Associations between childhood and adolescent emotional and behavioral characteristics and screen time of adolescents

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Abstract

The correlations between emotional and behavioral problems and increased screen time among young people has been highlighted in the literature. This study examined both longitudinal and cross-directional associations between the degree of childhood and adolescent emotional and behavioral problem characteristics and a higher level of daily screen time in adolescence using an extensive population study. Questionnaires providing data on a representative cohort sample (the Northern Finland Birth Cohort 1986 Study, NFBC 1986; n=6479; 3101 males) were completed at birth, in childhood, and in adolescence. Male gender, and self-reported behavioral issues (such as a higher degree of hyperactivity/distractibility problems at the beginning of formal schooling and adolescent rule-breaking problems), predicted higher daily screen time in adolescence, after controlling for confounding factors. Higher levels of anxious-depression symptoms among adolescents were inversely related to them having elevated daily digital screen time. Individual behavioral tendencies at the start of formal schooling and later in adolescence may predict higher screen time among young people.

Keywords: Adolescent; Computer; Video games; Behavior problems

“Compliance with Ethical Standards”

Disclosure

The authors declare that they have no conflict of

interest.

Informed Consent

All participants and

parents provided informed consent, and participation was voluntary.

The study procedure was conducted in accordance with the Declaration of Helsinki.

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1. Introduction

The digital screen landscape has changed constantly in the past three decades. Young people born in the 1980s and early 90s (sometimes called Generation Y or Millennials, born between 1981 and 1996) were shaped by the use of entertainment screen-form television and later by the gradual rise of the internet (Dimock, 2019). This generation remembers a time before the internet. The first generation to enter adolescence with smartphones were those born between 1996 and 2012 (referred to as the iGen generation [internet generation] or Generation Z), resulting in an increase in digital screen activity options (Dimock, 2019; Twenge, 2017). Consequently, data from a cross-national study involving 30 countries reported an enormous rise in the time youth had spent with digital screens between 2002 and 2010 as a result of changes in the technology environment (Bucksch et al., 2016). Currently, modern adolescents and young adults use a wide range of screen-based devices and related services, including smartphones, computers, digital gaming systems, and smart televisions. Indeed, the increasing popularity of mobile devices has allowed young people to access the internet in a variety of ways and to engage in diverse online activities (Ofcom, 2015). These shifts in the technological landscape have changed youths' lives in many ways, including their social interactions and health, but as yet the impacts of these alterations have not been fully comprehended.

In recent years, children have started using screen-based devices at younger ages (Duch, Fisher, Ensari, & Harrington, 2013; Kabali et al., 2015). In general, it has been observed that children typically become familiar with screens at an early age as a result of watching television and visual recordings (Kotilainen, 2011; Paudel, Jancey, Subedi, & Leavy, 2017). Children use these devices with their parents or other adults. Notable differences in children's screen use habits emerge around the age of seven, when

the use of and interest in digital games, mobile phones, and the internet increase significantly (Kotilainen, 2011; Paudel et al., 2017).

Adolescents may spend as much as seven hours a day (in their leisure time) using a screen of some sort (Rideout et al., 2015). For instance, data on children aged between 9 and 16 years from seven European countries showed that the number engaging in online gaming has increased significantly, from 16% in 2010 to 28% in 2014 (EU Kids Online, 2014). Furthermore, mid-adolescents (between 11 and 16 years old) are the demographic most likely to use social networking sites, gaming, and instant messaging (Coyne, Padilla-Walker, & Holmgren, 2018; EU Kids Online, 2014).

Research has not yet covered the full impacts – whether advantageous or disadvantageous – of screen exposure on child and youth development and well-being. In terms of the determination of the phenomenon, in previous studies researchers have characterized the amount of time engaged with digital devices/screens, or total screen time (i.e. playing videogames, using computers/smartphones, and watching television), as the central factor of harmful or positive implications (e.g. Przybylski & Weinstein, 2017). The harmful effects of screen use have been alternatively explained in terms of dependence-like behaviors (i.e., difficulties with self-regulation; Andreassen, 2015; Kuss, Griffiths, Karila, & Billieux, 2014) emphasizing the psychosocial qualities (e.g. focus on the activity despite the occurrence of harmful consequences) of the habit. Views of the impacts of screen time on young people have also included the displacement hypothesis (Neuman, 1988), which states that the negative influences of technology use (in a seminal work focused on television viewing) are directly linked to it substituting for other, more productive and developmental activities. As is further postulated in the Goldilocks hypothesis (which identifies a curvilinear relationship between digital screen time and well-being), very high use of technology may impair daily functioning as individuals

neglect other daily obligations or activities in family, school and work (e.g. Przybylski & Weinstein, 2017). This hypothesis also suggests that a moderate level of technology use per se is not harmful. In this study, the term 'digital screen time' will be used to refer to a unidimensional construct where the total daily screen time (including television viewing, digital game playing and computer use) is measured on a continuum ranging from low to more elevated exposure.

Screen activities can be beneficial for young people in many ways. For instance, youth use of social media sites has been found to increase new friendships, interpersonal capabilities (e.g. empathy) and social interaction (O'Keefe, Clarke-Pearson, & Media, Council on Communications, 2011). Furthermore, studies have reported the potential contribution of educational digital screen-based programs to enhance children's literacy by the guiding of a parent or caregiver (e.g. Radesky, Schumacher, & Zuckerman, 2015). These examples show that active screen use (i.e. being physically and cognitively involved in screen use) can be beneficial for young people's development.

Notwithstanding the potential benefits of screen use, there is a broad literature linking higher levels of screen time to negative health outcomes including sleep problems (Christensen et al., 2016; Parent, Sanders, & Forehand, 2016), peer problems (e.g., social withdrawal and antisocial behavior) (Pagani, Fitzpatrick, Barnett, & Dubow, 2010; Wu et al., 2017), behavioral or externalizing problems (e.g., attention problems or hyperactivity) (Nikkelen, Valkenburg, Huizinga, & Bushman, 2014; Swing, Gentile, Anderson, & Walsh, 2010; Zheng et al., 2014; Wu et al., 2017), and emotional or internalizing problems (e.g., problems of self-esteem, anxiety, or depression) among young people (Racine, Debate, Gabriel, & High, 2011; Wood & Scott, 2016; Wu et al., 2017). Elevated digital screen time has also been linked to unhealthy eating habits (i.e. high-fat/high-sugar foods) and obesity (Banks, Jorm, Rogers, Clements, & Bauman,

2011; Börnhorst et al. 2015; Pérez-Farinós et al., 2017), and it has been suggested that children with sedentary behavior involving high levels of cumulative screen time and low physical activity levels are especially prone to psychological problems (Page, Cooper, Griew, & Jago, 2010). A recent review concluded that the strongest evidence of the impacts of higher levels of screen time related to unhealthy diet, depressive symptoms and quality of life, whereas the weakest evidence was found among others such as behavioral problems, anxiety, hyperactivity and inattention, poorer self-esteem, poorer well-being and poorer psychosocial health (Stiglic & Viner, 2019). Nonetheless, although research into this phenomenon has accumulated in recent years, the evidence is still inconclusive (i.e., the associations that have been found are often small) and produced mixed outcomes (Orben & Przybylski, 2019; Przybylski & Weinstein, 2017).

The literature has scrutinized the possible underlying mechanisms by which screen use influences young people's development, behavior and well-being. Digital screen use among children and young adults increases with age, particularly during adolescence (Atkin, Corder, & van Sluijs, 2013; Houghton et al., 2015), and with the occurrence of various biological, cognitive, and psychosocial developments, potentially influencing youth behavior and well-being in multiple ways (Burnett, Sebastian, Cohen Kadosh & Blakemore, 2011; Giedd, 2012). Adolescence has also been identified as a crucial period in personality development (Klimstra, Hale, Raaijmakers, Branje, & Meeus, 2009). Simultaneously, the mechanism by which higher levels of screen time contribute to these implications is ambiguous, and it has been explained by biological, environment and psychosocial factors. One potential mechanism of this relationship is that among young people with pre-existing some emotional (Houghton et al., 2018) or behavioral (George, Russell, Piontak, & Odgers, 2018) health symptoms, accumulated time spent using digital screens could exacerbate further those impairments over time.

Likewise, some other longitudinal studies have indicated that higher digital screen engagement in adolescents related to subsequent psychosocial symptoms (Primack, Swanier, Georgiopoulos, Land, & Fine, 2009; Wu et al. 2016) but in contrast other research has revealed that existing psychosocial symptoms were associated with later digital screen involvement (Gunnell et al., 2016), possibly suggesting a pattern of coping or compensatory behavior (Kardefelt-Winther, 2014). Research has also suggested that very high engagement in digital screens may result in structural and functional changes in brain areas involving individual executive functions (e.g. Lin et al., 2012; Weng et al., 2013). Moreover, screen use patterns may strongly influence identity formation and the development of social relationship skills among children and youths (George & Odgers, 2015). The importance of parents' normative interaction with children in terms of the development of the social brain has been also highlighted (Lagercrantz, 2016). Customarily, young people's screen activities late in the evening have been found to be related to a likelihood of worse and decreased sleep (Cain & Gradisar, 2010), which in turn may increase the risk of childhood emotional and behavioral problems (Bagley & El-Sheikh, 2013; El-Sheikh & Sadeh, 2015). In term of contextual factors, young people of disadvantaged socioeconomic status (i.e., poverty or limited parental education) involve at particularly more for digital screen use compared to counterparts with higher socioeconomic status parents (Fairclough, Boddy, Hackett, & Stratton, 2009; Rideout, Foehr, & Roberts, 2010).

Consequent to the reported potential disadvantages of screen use, it was previously recommended that school-aged children and adolescents should be limited to two hours of screen time per day, but it is now suggested that parents should negotiate individual screen use plans with their children to establish consensual limits on screen time (American Academy of Pediatrics (AAP), 2016). It is also recommended that

children under 2 years of age should avoid screen viewing, and that preschool children should spend no more than one hour per day viewing screen media (Ponti et al., 2017). Instead of concentrating on the amount of time spent on digital screens, AAP emphasizes the importance of limits (i.e., consistency and children also having adequate time for behaviors essential to health), content (i.e., a focus on high-quality programs) and communication (i.e., co-discuss and view with them to help them understand healthy digital habits).

Thus, we can see then that there is a lot of research on the harmful effects elevated digital screen use may have on children and youths, though these studies are not without shortcomings or controversy. Nevertheless, there are still specific areas warranting further research in this context. Recent review studies have reported key limitations in terms of the measure of screen time (i.e., usually a single indicator and not objectively measured; dominated by studies on television-based screen time) and study design (i.e., the vast majority were cross-sectional) (Stiglic & Viner, 2019; Suchert et al., 2015). For instance, very few studies have comprehensively examined a wide spectrum of different screen use patterns including computer use, gaming and mobile screen devices (Stiglic & Viner, 2019). There is also a notable lack of high quality studies and great heterogeneity in terms of definition and measurement methods of screen time exposures and health outcomes (Stiglic & Viner, 2019).

As mentioned above, many research findings indicate that depression/anxiety and attention problems/hyperactivity are among the most dominant emotional (also referred as internalizing behaviors) and behavioral (also referred as externalizing behaviors) characteristics linked to individuals' susceptibility to higher digital screen use. Depressive symptoms can be categorized as a group of symptoms (representing a continuum varying from minor depression to major depression) including

loss of interest in everyday activities, decreased mood and fatigability (Ayuso-Mateos, Nuevo, Verdes, Naidoo, & Chatterji, 2010). It has been reported that around 20% of people experienced depressive symptoms by the end of adolescence (see Hoare et al. 2016) and this condition typically continues into adulthood (Kessler et al. 2007). Females are more likely to experience depressive and anxious moods compared to males (e.g. Ge, Conger & Elder, 2001; Hankin, Mermelstein & Roesch, 2007; Kessler at al. 2012). Earlier onset of depression in young people also increases risky behaviors such as alcohol and drug abuse and worse academic outcomes (see Werner-Seidler, Perry, Calear, Newby, & Christensen, 2017). Both depression and anxiety symptoms may result in notable distress, social difficulties and later mental health impairment (Bor, Dean, Najman & Hayatbakhsh, 2014; Kessler et al. 2007; Wesseihoeft, Sørensen, Heiervang, & Bilenberg, 2014).

Attention problems, hyperactivity and impulsivity (also referred to as Attention-Deficit/Hyperactivity Disorder [ADHD]) are a group of behavioral problem characteristics that often appear for the first time in childhood (American Psychiatric Association, 2000). ADHD symptoms tend to progress as a chronic course (Barbaresi et al. 2013) and young males are more prone than females to the condition (e.g. Visser et al. 2014). Children with ADHD symptoms may face functional challenges across life areas (e.g., peer problems, academic performance, etc.) (see Visser et al., 2014). The changes that have occurred in ADHD diagnosis rates in the past two decades (Visser et al., 2014) have resulted in concern among some experts that digital screen exposure might have influenced this trend (Christakis, 2009; Sigman, 2007). In this study, emotional and behavioral problem characteristics are conceptualized as a dimensional approach where the symptoms may vary from minor to major conditions.

1.2 Aims of the study

While there have been some studies on screen use and adolescent health using community samples, only a few studies have examined digital screen use patterns and their psychosocial implications over time. There are still few studies allowing experts to grasp a solid view of the implications in terms of the interplay between emotional and behavioral problem characteristics (or well-being) and high levels of digital screen time on children and adolescents (Orben & Przybylski, 2019). The aim of this work is to investigate the associations (longitudinal and cross-directional, using the data derived from three waves: the baseline and two follow-ups) between the degree of childhood and adolescent emotional and behavioral problem characteristics (i.e., internalizing and externalizing behaviors) and a higher level of daily screen time at 16 years of age. The study addresses the following questions: How much time do adolescents spend on an average day with digital screen media? How are different emotional and behavioral problem characteristics in childhood and adolescence associated with elevated digital screen time among adolescents? It is expected that elevated levels of screen time can be predicted by preexistent emotional or behavioral symptoms (particularly relating to anxiety, depression, attention problems and hyperactivity) in childhood. Moreover, the present study considers the conjoint cross-directional connections between these factors. Even if the digital media environment was entirely different at the time current data was collected compared to today (i.e., dominated by television viewing versus smartphones), this study gives insights that distinguish between the digital behaviors of the different human generations (i.e., Y and Z) and the possible impacts on youth.

2. Method

2.1 Sample

The secondary data analysis examined in this study is an ongoing prospective population-based cohort from northern Finland. The original study sample is based on the Northern Finland Birth Cohort 1986 Study (NFBC 1986), which included 9432 subjects (4865 males) whose expected date of birth fell between 1 July 1985 and 30 June 1986. The research was performed in accordance with the Declaration of Helsinki and was approved by the Ethical Committee of the Northern Ostrobothnia Hospital District in Oulu, Finland.

The original sample was obtained when the subjects' mothers visited a maternity health center; during these visits, the subjects' gender and birth weight were recorded together with information on the parents' sociodemographic characteristics. When the cohort subjects were aged 8 (in 1993-1994) and 15 or 16 (in 2000-2001), additional research data were collected from the subjects and their mothers via interviews and postal questionnaires.

When the study participants were 8 years old, their teachers completed questionnaires that included items relating to their early emotional and behavioral problems. Questionnaires were completed by 8525 subjects (sample attrition 8.3%). In the years 2000 and 2001, the cohort members (then aged 15–16) were asked to complete a postal survey on behavioral and lifestyle variables that included sections on digital screen use, and the Youth Self-Report (YSR) questionnaire (Achenbach, 1991; Achenbach & Resorta, 2001). At the time of this follow-up assessment, 9349 subjects (4806 males) were alive and data was received from 7182 subjects (sample attrition 22.1%). The NFBC1986 data and the recorded externalizing and internalizing characteristics, are described in detail elsewhere (Miettunen et al., 2014; Taanila et al., 2004).

Only participants with data on both screen exposure and externalizing and internalizing problem characteristics at age 8 or age 15–16 were included in the analyses.

The final sample consisted of 6 479 adolescent subjects, including 3101 males. Attrition analyses for the 15–16-year follow up revealed that of the study group who were alive at the time of follow-up, 75.0% participated. The proportion of male subjects participating in the follow-up study was lower than that of female subjects (48% v. 52%). The attrition analysis characteristics of the current data are described in more detail elsewhere (Miettunen et al., 2014). Across data collection phases on average 2.5% of the data was missing. Missing data were dealt with by listwise deletion to maximize the statistical power, and cases were perceived to be missing at random.

- Please, insert figure 1 here -

2.2 Measures

Data gathered at the subjects' birth was obtained when their mothers visited a maternity health center. Variables recorded at this point include the subject's sex, birth weight and the socioeconomic status of their mother or parents (including family type, and occupational status). Cumulative risk was measured using a standard method based on a total count of dichotomized risk indicators (Evans, Li, & Whipple, 2013). This approach reportedly yields higher measurement accuracy, validity, and statistical power than individual risk factor methods (Evans et al., 2013). The following indicators were used to assess contextual risk during the prenatal/birth period: low birth weight (under 2500 g; Zegers-Hochschild et al., 2009), single mother (unmarried, widowed, divorced, or not cohabitating with a partner), and economic exclusion (highest occupational status of the household's adult members was either unskilled worker, unemployed, or on disability benefit). Each indicator was coded 1 or 0, meaning that the risk factor was present or absent, respectively. Scores for these indicators were summed and the totals were used as covariates in the analyses.

When the children were 8 years old, the Children's Behavior Questionnaire (Rutter B2 scale; Elander & Rutter, 1996) was completed by their teachers, and the responses were used to create five emotional and behavioral scales based on questionnaire items that were answered using a three-point Likert scale with possible answers of "Doesn't Apply" (0), "Applies Somewhat" (1), and "Certainly Applies" (2). The reliability and validity of the Finnish version of the scale has been shown to be adequate (Kresanov, Tuominen, Piha, & Almqvist, 1998) and the subscales used are described in previous reports (e.g. Miettunen et al., 2014). The questionnaire required teachers to rate subjects' behavior over the preceding year. Two items assessed peer aggression: "Fights every so often or quarrels often with other children" and "Teases other children", and these items were summed to determine the subject's degree of peer aggression ($\alpha = .85$). Behavioral problems ($\alpha = .69$) were determined by incorporating the raw scores for three items ("Is often disobedient," "Lies often," and "Gets annoyed or behaves aggressively when corrected"). The raw scores for another three items ("Child is restless, does not have patience to sit down for a long period of time," "Wiggles and is restless," and "Is not able to concentrate on anything for a longish period") were summed to determine the subjects' Hyperactivity/Distractibility tendencies ($\alpha=.88$). Fearfulness/Inhibition ($\alpha=0.73$) was assessed as the sum of five items ("Is often scared of new things or situations," "Is often worried," "Is passive, slack or apathetic," "Seems often low-spirited, unhappy, weepy or anguished," and "Child has tears in his/her eyes when coming to school or has refused to come into the school building"). Finally, two items were summed to create the Peer Marginalization variable ($\alpha = .50$) ("Other children don't particularly like him/her" and "Tends to spend time alone, is quite seclusive"). Cronbach's alpha values between .71 and .90 is usually preferred (Taber, 2018). The internal consistency of the Peer Marginalization is relatively low, probably due to the low number of items (under three

instances) (Taber, 2018). However, the corresponding alpha value is consistent (parents' rating) with the previous rating (Miettunen et al., 2014), and is thus included in the analyses. These emotional and behavioral problem characteristics were assessed as unidimensional constructs where symptoms ranged on a continuum from low to high severity.

The subjects' behavioral problems at the age of 16 were assessed using the Youth Self-Report (YSR; Achenbach & Resorta, 2001) scale. This scale is widely used (e.g., also in Finnish sample: Helstelä & Sourander, 2001) and has excellent psychometric properties (Abad, Forns, & Gómez, 2002; Achenbach & Resorta, 2001). Eight sub-scales of problem behaviors were used in this study, including anxious-depressed (consisting of 13 items, e.g., I cry a lot; I feel that I have to be perfect; I feel worthless or inferior, etc: α = .81), withdrawn-depressed (consisting of seven items, e.g., I refuse to talk; I am secretive or keep things myself; I am shy, etc: α = .66), somatic complaints (consisting of 10 items, e.g., I have nightmares; I feel dizzy; I feel overtired, etc: α = .74), thought problems (consisting of 12 items, e.g., I can't get my mind off certain thoughts; I deliberately try to hurt or kill myself; I pick my skin or other parts of my body, etc: α = .72), social problems (consisting of 10 items, e.g., I am too dependent on adults; I feel lonely; I don't get along with other kids, etc: α = .62), attention problems (consisting of seven items, e.g., I act too young for my age; I have trouble concentrating or paying attention; I have trouble sitting still, etc: α = .63), rule-breaking behavior (consisting of 12 items, e.g., I don't feel guilty after doing something I shouldn't; I hang around with kids who get in trouble; I lie or cheat, etc: α = .70) and aggressive behavior (consisting of 17 items, e.g., I argue a lot, I am mean to others; I try to get a lot of attention, etc: α = .83). Each item statement relating to one of these sub-scales was scored on a three-point

Likert scale where scores of 0, 1, and 2 indicate that the problem behavior in question is absent, occurs sometimes, and occurs often, respectively.

When the cohort members were 16 years old, their screen use patterns were assessed by survey. Participants were asked to report the amount of time (open-ended response, in hours per day) they spent watching television (question 1) and playing digital games or working on personal computers (question 2) on a typical day (excluding activities related to work or study). Consistently with other studies (e.g., Ferguson, 2017), an average daily use variable known as the total daily screen time was created by summing these two variables.

2.3 Statistical analysis

Descriptive statistics including internal consistencies, means and standard deviations (SDs) were computed for the dataset. Statistical differences between the genders were analyzed using the independent t-test. Pearson correlation coefficients were calculated to evaluate the relationships between each combination of the study's variables. A linear hierarchical regression analysis was conducted using the total daily screen use as the dependent variable. The linear hierarchical regression model was used to analyze variance in the outcome variables based on predictor variables collected under different conditions. Contextual risk factors (i.e. risk factors existing during the prenatal/birth period) were incorporated in the first step of the hierarchical regression. Gender was dummy coded and the first group (i.e., female) comprised the reference category. In the second phase, emotional and behavioral tendencies at the age of 8 were incorporated. In the third step, emotional and behavioral tendencies at the age of 16 were incorporated. A preliminary analysis demonstrated that there were no problems of multicollinearity (the variance inflation factor, or VIF, was below 5, and the tolerance score for predictors, or Tolerance,

was above .20) or the values of the residuals were independent (based on the Durbin-Watson coefficients), and that the assumption of the values of the residuals' normal distribution held. The statistical analyses were carried out using the SPSS statistical software package (version 24). The significance threshold was set at $p < .01$.

3. Results

Table 1 summarizes the mean scores and standard deviations for each studied variable. Participants reported spending an average of 3.80 h (*SD* 2.90 h) per day on different screens at the age of 16. The average daily screen use for boys (4.55, *SD* = 3.31) was significantly higher than that for girls (3.09, *SD* = 2.25; $t_{(5913)} = 21.41$, $p < 0.001$). The average emotional and behavioral characteristic scores were significantly higher for boys than for girls at the age of 8. However, at the age of 15–16, girls had significantly higher emotional and behavioral characteristic scores than boys.

- Please, insert Table 1 here -

Table 2 shows the observed relationships between the study variables for the two genders separately. Hyperactivity/distractibility and peer aggression problems at the age of 8 and behavioral characteristics relating to rule-breaking, aggressiveness and attention at 15–16 years of age exhibited the strongest positive correlation with total daily screen use in both genders. Contextual risk factors identified at birth did not correlate significantly with any of the study variables among boys. For girls, contextual risk factors correlated significantly and positively with the total daily screen use at the age of 15/16. For girls, the total daily screen use overall showed a moderately high correlational pattern with the symptom variables of emotional and behavioral problems.

- Please, insert Table 2 here -

A three-step hierarchical multiple regression analysis was performed to predict daily screen use at age 15–16 (Table 3). Multicollinearity tests using condition indices and regression coefficient variance-decomposition matrices, tolerances, and VIFs revealed that the analysis had no multicollinearity problem (i.e., $tolerance_{min}$ = .36, all VIF_{max} = 2.56), and the analysis showed that the 15 predictors collectively explained 9.7 % of the total variance in total daily screen time (F (15,6463) = 46.090, p < .001).

Model 1, which incorporates only contextual risk factors and gender (reported at baseline), explained 6.6% of the total variance in total daily screen time (F (2,6476) = 229.906, p <.001). Contextual risk factors were not a significant (final β = .02, p = .050) unique predictor of total daily screen use. However, male gender was a significant (final β = .23, p < .001) predictor of increased daily screen time, indicating that it has an important effect on total daily screen use when all other independent variables are controlled for.

Model 2, which also includes data on the subjects' emotional and behavioral characteristics at the age of 8, explained a further 0.7% of the total variance in total daily screen use (F (7,6471) = 72.691, p < .001). More severe symptoms of hyperactivity/distractibility (final β = .06, p < .001) in childhood predicted higher daily screen time in adolescence, indicating that screen use increased as symptoms relating to this problem became more severe, when all other predictors were controlled for.

Model 3, which also includes data on the subjects' emotional and behavioral problems during adolescence, explained an additional 2.4% of the total variance in higher daily screen use (F (15,6463) = 46.090, p <.001). Anxious-depressed emotions had a negative and significant effect (final β = -.05, p = .007) on higher daily screen use. Rule-

breaking problems (final β = .13, p < .001) were significant positive unique predictors of higher daily screen time. Attention problems also contributed positively (but not significantly: final β = .04, p = .017) to total daily screen time.

- Please, insert Table 3 here -

4. Discussion

This work examined the associations between the degree of childhood and adolescent emotional and behavioral problem characteristics (i.e., internalizing and externalizing behaviors) and a higher level of daily screen time in adolescence in a large population-based Finnish birth cohort. Taking the findings as a whole, participants with higher levels of hyperactivity/distractibility problems during the beginning of formal schooling (at the age of 8) and adolescent (at the age of 15–16) rule-breaking problems were found to have a significantly higher risk of more elevated daily screen use in adolescence after controlling for contextual risk factors and gender. A hierarchical multiple regression analysis indicated that contextual risk factors and male gender alone explained 6.6% of the variance in total daily screen time. Furthermore, emotional and behavioral problem characteristics explained 3.1% of the total variance in total daily screen use after controlling for contextual risk factors.

The subjects reported that they spent almost four hours a day on average using a screen of some sort. Previous studies have shown that computer use, video gaming, and television viewing were among the most common sedentary, screen-based activities of European adolescents between 2002 and 2010, and that the total screen time for this group ranged from between three and seven hours (Bucksch et al., 2016; Verloigne et al., 2016). The average daily screen usage levels reported by the subjects in

this work were very similar to those reported in earlier European studies. However, earlier studies used study designs and measures differing from those adopted here, and recorded greater variation in screen use among adolescents (Bucksch et al., 2016; Verloigne et al., 2016). Male gender was found to be associated with high screen exposure, in keeping with earlier reports (Bucksch et al., 2016; Seveg et al., 2015). Overall, concerning the different screen-based activities, there is a gender differences observed in previous studies that showed boys are more likely to use computers for gaming whereas girls favored computers for nongaming activities (Bucksch et al., 2016; Seveg et al., 2015). Nevertheless, most recent studies have shown that females tend to use a smartphone for more different purposes (i.e., social media and texting) (e.g. Lopez-Fernandez et al., 2017).

Studies have also shown a shift in time spent on different forms of digital screens and related activities in the past three decades. While television viewing has dominated and shown stable or increasing trends among young people in studies published before the mid-2000s (Marshall, Gorely, & Biddle, 2006; Samdal et al., 2007), other forms of screen-based activity (online activities and computer use for gaming and nongaming purposes) have replaced television viewing to a large extent in recent years (Bucksch et al., 2016; Mullan, 2018; Ofcom, 2015; Ólafsson, Livingstone, & Haddon, 2014). Notwithstanding, although children and adolescents have increasing access to and use of portable screen-based devices (Lauricella, Wartella, & Rideout, 2015; Ofcom, 2015), screen-based activities appear to be interwoven with daily life (i.e., used in parallel with non-screen based activities); as a result, young people have accommodated their habits to incorporate devices (Mullan, 2018).

The baseline contextual risk factors were not significantly related to higher levels of daily screen use in adolescence. This may be partly explained by the view that

there may be other contextual characteristics (that were not examined in this work) in the home environment, such as a television in the child's bedroom, parental co-viewing, parental modeling and eating in front of the television, that may impact on young people's screen use (Gebremariam et al. 2015). A recent study found that increasing age, male gender, lower socio-economic status (i.e. low maternal education and household income), and parental divorce and/or the father being the primary caregiver all predicted higher screen use (Zhao et al., 2018). Previous studies have indicated that children with unemployed (Iguacel et al., 2018) or single (Langøy, Smith, Wold, Samdal & Haug, 2019) parents are more prone to higher screen use. Conversely, other studies have failed to identify significant associations between higher screen use and familial composition (e.g. McMillan, McIsaac, & Janssen, 2015), providing inconclusive results.

The main aim of this work was to investigate the associations between higher degree of childhood and adolescent emotional and behavioral problem characteristics (i.e., internalizing and externalizing behaviours) and levels of total daily screen time in adolescence. The results indicated that rule-breaking behavior (which were used as indicators of behavioral or externalizing problems) in adolescence were related to higher daily screen time in adolescence. Furthermore, as expected, the occurrence of such behaviors (namely hyperactivity/distractibility) at 8 years of age (at the beginning of formal schooling) significantly predicted higher screen use later in adolescence. The current study also showed a co-occurrence (i.e., a significant bi-directional correlation) of hyperactivity/distractibility, peer aggression problems (at the ages of 8 and 16) and behavioral problems (i.e., relating to attention, rule-breaking and aggressive) at the age of 16. However, it is worth noting that while we found certain behavioral problems had a positive association with adolescent higher screen use, that marked small effect implied that the associations might be driven more by other factors.

Previous studies have found that children and adolescents with observed symptoms of ADHD including hyperactivity, attention problems, and impulsivity all had higher screen use (Charmaine, Waring, Pagoto, & Lemon, 2015; Gentile, Swing, Lim, & Khoo, 2012). Additionally, previous longitudinal studies have found that higher television viewing in childhood was related to social difficulties (social isolation and antisocial behavior) and aggression (proactive aggression and aggressive personality traits) later in early adulthood (Pagani, Lévesque-Seck, & Fitzpatrick, 2016; Robertson, McAnally, & Hancox, 2013). Furthermore, a meta-analysis (incorporating 29 cross-sectional, 12 longitudinal, and four experimental studies) reported that media use, including television viewing or gaming, among children and teenagers (4–17 years old) correlated slightly (effect size r = .12) with ADHD-related symptoms (Nikkelen, Valkenburg, Huizinga & Bushman, 2014). Nevertheless, the possibility that levels of hyperactivity and rule-breaking symptoms are comparable with overall levels of screen use, and bi-directional links between those factors warrant further research. It is also worth noting that previous studies have concentrated predominantly on media activities such as television viewing and gaming.

The proposed effect of screen use on ADHD has been attributed to overall time engaged with fast-paced media content (flashing lights and scene changes may overstimulate to developing brains; e.g., Christakis, 2009; Geist & Gibson, 2000). Furthermore, it may be that severe externalizing behavior problems reduce access to activities that are traditionally considered more advantageous for individuals and that may better stimulate cognitive abilities. It has been argued that young people with attention/hyperactivity problems may be more likely to face peer difficulties compared with typically developing counterparts (e.g., Hoza, 2007; Mikami & Normand, 2015) and thus will favor more solitary activities such as gaming and television viewing. Again,

externalizing symptoms in adolescence may impede educational attainment by increasing the probability of upper-secondary drop-out and lack of post-secondary education (Evensen, Lyngstad, Melkevik, & Mykletun, 2016).

In contrary what was expected, emotional problems such as anxious-depressed characteristics at the age of 16 was inversely and negatively associated with more higher screen time. Furthermore, withdrawn-depressed characteristics contributed slightly (but not significantly) to higher screen time, which may indicate that the inverse relationship relates more to anxious tendencies than to depression. Conversely, a large cross-sectional study (n = 2482) of Canadian adolescents found that screen use (hours per day of television viewing, video games, and computer use) was associated with more severe symptoms of anxiety and depression (Maras et al., 2015).

A recent review study of reviews concluded that empirical support for the impact of screen time exposure on different mental health factors other than depressive symptoms was patchy (Stiglic & Viner, 2019). Similarly, a recent meta-analysis revealed a significant inverse relationship between mental health and all forms of screen-based sedentary behavior in young people (Asare, 2015). The largest effects were found for depression and psychological distress, while the smallest effects were seen for anxiety and quality of life. The screen-based behaviors with the largest positive effects were general screen use and television viewing. It should be noted however that this meta-analysis was primarily based on cross-sectional studies (meaning that the temporal direction of the associations is not clear) with diverse methodological limitations, so its results should be interpreted with care.

Nevertheless, a recent study by Houghton et al. (2018) investigated different trajectories among adolescents (aged 10–17 years) experiencing depressive symptoms in parallel screen with use patterns (social networking, gaming, web browsing, television

viewing) over two years. This study found three distinct trajectories of depressive symptomatology (low-stable, high-decreasing, and low-increasing). The authors found obvious associations between the trajectories of depression (especially in the low–increasing depression trajectory) and patterns of screen use. However, in one of the trajectory groups (high–decreasing depression), screen use was not closely related to the depression symptoms, which indicated a modest temporal relationship (no causal pathway) between screen engagement and depression.

Associations between specific screen-based activities and anxiety and depression in youth are also limited. Some studies have found that greater time spent using a computer was related to increased likelihood of anxiety (Khouja et al., 2019) or depression (Khouja et al., 2019; Maras et al., 2015). Consequently, some studies fail to find associations between increased television viewing time and depression and anxiety (Maras et al., 2015; Mathers et al., 2009). One study (Segev et al., 2015) showed associations between emotional or behavioral problems (symptoms of hyperactivity, and emotional, conduct, peer, and prosocial difficulties) and increased time spent using computers. This association was not evident in the use of smartphones (used for purposes such as talking, texting, and gaming) or small-screen gaming (smartphones and tablets). A possible explanation could be that small-screen devices are commonly used for casual purposes rather than persistent and focused activity. Mixed outcomes may also be partly due to the rapidly changing nature of digital screen use; it may be that certain vulnerable individuals (e.g. those suffering from social anxiety) tend to use these services for compensatory purposes to relieve distress and/or unpleasant emotions (Kardefelt-Winther, 2014), for instance by social networking. Several authors have proposed psychosocial hypotheses in which social problems or withdrawal (for instance relating to parent-child interaction) are a key risk factor for excessive screen use (Hinkley et al.,

2014; Wu et al., 2017; Zhao et al., 2018). Perhaps this view explains why impaired social abilities correlate with higher screen use, especially as the development of social skills naturally occurs in the context of social interaction with others (Semrud-Clikeman, 2007).

The current study has some limitations that must be accounted for before drawing conclusions based on its results. First, the population was drawn from northern Finland and this restricts the generalization of the conclusions. Another limitation relates to the extent of attribution of participants (average loss of follow-up), which indicates an increased likelihood of bias. Although the loss of even a small proportion of participants from follow-up may create significant bias, the data in the current study are considered suitable for the given estimations (e.g., a minimal possibility for attrition bias, as reported elsewhere; Miettunen et al. 2014). One key limitation is that the subjects' emotional and behavioral traits at the start of their formal education were analyzed on the basis of reports made by their teachers, whereas the same traits during adolescence were evaluated on the basis of self-reports. In addition, the subjects' screen use was evaluated on the basis of a single self-reported survey with no independent screen-time tracking, so we could not study variation in screen exposure over time among the studied population. Furthermore, self-reports lack objectivity and often result in inaccurate data; respondents tend to give responses they consider socially desirable (heavy users tend to underestimate and infrequent users overestimate their screen use; Scharkow, 2016). The current study focused on common screen-based behaviors such as using computers, watching television, and playing video games. Modern digital device use differs significantly from that prevailing in the 1990s and early 2000s: the increasing accessibility of portable screen-based devices has provided a new major daily source of screen exposure among adolescents, especially in developed countries (Kabali et al., 2015). Because the study measuring screen exposure focused on total screen exposure time, the distribution of that

time between specific screen activities is unknown. Findings of the present study should be interpreted with caution when comparing these to the most recent evidence because of the changes in the digital landscape in recent years.

Overall, the results presented here suggest that specific individual behavioral tendencies at the start of formal schooling generally predict screen use patterns (particularly for traditional forms of screen activity including television viewing, game playing and computer use) later in adolescence. Even in the few cases where a relationship between such tendencies and adolescent screen use was observed, the possible influence on young people was very small, supporting the conclusion that other factors (e.g., availability of screen media, parent-child interactions/media parenting practices, attachment to peers and parents) have more important effects on total screen time. Furthermore, while boys spent significantly more time with screens, girls reported more emotional and behavioral problem characteristics during adolescence. Therefore, further longitudinal studies using both objective and subjective assessments together with measures of different aspects of screen use (e.g. content types) as well as social contextual and behavioral factors are needed to understand how behavioral problems and screen use are related among adolescents. Because the digital landscape continues to evolve rapidly, much remains to be learned about how screen use affects the wellbeing of children and adolescents.

Declaration of interests

The authors declare that they have no conflict of interest.

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Table 1. Sample Description

Variable	Male n/Mean (*SD*)		Female n/Mean (*SD*)		*t*-test
Emotional and behavioral characteristics at the age of 7/8 years					
a. Peer aggression (α = .85; range 0–4)	4240	0.62 (1.05)	4058	0.18 (0.57)	23.60***
b. Behavioral problems (α = .69; range 0–6)	4240	0.65 (1.14)	4057	0.27 (0.72)	18.43***
c. Peer marginalization (α = 50; range 0–4)	4238	0.44 (0.78)	4056	0.32 (0.67)	7.05***
d. Fearfulness/Inhibition (α = .73; range 0–10)	4241	0.89 (1.46)	4058	0.73 (1.34)	5.28***
e. Hyperactivity/Distractibility (α = .88; range 0–6)	4240	1.30 (1.72)	4059	0.49 (1.10)	25.62***
Emotional and behavioral characteristics at the age of 15/16 years					
a. Anxious-Depressed (α = .81; range 0–22)	3397	1.95 (2.48)	3660	4.33 (3.72)	-31.88***
b. Withdrawn-Depressed (α = .66; range 0–13)	3392	2.10 (1.93)	3660	2.87 (2.26)	-15.20***
c. Somatic Complaints (α = .74; range 0–63)	3385	2.35 (2.31)	3656	4.49 (2.87)	-34.43***
d. Social Problems (α = 62; range 0–16)	3392	1.64 (1.87)	3656	2.17 (2.13)	-11.01***
e. Thought Problems (α = .72; range 0–20)	3393	1.67 (2.12)	3655	2.88 (2.91)	-20.00***
f. Attention Problems (α = .63; range 0–15)	3394	3.21 (2.05)	3656	4.22 (2.17)	-20.02***
g. Rule-Breaking Behavior (α = .70; range 0–20)	3397	3.43 (2.62)	3661	3.69 (2.87)	-4.02***
h. Aggressive Behavior (α = .83; range 0–32)	3399	5.59 (4.15)	3662	7.13 (4.50)	-14.96***
Total screen time per day (hours) at the age of 15/16 years	3390	4.55 (3.31)	3646	3.09 (2.25)	21.41***

Note. α = Cronbach's alpha; *** $p < .001$

Table 2. Correlation matrix for study variables by gender

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Contextual risk factors		.027	.041	.041	-.009	.028	.030	.011	.002	.035	-.002	.008	.022	-.002	.063**
2 Peer aggression[a]	-.021		.703**	.246**	.127**	.497**	.046**	-.015	.080**	.056**	.072**	.116**	.121**	.116**	.089**
3 Behavioral problems[a]	-.007	.735**		.247**	.210**	.553**	.063**	.003	.075**	.069**	.071**	.120**	.124**	.112**	.068**
4 Peer marginalizing[a]	-.017	.353**	.370**		.489**	.158**	.058**	.119**	.023	.131**	.060**	.056**	.053**	.022	.051**
5 Fearfulness/Inhibition[a]	.016	.174**	.268**	.476**		.195**	.051**	.083**	.035	.082**	.028	.061**	.047**	-.001	.026
6 Hyperactivity/Distractibility[a]	.038	.595**	.637**	.278**	.230**		.032	-.038	.047**	.043	.042	.129**	.102**	.085**	.124**
7 Anxious-Depressed[b]	.004	.039	.037	.038	.032	.044		.601**	.509**	.634**	.568**	.519**	.330**	.453**	.053**
8 Withdrawn-Depressed[b]	.016	-.025	-.019	.086**	.062**	-.036	.557**		.348**	.582**	.392**	.361**	.202**	.254**	.068**
9 Somatic Complaints[b]	.019	.047**	.040	.005	.004	.035	.419**	.293**		.389**	.490**	.416**	.409**	.434**	.090**
10 Social problems[b]	.001	.039	.034	.088**	.056**	.061**	.639**	.524**	.360**		.466**	.481**	.296**	.391**	.083**
11 Thought problems[b]	.007	.059**	.047**	.030	-.016	.052**	.537**	.353**	.381**	.445**		.509**	.457**	.529**	.096**
12 Attention Problems[b]	.013	.112**	.107**	.027	.022	.151**	.502**	.341**	.349**	.455**	.421**		.479**	.605**	.141**
13 Rule-Breaking Behavior[b]	-.025	.097**	.096**	-.022	-.029	.099**	.328**	.212**	.307**	.279**	.387**	.465**		.638**	.199**
14 Aggressive Behavior[b]	-.017	.139**	.116**	.003	-.021	.111**	.453**	.245**	.377**	.391**	.435**	.581**	.618**		.131**
15 Total screen time[c]	.001	.041	.033	.040	.036	.058**	.041	.040	.017	.068**	.053**	.086**	.138**	.093**	

Notes. ** $p < .01$. Correlations for girls are above the diagonal, and correlations for boys are below the diagonal. [a] Age 8 variables of emotional and behavioral problems; [b] Age 15–16 variables of emotional and behavioral problems; [c] At the age of 15–16 ye

Table 3. Hierarchical regression predicting excessive screen use

	Predicted variable	***B***	*B 95%* CI [LL, UL]	*β*	*t*	*p*
1	Contextual risk factors (at baseline)	0.19	[0.00, 0.38]	.02	1.93	.05
	Male gender	1.36	[1.21, 1.52]	.23	17.29	<.001
2	a. Peer aggression (at the age of 8)	0.06	[-0.06, 0.18]	.01	0.98	.323
	b. Behavioral problems	-0.09	[-0.22. 0.00]	-.03	-1.87	.061
	c. Peer marginalization	0.09	[-0.02, 0.20]	.02	1.61	.105
	d. Fearfulness/Inhibition	0.01	[-0.04, 0.07]	.00	0.54	.589
	e. Hyperactivity/Distractibility	0.12	[0.06, 0.19]	.06	4.00	<.001
3	a. Anxious-Depressed (at the age of 16)	-0.04	[-0.07, -0.01]	-.05	-2.70	.007
	b. Withdrawn-Depressed	0.03	[-0.01, 0.07]	.02	1.49	.135
	c. Somatic Complaints	-0.01	[-0.04, 0.01]	-.01	-1.19	.234
	d. Social Problems	0.04	[-0.00, 0.08]	.03	1.82	.068
	e. Thought Problems	-0.00	[-0.03, 0.03]	-.00	-0.13	.893
	f. Attention Problems	0.05	[0.00, 0.09]	.04	2.38	.017
	g. Rule-Breaking Behavior	0.14	[0.11, 0.17]	.13	8.84	<.001
	h. Aggressive Behavior	-0.00	[-0.02, 0.02]	-.00	-0.05	.954

Note. *B*: the unstandardized beta; *95%* CI [LL, UL]: the lower and upper limits of 95% confidence interval for unstandardized beta; *β:* the standardized beta; *t*: *t*-test statistic; R^2= .097; Adjusted R^2 = .095 F= 46.090, df = 15,6463, $p < .001$.