min/day, P = .049). The 'time-by-sex interaction was significant between the ages 12 and 14 ($F_{timexsex}$ = 37.1, P < .001, η_p^2 = .023). There was a significant decrease in electronic gaming among girls (−7.4 min/day, P = .003), while there was a significant increase in boys (+33.5 min/day, P < .001).

Social networking and online communication

Social networking and online communication (Figure 3, D) increased between the ages 10 and 14 (F_{time} = 3.2, P = .056, η_p^2 = .002), including a significant trend (F = 4.0, P = .046, η_p^2= .002). Post-hoc tests revealed that social networking and online communication significantly increased between the age 10 (0.7 min/day) and the age 12 (10.5 min/day) and again at the age of 14 (25.6 min/day; all P < .001).

Sex differences in social networking and online communication

The change in social networking and online communication over four years differed by sex ($F_{timexsex}$ = 13.4, P < .001, η_p^2 = .010) (Figure 3, D). The 'time-by-sex' interaction was significant between the ages of 10 and 12 ($F_{timexsex}$ = 38.3, P < .001, η_p^2 = .023), showing a significant increase in social networking and online communication among girls (+15.2

min/day, P < .001), while there was a smaller increase in boys (+4.3 min/day, p < .001). The increase in social networking and online communication between the ages 12 and 14 did not significantly differ by sex ($F_{timexsex}$ = 0.4, P = .507, η_p^2 = .000).

>>>PLEASE INSERT FIGURE 3 HERE<<<

DISCUSSION

In this sample of Australian adolescents, the estimated total screen time significantly increased over four years (+85.9 min/day), with increases in TV viewing (+17.2 min/day), computer use (excluding games) (+55.6 min/day), and social networking and online communication (+24.9 min/day). However, these increases differed according to the adolescents' sex.

Our findings are consistent with other studies [10,30,31], that also show that boys increased their total screen time more than girls. Boys increased time using electronic-games, while this decreased in girls. In contrast, the increase in TV viewing, computer use (excluding games) and time communicating online and social networking was larger in girls than in boys. All effect sizes, except for social networking and online communication were considered small [27] in the total sample.

Our findings for trends in TV viewing differ from previous cross-national findings that showed a decrease in time spent watching TV between 2002-2010 [10]. Current findings present more recent data on temporal trends, as the total sample (2010-2014) identifies a significant increase in TV viewing. It is plausible that adolescents had easier access and more opportunities to stream TV content on a multitude of screen-based devices and platforms. For example, recent innovations in mobile technology (e.g. iPad introduced in 2010) allow adolescents to stream TV media on demand [32]. Future research on the nature of contemporary TV viewing among adolescents, including the online streaming via mobile technology, is warranted. Our findings suggest that there have been significant changes in time allocated to other types of screen-based devices. Consistent with previous findings in the U.S. [33] and across multiple countries [10], time spent using the computer increased among Australian adolescents. However, by combining computer use for gaming and non-gaming purposes, it is likely that previous findings have overlooked differences in gender-specific motivations for computer use. Importantly, our study is the first to distinguish between computer use (excluding games) and video-gaming. In boys, screen time was predominantly electronic gaming, while this decreased in girls. In contrast, girls' screen-use was focused on non-gaming and social purposes. These gender-specific findings should be considered when designing approaches to reduce screen-based behaviors.

The current study is important because it provides the first insight into the time-use trends among newer forms of screen time (e.g., social networking, including Facebook), and online communication (such as Instant Messenger) among Australian adolescents. Excessive screen time can be detrimental to adolescent health [2]; limiting this time should be a public health concern, especially as this study shows that screen time is increasing. It is plausible to expect that the recommended limit of ≤2 h/day for recreational purposes will become increasingly unrealistic for adolescents, and more challenging for parents to manage. The appropriateness of having quantitative public health guidelines on sedentary behavior [34] will no doubt garner future debate.

The current findings may have important implications for interventions designed to reduce excessive levels of screen time among adolescents. We showed that the amount of time adolescents spend on screens increases as they age, although the source of this increase differs by sex and screen time domain. Indeed, future screen time reduction interventions may choose to focus on recreational computer use and electronic gaming in boys, and TV viewing and time spent communicating online and social networking for girls.

This study has several limitations that should be acknowledged. First, as this is exclusively Australian participant derived data, conclusions may not apply to other nations [35]. Further to this, there was a modest response rate and a potential oversampling of higher income families [36], which may have further biased our results. We therefore urge caution in inferring that the key findings presented in the current study are population representative. Second, while time-use diaries provide detailed information for health-related research [37], self-reported data can be subject to measurement bias. Third, since the time-period of data collection (2010-2014), there have been changes in the availability of technology, in addition to the ways in which adolescents can access media. For example, the introduction of subscription video on demand (SVOD) services in Australia—including *Netflix* and *Stan* in 2015—means that we did not capture newer screen-based activities, especially on more portable and accessible devices, such as smartphones and tablets. However, this study uses the only available longitudinal dataset concerning screen time among Australian adolescents. Tracking time-use on modern devices, in addition to where adolescents spend time on these new media (e.g., home, school, and transport) will be an important direction in future research. Fourth, there is emerging evidence to suggest that adolescents engage in screen-multitasking (i.e., two or more devices simultaneously) [38], which precludes accurate estimates of individuals total screen time [7]. While the current study did not account for this;

understanding screen-multitasking, in addition to other contextual characteristics (e.g., content, timing exposure) should be considered. Fifth, the LSAC methodology could not determine which devices adolescents used to social network and communicate online. As technological innovations move away from unifunctional devices to portable, multifunctional devices, activities may have been performed on newer digital media (e.g., smartphones, tablets) [30]. Understanding the nature of contemporary screen time, including the devices used, should be a focus of future research. Finally, it is possible that cohort- and period-effects may have been present in this study [39]. Variations in screen-use over time may be related to the effects of aging; to the different life experiences of generations of people born at different times (cohort-effects); or, to societal and environmental changes which affect the population as a whole (period-effects).

The study's strengths include the utilization of a large dataset with a standardised protocol and extensive quality control; the investigation into trends of total screen time and domain specific screen-based behaviors; and, the control of potential sociodemographic and lifestyle covariates. Further, as technology develops, time-use diaries offer a valuable resource for examining trends over time in sedentary behavior [40], including domain-specific screen time activities.

CONCLUSION

Australian adolescents' time spent using screens increased between the ages of 10 and 14. This appears to be driven by pronounced surges in computer use (excluding games) and time spent communicating online and social networking. This study contributes to knowledge by showing that the amount of time adolescents spend on screens increases as they age, although the source of this increase differs by sex and screen time domain. These findings should be considered when designing interventions to reduce screen time among adolescents.

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