Longitudinal Mediated Relations Between Screen Time and School Adjustment Through Executive Function Difficulties

by

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ABSTRACT

As screen time (ST) constitutes an integral part of the daily lives of young children today, parents, educators, and researchers have started to explore the associations of ST with children's cognitive, behavioral, and social outcomes. The majority of existing studies have primarily focused on the duration of ST in relation to these outcomes despite the importance of other aspects such as content and type of device in the context of an evolving digital landscape marked by high mobility, ubiquity, and diversity. Addressing this gap, the current study aimed to explore the intricate relations between multiple aspects of ST (i.e., duration and content), executive function (EF) difficulties, and school adjustment in school-aged children, with a particular focus on the mediating role of EF difficulties linking the relations between ST and school adjustment. The current study employed data from the Panel Study on Korean Children, tracking 1,484 South Korean children from third to fourth grade. The duration of ST was measured by the average daily hours spent on smart devices and computers. Parent reports of the levels of engagement in recreational and educational ST and EF difficulties were assessed on Likert scales. School adjustment was reported on by teachers. The results from a half-longitudinal mediation model demonstrated that more frequent engagement in educational ST was related to fewer EF difficulties, which was in turn associated with better school adjustment. The current findings suggest that multiple approaches are needed to effectively guide children's ST use in their everyday lives and interventions that target EF might be an effective way to promote children's behavioral and social adjustment in school settings.

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INTRODUCTION

Screen time (ST), which refers to the amount of time individuals spend on screen-based media devices, has become an increasingly pervasive and inevitable part of child development as children in contemporary society are "digital natives born into an ever-changing digital ecosystem" (Radesky & Christakis, 2016, p. 827). Due to dramatic increases in the use of new media characterized by high mobility, children around the world may be exposed to various ST activities in many contexts with almost no constraints on time and space, making the impact of ST on children's learning and adaptation a matter of increasing concern.

South Korea, particularly, is a country where the impact of ST on learning and adaptation is likely to be highly influential due to the wide accessibility of various media devices, the rapid development of relevant technology, and a high interest in education. In fact, the South Korean government was so concerned about the potential negative effects of ST that they introduced an online game shutdown law, known as the "Cinderella law", in 2011. The law restricted access to online games for children and adolescents under the age of 16 between midnight to 6 a.m. to prevent game addiction and promote healthy lifestyles. However, there has been controversy regarding its effectiveness, and eventually, the law was repealed in 2021. As this example demonstrates, strict restrictions on ST may not be effective. Instead, it is important to understand the various aspects of ST and potential benefits as well as risks to better guide children's ST.

Given the growing importance of ST in children's everyday lives, the current study aimed to examine the relations between different aspects of ST (i.e., duration and content) and behavioral and social adjustment in school among school-aged children from thrid to fourth grade in South Korea. Considering that school adjustment in the elementary school years is closely linked to later success (e.g., Caemmerer & Keith, 2015; Duncan et al., 2007), understanding how ST is related to children's school adjustment during this period is important to help children develop positively and adaptively. Furthermore, the current study aimed to examine the role of executive function (EF) as the mechanism underlying this association to obtain a more comprehensive understanding of the sophisticated relations between ST and school adjustment.

Screen Time

Importance of Considering Various Aspects of Screen Time

Research has explored children's ST and its relations with various developmental outcomes. However, most studies have primarily focused on traditional ST (e.g., television (TV), video games) with recreational content and often defined ST as the total time combining different ST activities and content with mixed findings of both positive and negative outcomes (see Zahedi et al. 2021 for a review). A recent review regarding the relations between children's TV viewing and cognitive and behavioral developmental outcomes suggested that *what* children watch can be more important than *how much* they watch considering the mixed findings regarding the relations between the duration of ST and developmental outcomes (Kostyrka-Allchorne et al., 2017). In addition, more contemporary ST devices such as smartphones and tablets have characteristics distinctive from traditional types of ST like TV viewing or video gaming. For instance, they are more portable and less likely to be supervised by parents, allowing children to more easily access ST and granting them greater autonomy in ST usage.

Understanding different aspects of ST is particularly important in middle childhood because children become more likely to possess their own devices upon entering formal schooling and have greater accessibility to a wider variety of content (Lee & Kim, 2019), which provides them with more autonomy in planning and managing their ST with less parental supervision and monitoring (Kostyrka-Allchorne et al., 2017; Linebarger et al., 2014). As a result, their overall ST consumption using various ST devices increases, and the types of ST content they consume become diverse (e.g., recreational, educational; Lee, 2021a).

Despite the increasing importance of contemporary ST devices and various types of content in school-aged children, very little research has been done on understanding how different types of ST content using such devices are related to children's cognitive, behavioral, and social outcomes. Therefore, the current study focused on relatively newer types of ST (i.e., computers and smart devices) and included the extent to which children engage in educational or recreational ST in addition to the overall duration of ST.

Screen Time in South Korea

In South Korea, ST is a huge societal issue due to its ubiquity and inevitability in everyday life. Almost all of the population in South Korea can access the Internet using dial-up, ADSL, or cable broadband access. According to the Organization for Economic

Co-operation and Development (OECD) report, the percentage of households with Internet access in South Korea is 99%, which is the highest among 42 OECD countries (OECD, 2022). In a recent report about media use among 0- to 6-year-old South Korean children, almost all households had smartphones (99%), televisions (94.3%), and personal computers (90.7%) at home, and the average daily hours of children's ST using these devices was 3 hours (Lee et al., 2021). In addition, the percentage of children who had their own smartphones was 17.2%, and among them, the average age of the first smartphone possession was 3.6 years old. These statistics suggest that children in South Korea can easily access various media devices from a very young age, and ST constitutes a large portion of children's daily lives.

As ST is a huge part of children's everyday lives and the age of first exposure to ST becomes lower, parents, educators, and policymakers in South Korea have a high interest in children's ST use, the influences of ST on various developmental outcomes, and the development of proper ST guidelines. As a result, relevant research has started to emerge in South Korea (e.g., Byun & Kim, 2007; Jang & Kim, 2008; Lee et al., 2013). However, few studies have been conducted using a longitudinal design and most studies have not included different aspects of ST such as content and duration. Moreover, there is a lack of research exploring possible mechanisms of the associations between ST and developmental outcomes. Thus, the current research that explored complex longitudinal relations between ST and school adjustment through EF difficulties will shed new light on the role of ST in South Korea.

School Adjustment

As children start formal schooling, they face the challenge of adjusting to new environments, including not just physical surroundings but also academic and social settings. This transition brings about greater demands in terms of schoolwork and social interactions, requiring higher levels of social and cognitive skills (Linebarger et al., 2014; Moilanen et al., 2010). For instance, children are expected to develop intellectual skills, foster learning motivation, and grow a positive identity as students (Perry & Weinstein, 1998). Moreover, the significance of relationships with both peers and teachers amplifies as children spend more hours at school (Lee et al., 2015). The dynamics of children's relationships with peers, especially, become more intricate as they often involve larger groups and require more organized and rule-oriented interactions in contrast to predominantly dyadic play typical of the preschool years (Fabes et al., 2009). Therefore, in order to thrive and adapt successfully throughout their elementary school years, various behavioral, cognitive, and social skills are needed.

Despite the importance of various skills for successful adaptation, most research has measured children's school success with academic achievement or educational success based on teacher reports or school records such as GPA and test scores (Jimerson et al., 2003). Although academic achievement is an essential indicator of school success, it can only capture children's academic competence. Thus, some researchers have suggested that children's school functioning should be understood using "real-world" measures of children's behaviors in school instead of standardized tests (Nelson et al., 2017).

Many studies have included behavioral and social aspects of children's school functioning but they have primarily focused on the extent to which children engage in or refrain from problematic behaviors such as aggression, disruptive behaviors, or inattention (e.g., Gentile et al., 2012; McArthur et al., 2022; Özmert et al., 2002; Sharif et al., 2010; Tamana et al., 2019). Albeit important, these findings are limited to information about children's (mal)functioning or (mal)adaptation. Thus, the current study focused on positive aspects of school adjustment including behavioral adjustment (e.g., how well children adhere to school rules and expectations and how actively they participate in classroom activities) and social adjustment (e.g., how well children create and maintain healthy relationships with peers and teachers). This approach reflects children's competence in understanding and meeting situational and contextual demands as well as achieving their pursuit of socially valued goals (Wentzel, 2013).

Relations Between Screen Time and School Adjustment

Duration of Screen Time and School Adjustment

Plenty of research has demonstrated that the duration of ST is related to problem behaviors in general such as hyperactivity, inattention, impulsivity, aggression, and so on although not specific to behaviors in school settings (e.g., Gentile et al., 2012; McArthur et al., 2022; Özmert et al., 2002; Sharif et al., 2010; Tamana et al., 2019). In such studies, the ways of measuring ST and problem behaviors were different and the age range of the participants varied, but the results were consistent – higher ST was related to the increased likelihood of reporting problem behaviors.

Albeit fewer, some studies have explored whether the duration of ST is related to positive behavioral functions specifically in school such as classroom engagement and learning-related behaviors. For instance, Pagani and colleagues demonstrated that more exposure to TV at 29 months of age was related to poorer classroom engagement (i.e., task orientation, compliance, and persistence) in kindergarten and fourth grade (Pagani et al., 2010, 2013). Therefore, higher levels of ST duration seem to be related to the increased likelihood of problem behaviors and the decreased likelihood of positive behavioral functions in school.

The existing literature also reveals consistent findings that a longer ST duration is associated with peer problems or lack of other relevant characteristics like social skills whereas lower levels of ST duration are related to positive peer relationships. For instance, 4- to 12-year-old children who watched videos more than 3 hours a day had more problems in peer relationships and prosociality than those watching videos less than 3 hours a day (Shiue, 2015). A longitudinal study also found that more TV viewing at 29 months old was related to more victimization by peers two years later (Pagani et al., 2013) and at age 10 (Pagani et al., 2010). Similarly, more ST was associated with poorer communication or social skills (Hu et al., 2020; Rocha et al., 2021; Sanders et al., 2019; Yang et al., 2017) and more social problems (Özmert et al., 2002) in early and middle childhood. On the other hand, watching less than the recommended hours of leisure ST (less than 2 hours) was related to higher levels of peer acceptance in children ages 8 to 12 years old (Belton et al., 2021). Thus, engaging with a large amount of ST may interfere with interactions with others and the acquisition of necessary social skills. However, consuming an appropriate amount of ST may not be negatively associated with relationships with others.

The above-mentioned research mainly included TV or video viewing when measuring ST, but more current studies have included various types of ST. For example, a longitudinal study that measured ST as a composite of TV viewing and gaming using tablets, computers, game consoles, and phones demonstrated that more ST at age 4 predicted lower emotion understanding, an essential skill in social interactions, two years later (Skalická et al., 2019). A cross-sectional study with infants and preschoolers from 0 to 60 months old observed similar findings that excessive ST was related to lower scores in children’s interaction skills and abilities to play (Rocha et al., 2021). The results were consistent when they ran separate analyses for TV and interactive media (e.g., video games, smartphones, and tablets), suggesting that the findings from previous research with traditional types of ST (e.g., TV viewing) may apply to more contemporary types of ST.

Research conducted in South Korea has documented similar results. For instance, a cross-sectional study by Jeong (2020) investigated how ST including Internet, games, mobile devices, and TV was related to school readiness skills measured by social and emotional development, approaches to learning, cognitive development, and general knowledge during the kindergarten year. The results demonstrated that more consumption of ST was related to poorer school readiness skills. Similarly, higher levels of ST duration in first graders, measured by hours spent watching TV or video and using computers or gaming devices, were concurrently related to poorer school adjustment including academic activities, school rules, peer relationships, and relationships with teachers (Ahn et al., 2017).

Longitudinal studies in South Korea also found that ST duration was significantly related to school adjustment. Lee (2021b) demonstrated that the longer hours children spent with ST upon entering elementary school were related to the lower levels of initial school adjustment. In addition, as the duration of ST increased from first to third grade, children's school adjustment became poorer. This finding suggested that the duration of ST at the beginning of formal schooling could be an important factor influencing the extent to which children adjust to new environments in school settings. Another longitudinal study that followed participants from first grade to fourth grade raised the possibility of more prolonged relations between ST and school adjustment (Lee & Lee, 2022). In this study, ST predicted school adjustment two years later, but not one year later. It may indicate that some amount of time is required for ST to take effect on children's school adjustment. Or, it can also imply a need for a mediator bridging early ST and late school adjustment.

As observed in the above-mentioned studies, ST duration was negatively related to children's school adjustment but some inconsistent findings exist. For instance, a study found no significant relations between ST and school adjustment measured by rule compliance and relationships with peers and teachers in 9- to 15-year-old children (Byun & Kim, 2007). Other studies also observed no association between ST and problem behaviors in preschoolers (Hu et al., 2020; Tansriratanawong et al., 2017). In Hu et al. (2020), non-significant relations were found regardless of the type of ST activities (e.g., passive ST such as watching TV or video vs. active ST such as playing on computers or smart devices). These mixed findings may suggest that the content of ST should be considered in order to more accurately navigate the associations between children's ST use and school adjustment.

Content of Screen Time and School Adjustment

Although it is clear that an excessive amount of ST is negatively related to children's school adjustment in general, it is less clear if the content of ST is important to consider when examining the relations between ST and school adjustment. A recent systematic review regarding the relations between TV viewing and children's cognition and behaviors pointed out that most studies did not take into account the content of TV programs despite some findings that what children watch rather than how much they watch may better predict developmental outcomes (Kostyrka-Allchorne et al., 2017).

Most studies examining how ST content is related to children's school success have focused on academic achievement (e.g., Baydar et al., 2008; Ishii et al., 2020; Sanders et al., 2019; Skvarc et al., 2021). However, some studies have explored the relations between ST and children's general behavioral outcomes although not specifically in the school context. For instance, a longitudinal study with children at 21 and 33 months revealed that watching non-educational programs was concurrently and longitudinally associated with an increase in aggressive behaviors and externalizing problems, but no significant relation was found between watching educational programs and behavior problems (Tomopoulos, Dreyer, et al., 2007). Similarly, a longitudinal study following children from 10 and 11 years old to 14 and 15 years old demonstrated that educational ST had no significant relations with social and emotional functions as measured by the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), but social media use was negatively associated with social and emotional functions (Sanders et al., 2019). In sum, research on the association between the content of ST and behavioral school adjustment is sparse but it appears that non-educational or recreational ST is related to maladaptive behavioral functions with the results regarding the role of educational ST less clear.

On the other hand, there is growing evidence that different types of content may have different associations with relationships with peers or teachers. For example, more engagement in recreational or non-educational ST is likely to be related to more problems or poorer quality in social relationships. One study with preschoolers from low-SES families found that watching age-inappropriate or non-educational content was related to lower social skills and more problematic behaviors in school (e.g., aggression, hyperactivity), which may interfere with positive social relationships (Conners-Burrow et al., 2011). Another study found a negative relation between recreational ST at age 4 and peer attachment at age 10 (Park et al., 2019). The authors suggested that children who spent more time on recreational ST might have less time to spend with peers, which could lead to lower attachment to peers. On the other hand, educational ST tends to have opposite patterns. A meta-analysis demonstrated that educational TV programs portraying prosocial content had positive associations with altruism or positive interactions with others because children possibly learned prosocial skills from observation (Mares & Woodard, 2005).

Studies using a latent variable or composite score of school adjustment including both behavioral and social adjustment dimensions have documented similar findings. One study with children ages 8 to 12 years old investigated the associations between leisure ST (i.e., TV or video viewing, playing games, playing on a smart device) and some indicators of physical, psychological, and social well-being (Belton et al., 2021). The results showed that children with higher levels of leisure ST (more than 2 hours) were likely to have lower levels of peer acceptance and poorer school well-being (i.e., perception of their cognitive abilities, learning, attention, and feelings about school) compared to those with lower levels of leisure ST. Similarly, a study with fifth graders in South Korea investigated how children used their mobile phones and how it was related to school adjustment measured by several different factors including academic performance, rule compliance, and relationships with peers and teachers (Sung, 2013). This study found that using phones to communicate with others (e.g., talking or texting with family members and friends) or to take pictures was related to better adjustment, whereas gaming on the phone was associated with poorer adjustment. These studies did not include ST for learning, focusing only on recreational and communication ST. Nevertheless, the results suggested that ST content may be important to consider when studying the relations between ST and school adjustment.

One study included both recreational and educational ST along with various dimensions of school adjustment, albeit with older participants ages between 13 and 17 years old. Jang and Kim (2008) examined how computer use was related to social relationships and school adjustment in adolescence and if these relations differed by how adolescents used computers (i.e., communicating, information-seeking, and entertaining). The results showed that the total duration of computer use was negatively related to overall school adjustment. However, when examining the relations between the content of computer use and school adjustment, the authors found some unique associations. Although using computers for communication had no significant relation with school adjustment, using computers for information-seeking and entertainment was associated with school adjustment significantly, but in opposite directions. More frequent engagement in information-seeking use was related to better school adjustment, whereas more frequent engagement in entertainment use was associated with poorer school adjustment. This research also demonstrated negative relations between the amount of computer use and students' attachment to parents, peers, and teachers. However, the specific relations differed by the content of computer use. Computer use for communication was related to high attachment to parents, peers, and teachers. However, using computers for entertainment was negatively associated with attachment to teachers, but had no significant relations with attachment to parents and peers.

In sum, research has suggested the content of ST matters in explaining the associations between ST and school adjustment. Overall, recreational ST tends to be negatively related to children's behavioral and social adjustment in school settings, but the associations between educational ST and school adjustment are inconsistent and need further examination. In particular, further exploration regarding the longitudinal relations between the content of ST and school adjustment is needed given the lack of longitudinal investigations.

Taken together, the findings regarding the relations between ST duration and school adjustment are generally consistent (i.e., longer duration related to poorer adjustment) but only partially explain the roles of ST because most studies have neglected the content of ST. Although several scholars have pointed out the necessity of research considering various aspects of ST (Kostyrka-Allchorne et al., 2017; Sharif et al., 2010; Shin, 2004), there has been little empirical research on this topic and the results are less clear. In particular, the prospective consequences of different types of ST content are not well understood. Thus, the current study took into account the long-term contributions of both the duration and content of ST to school adjustment in school-aged children.

Executive Function

The current study extends the literature by proposing EF as a possible mechanism explaining the relations between ST and school adjustment. Lezak (1982) defined EF as "mental capacities necessary for formulating goals, planning how to achieve them, and carrying out the plans effectively (p. 281)". Since its first use in the 1980s, researchers have developed numerous definitions of EF based on their research focus and interests, making EF a complex concept that is difficult to define (see Baggetta & Alexander, 2016 for a review). However, most researchers agree that EF consists of several distinct but interrelated components or processes, and some even use the plural term *executive functions* to emphasize that EF is a collection of different skills (Diamond, 2013). In the current study, I have incorporated several definitions that are most widely used (e.g., Carlson et al., 2013; Miyake et al., 2000) and defined EF as an umbrella term referring to a set of separate but related goal-directed skills of managing, controlling, and directing cognitive, emotional, and behavioral functions, particularly in novel and complex situations (Gioia et al., 2000; Zelazo et al., 2016).

The current study used a latent factor of EF consisting of several different components, supporting the perspective that EF is made up of separate but related components. Specifically, the current study included four different sub-domains: behavioral control, emotional control, planning, and attention. Behavioral control is the ability to deliberately control dominant or automatic behaviors to respond more appropriately to the situation (Diamond, 2013). Emotional control is the ability to manage and control emotional responses (Gioia et al., 2000). Planning and attention are considered more advanced EF skills because they require complex cognitive processes that need multiple EF skills such as inhibitory control, working memory, and cognitive flexibility (Garon et al., 2008). Planning is the capacity to identify and arrange the steps and components needed to accomplish a goal (Lezak et al., 2004). Attention refers to the ability to concentrate on a given task and ignore other irrelevant stimuli (Garon et al., 2008).

Relations Between Screen Time and Executive Function

The development of EF depends on neural circuits in the prefrontal cortex, which is highly interconnected with other areas of the brain and responsible for coordinating activities (Zelazo et al., 2016). The prefrontal cortex develops for a prolonged period and neural circuits related to EF are highly plastic and malleable during development, which makes EF vulnerable to environmental influences (Bernier et al., 2012; Huttenlocher, 2002; Zelazo et al., 2016). Considering that ST is one of the most common and dominant environmental features nowadays, it can play an important role in the development of brain areas relevant to EF. For instance, excessive exposure to ST is known to affect brain development by causing chronic sensory stimulation (Neophytou et al., 2021) and decreases in white matter integrity and functional connectivity between brain regions (Horowitz-Kraus & Hutton, 2018; Hutton et al., 2020).

Although no studies have examined how different types of ST content contribute to brain development, a study about the relations between reading time and brain development (Horowitz-Kraus & Hutton, 2018) may provide hypothetical support for different associations between ST and EF by content. According to this study, reading time could encourage the practice of visualizing incoming information, which increases functional connectivity between several different brain regions responsible for visual processing, language, cognitive control, and EF. Indeed, ST activities were found to be related to brain structural patterns regarding greater maturation in the visual system (Paulus et al., 2019). If ST content can increase functional connectivity between brain areas relevant to the visual system and cognitive competence including EF, it may foster the development of EF. Compared to recreational ST, educational ST appears to be more likely to assist children in deliberately visualizing the information on a screen because it requires more active focus and attention in order to effectively process incoming information.

There is growing empirical evidence that the duration of ST is negatively associated with EF although most studies have focused on TV viewing. For example, a systematic review of the relations between TV exposure and children's cognition and behaviors concluded that the duration of TV exposure is negatively related to EF or other related features such as attention (Kostyrka-Allchorne et al., 2017). The findings were consistent regardless of how EF was measured. For example, Nathanson et al. (2014) used four performance-based measures of EF with preschoolers and found that cumulative TV viewing was related to poorer EF. Other studies using parent-report measures such as the NEPSY-II (A Developmental Neuropsychological Assessment, Second; Korkman et al., 2007) and the BRIEF-P (the Behavior Rating Inventory of Executive Functioning – Preschool Version; Gioia et al., 2003) had similar findings that more hours of TV viewing had significant relations with poorer EF concurrently in 5- to 12-year-old children (Rosenqvist et al., 2016) and longitudinally from 1 years old to 4 years old (Barr et al., 2010).

Research including computers or smart devices is rare but has yielded similar results. For instance, a longitudinal study showed that ST measured by TV or DVD, computers, and touch-screen devices at 2 years old was related to poorer EF at 3 years old (McHarg et al., 2020). However, this study used a composite ST combining hours of ST in a traditional way (i.e., video viewing) and ST on more contemporary devices (i.e., computers and touch-screen devices). Studies with a primary focus on contemporary media devices have yielded similar findings. For instance, a study found that preschoolers ages between 3 and 5 years old with a higher level of mobile application use and gameplay using tablets, computers, consoles, or other devices (more than 30 minutes per day) had lower inhibition measured by a performance-based task compared to those with a lower level of mobile application use and gameplay (McNeill et al., 2019). Li et al. (2021) investigated the relations between preschoolers' tablet use and EF using both performance-based measures of EF and brain imaging. Both behavioral findings and brain imaging supported negative relations between tablet use and EF in children ages between 4 and 6 years old. In the EF tasks, non-users significantly outperformed heavy users. In addition, non-users showed healthy activation patterns in the prefrontal cortex whereas heavy users showed patterns that need further exploration. Thus, research with newer types of ST has demonstrated excessive ST may be related to decreases in EF, similar to the findings from studies with traditional ST.

Despite the extensive body of empirical evidence linking high ST duration to poorer ST, inconsistent findings exist (e.g., Blankson et al., 2015; Foster & Watkins, 2010; Jusienė et al., 2020; Kim & Shin, 2019; Stevens & Mulsow, 2006). For instance, one study examined the different relations between ST and EF by including separate ST variables of TV, computers, smartphones, and tablets but found no significant relations from any type of ST to EF in preschoolers with a mean age of 58 months (Jusienė et al., 2020). A study with South Korean preschoolers ages 5 to 6 years old also found that the duration of ST was not significantly related to self-regulation, inhibition, or attention skills (Kim & Shin, 2019). Moreover, a longitudinal study showed that children's TV viewing at 3 to 4 years old did not significantly predict EF at 5 years old (Blankson et al., 2015). Researchers explained their null findings with some possible reasons including low variability in EF among children (Kim & Shin, 2019) and the effects of third factors such as socioeconomic status (SES; Foster & Watkins, 2010; Stevens & Mulsow, 2006) and home environments (Blankson et al., 2015).

One study with 3- to 12-year-old children showed a contradictory finding that higher levels of ST were associated with better EF (Yang et al., 2017), which could imply the potential role of ST content as a possible third factor. When they examined the relations between different types of ST and EF, child-directed educational TV programs and classical cartoons were related to better EF but adult-directed TV programs and other kinds of programs (e.g., action cartoons and comedies) were not significantly related to EF. In this study, children were more likely to watch educational TV programs and classical cartoons than adult programs, which might make higher levels of ST related to better EF. These findings suggested that if educational ST and recreational ST have different relations with EF, combining all ST hours into one variable could obscure the effects of different types of content and lead to inconsistent findings.

Additional studies have reported that different types of ST content had different relations with EF although specific results were mixed. For instance, Nathanson et al. (2014) found that the total duration of ST was typically associated with poorer EF in preschoolers but watching high-quality educational programs (e.g., PBS) was related to better EF. Children's entertainment program viewing, on the other hand, had no significant relations with EF. Interestingly, the authors found that educational cartoon viewing was associated with poorer EF. They explained that it might be an animated and stimulating format of cartoons that could prevent children from effectively processing incoming information.

Several experimental studies offer additional support for exploring the association between ST content and EF. For example, Lillard and Peterson (2011) had 4-year-old children watch either an entertainment show or an educational show for 9 minutes with a control group assigned to draw for 9 minutes. After watching the show or drawing, the participants completed a series of EF tasks. The findings showed that children who watched the entertainment show performed significantly worse than the control group on the EF tasks; no difference was found in comparison to the children who watched the educational show. Additionally, Huber et al. (2018) demonstrated the positive role of educational ST by showing that children ages 2 to 3 years old who played an educational app had better performance on a battery of EF tasks in comparison to children who watched a cartoon.

In sum, the findings regarding the duration of ST are relatively consistent as higher ST was related to poorer EF despite some exceptions, which indicates the potential importance of ST content. However, research about the role of the content of ST is scarce and the results are mixed. Furthermore, the previous studies have mostly focused on early childhood leaving middle childhood relatively unexplored despite the fact that children's EF continues to develop and ST consumption is likely to change (Best et al., 2009; Linebarger et al., 2014), highlighting the need to examine the relations between multiple ST aspects and EF in school-aged children.

Relations Between Executive Function and School Adjustment

Accumulating empirical evidence has identified positive concurrent and prospective relations between EF and indicators of school adjustment such as school engagement, learning-related behaviors, relationships with peers and teachers, and relevant social skills. First, better EF skills were associated with better school engagement or learning-related behaviors, concurrently (Brock et al., 2009; Sasser et al., 2015) and longitudinally (Anthony & Ogg, 2020; Nelson et al., 2017; Neuenschwander et al., 2012). The positive relation between EF and learning-related behaviors was significant even after accounting for the level of general cognitive ability in first graders (Brock et al., 2009) and verbal IQ in the pre-kindergarten year (Sasser et al., 2015).

Longitudinal research has demonstrated similar results. The research of Anthony and Ogg (2020) found short-term longitudinal relations between higher EF in the fall of kindergarten and better learning-related behaviors in the spring of kindergarten. Longitudinal studies with an extended term have found similar results. For instance, EF at 5 years old was significantly related to better classroom learning engagement in first grade (Nelson et al., 2017). Specifically, better EF was associated with more focused engagement and fewer inappropriate responses. Similarly, Neuenschwander et al. (2012) found a unique contribution of EF at 7 years old to learning-related behaviors one year later.

In addition, studies have found significant relations between lower EF and behavioral difficulties in school. For instance, poorer EF at 3 to 4 years old was significantly related to more problem behaviors (Hughes & Ensor, 2008), and low gains in EF during the transition to formal school were associated with more problems in teacher-rated externalizing and internalizing behaviors (Hughes & Ensor, 2011). A study in South Korea with 9-year-olds also showed that children with higher levels of EF difficulties had lower levels of school adjustment and higher levels of externalizing and internalizing problem behaviors (Cho & Ha, 2020). Thus, better EF is related to positive behaviors whereas poorer EF is associated with problematic behaviors.

Second, a large body of research has documented significant associations between EF and children's relationships with peers and teachers or related social skills. In a study that examined the relations between EF at 4 years old and the risk of bullying involvement in first or second grade, inhibition problems were related to a higher risk of bullying involvement as a bully, victim, or bully-victim (Verlinden et al., 2014). Similar patterns were found with older children. Better EF was associated with a reduced likelihood of experiencing peer problems over a long period from preschool to adolescence (Holmes et al., 2016). Specifically, the paths from better EF to lower peer problems were significant from 4.5 to 6 years old, from 4.5 to 9–10 years old, and from 9–10 to 15 years old.

Relatively few studies have addressed whether EF is associated with children's relationships with teachers. According to McKinnon et al. (2018), EF prior to school entry was a significant predictor of better teacher-child relationships. Specifically, better EF predicted higher levels of closeness and lower levels of conflict with teachers in kindergarten. Research assessing self-regulation or effortful control, which is a temperamental feature of self-regulation, has provided similar results. Low self-regulation or effortful control in kindergarten or first grade was related to more closeness and less conflict with teachers concurrently (Valiente et al., 2012) and longitudinally (Portilla et al., 2014; Rudasill, 2011).

There is also evidence that stronger EF is related to better social skills. A review article by Riggs et al. (2006) documented that deficiencies in EF were related to difficulties in social-emotional functioning such as impulsivity, distractibility, and inattention, in early childhood. On the other hand, competencies in EF were associated with adaptive functioning in social-emotional domains such as understanding of mental states, theory of mind, and delay of gratification. A study with older children observed similar results. Zorza et al. (2016) found that better EF was associated with higher levels of teacher-reported prosocial behaviors in children ages 8 to 13 years old even though no significant relations were found between EF and social nomination rated by peers.

Some studies including various indicators of school functioning at the same time have demonstrated similar results concurrently and longitudinally. For instance, Carrera et al. (2019) reported that higher levels of caregiver-reported EF were related to higher levels of teacher-report school adjustment in 5- to 9-year-old children (i.e., learning capacity, academic performance, academic motivation, and teacher-child relationships). Another study with homeless children entering kindergarten or first grade found that better EF had concurrent associations with better school adaptation such as higher levels of academic achievement, peer acceptance, and prosocial behavior, and fewer problems of impulsivity, inattention, aggression, or non-compliance (Masten et al., 2012). Similarly, South Korean children with higher levels of EF difficulties in kindergarten were more likely to be classified into a group with lower levels of school adjustment as measured by academic performance, relationships with others, and classroom engagement in first grade (Goh & Jeon, 2020).

Taken together, better EF can be associated with more positive and adaptive functioning in school in terms of behavioral and social competence whereas poorer EF appears to be related to difficulties in adjusting to school environments. Few studies have documented the relations between EF and school adjustment in middle childhood as most studies have focused on preschoolers or the transition period to elementary school. Preschool years are a sensitive period for EF development (Diamond, 2006), as such, research has primarily focused on this period. In addition, the transition to elementary school is another unique period as children experience dramatic changes in school life and significant cognitive development occurs during the so-called “5 to 7-year shift” (Sameroff & Haith, 1996). Although these periods are critical, it is also essential to recognize the importance of the relations between EF and school adjustment in middle childhood as EF continues to develop during middle childhood (Best et al., 2009). Additionally, school adjustment has unique characteristics during this period, such as more time spent in school and the growing importance of learning. Thus, conducting more studies on the relations between EF and school adjustment in middle childhood, which has received less research attention, can further the understanding of children’s EF and school adjustment.

Executive Function as a Mediator

Why is ST related to school adjustment? The most popular explanation of why ST is related to school adjustment is the time displacement hypothesis (Neuman, 1988). According to this view, ST displaces time for schoolwork, other learning activities, and interactions with others, which hinders children from developing skills for learning and adjustment. Alternatively, extensive experience with ST can make children passive learners. Thus, children who spend lots of time with ST are less likely to develop an interest in schoolwork, actively participate in classroom activities, behave well in school, or interact with others. However, some studies reported that time spent with ST does not substantively displace other cognitive or educational activities such as reading books, doing homework, and so on (e.g., Anderson et al., 2001; Mutz et al., 1993). Rather, ST displaces other functionally similar media activities like going to a movie theater or listening to the radio (Kirkorian & Anderson, 2009). Furthermore, unlike traditional ST devices, newer types of ST can encourage active learning among children (Butcher, 2014). Therefore, it is important to explore alternative mechanisms that can better explain the relations between ST and school adjustment.

Considering the limitations of the displacement hypothesis, the current study proposed EF as an alternative mechanism that can better explain the sophisticated relations between ST and school adjustment. Indeed, Pagani et al. (2013) suggested more carefully and systematically exploring the role of EF as a mediator because excessive ST in early years could negatively impact later school success by undermining EF, which manages and regulates task orientation, productivity, autonomy, cooperation with peers, and observance of rules and instructions in a classroom. Thus, the exploration of EF as a possible mechanism may offer a promising direction for future research and interventions aimed at mitigating the negative effects of ST and encouraging positive effects on school adjustment.

The overarching view that ST is related to children's school adjustments through EF is based on the developmental cascades model (Masten & Cicchetti, 2010) and the iterative reprocessing model (IRM)(Cunningham & Zelazo, 2007; Zelazo, 2015). According to the developmental cascades model, development occurs through cumulative consequences of multiple interactions and transactions across different levels, systems, domains, or generations (Masten & Cicchetti, 2010). Therefore, competence in one domain can serve as a foundation for the development of competence in other related domains. On the other hand, incompetence in one domain may prevent children from developing skills in other domains. In this study, the cascading interplay from the contextual level (i.e., ST) to the individual level (i.e., EF difficulties) may spill over into children's adaptive functions in school settings. For instance, proper use of ST, which may include limited hours and more education-focused content, can benefit EF. In turn, EF may scaffold successful learning and promote productive school experiences by helping children stay focused, control their behaviors, and follow rules (Zelazo et al., 2016). On the contrary, improper use of ST, such as excessive ST, may be negatively related to EF, which can interfere with children's adjustment to school settings because EF difficulties make it difficult for children to develop necessary abilities for effective learning and adjustment such as attention skills and behavioral and emotional control.

The specific cascade paths from ST to EF to school adjustment can be better understood in relation to the IRM (Cunningham & Zelazo, 2007; Zelazo, 2015). According to this model, EF is supported by reflection, an elaborative reprocessing of information in the context of goal achieving, which mainly occurs through neural processes in hierarchically arranged brain regions in the prefrontal cortex. Reflection permits the formulation of more complex rules and representations, as manifested in the interplay between specific EF skills such as working memory, inhibitory control, and cognitive flexibility. These EF skills then can help children modulate goal-directed attention and behaviors, which lead to effective learning and adaptation. That is, children practice their EF skills in favor of their goals after reflecting upon the situation and processing incoming information. If they properly process situational information in the brain and redirect their attention and behaviors accordingly to achieve goals using EF, they can eventually perform in a positive and adaptive way. However, if they fail to elaboratively reprocess information, they cannot exert EF to accomplish their goals, which leads to ineffective learning and adjustment.

Reflection occurs when consciously and actively considering one's situation and developing ideas to achieve a goal (Zelazo, 2015). Excessive ST or recreational ST without intentional problem-solving may not lead to the processes of reflection and reconstruction of complex information, which discourages EF development. Indeed, excessive ST appears to decrease functional connectivity between brain regions related to EF and other relevant skills, which may indicate little reflection (Horowitz-Kraus & Hutton, 2018). In turn, underdeveloped EF may prevent children from developing skills for successful school adjustment such as focusing on a given task, using various strategies to achieve a goal, following rules, and controlling behaviors and emotions (Zelazo et al., 2016). On the other hand, proper use of ST such as educational ST which encourages goal-directed problem-solving may foster reflection thereby promoting EF skills. Then, EF skills can enhance children's functioning in the classroom by encouraging their motivation, engagement, and attention, thereby promoting opportunities to obtain benefits from the school context (Sasser et al., 2015).

Preliminary support for the mediating role of EF comes from recent longitudinal studies. Cerniglia et al. (2021) showed that dysregulation symptoms (i.e., anxiety, attention problems, and aggression), which have some features in common with EF, mediated the link between ST exceeding the American Academy of Pediatrics recommendation of 1 hour/day at 4 years old and mathematics grades four years later. Although useful, this study included academic achievement only as an outcome and overlooked the role of ST content. A study conducted in South Korea also found a significant indirect relation between the duration of ST at 7 years old and school adjustment at 9 years old through EF difficulties at 8 years old (Park et al., 2021). However, this study did not control for the prior levels of EF difficulties and school adjustment. Moreover, this study did not investigate unique relations by ST content either. Hence, the current study considering the longitudinal mediated relations between the duration and content of ST and various aspects of school adjustment through EF difficulties will advance the existing literature.

In summary, both theory and empirical evidence have clear implications for mediated processes from ST to school adjustment through EF. By exploring such nuanced and complex relations, this study can provide important insights for researchers, educators, and caregivers who are interested in optimizing children's behavioral, cognitive, and social development. Understanding mediated processes is important to identify the mechanism underlying the relations between ST and children's school adjustment and figure out a possible factor that could be changed to foster children's school adjustment. According to the developmental cascades model, an intervention designed to initiate changes in mediated processes may in turn change the outcomes (Maten & Cicchetti, 2010). In this manner, efforts can be made to reduce problems in domains that possibly cascade to other problems or to foster adaptive functions that can lead to improvement in other domains. For instance, interventions targeting EF can be effective in weakening the negative associations between ST and school adjustment. Caregivers and educators may guide children to properly and wisely use ST, which can enhance children's EF and in turn facilitate positive and adaptive functioning at school.

Current Study

Study Aims

The current study has three primary aims. The first and second aims are to explore the longitudinal relations of ST duration and content (i.e., educational and recreational) with EF difficulties and school adjustment. The third aim is to investigate the role of EF difficulties as a mediator linking early ST and later school adjustment. The ultimate goal of addressing these aims is to provide foundational information and knowledge to create proper and effective ST guidelines and develop intervention programs to improve EF, which has been shown to be very responsive to intervention (Diamond & Lee, 2011), and ultimately foster school adjustment.

Hypotheses

Specific hypotheses for each aim are followed.

Aim 1. To examine the longitudinal relations of ST with EF difficulties

Hypothesis 1a. The overall duration of ST will be positively related to EF difficulties.

Hypothesis 1b. The educational content of ST will be negatively related to EF difficulties.

Hypothesis 1c. The recreational content of ST will be positively related to EF difficulties.

Aim 2. To explore the longitudinal relations of ST with school adjustment

Hypothesis 2a. The overall duration of ST will be negatively related to school adjustment.

Hypothesis 2b. The educational content of ST will be positively related to school adjustment.

Hypothesis 2c. The recreational content of ST will be negatively related to school adjustment.

Aim 3. To investigate if EF difficulties serve as a mediator of the relations between ST and school adjustment

Hypothesis 3a. EF difficulties will mediate the link between the duration and content of ST and school adjustment.

CHAPTER 2

METHODS

Participants

The current study utilized data from the Panel Study on Korean Children (PSKC), which is a national longitudinal study in South Korea that follows the participants from birth. The PSKC started collecting data with newborns born from April to July 2008 and plans to track the participants for 20 years. The initial sample for the first year of data collection included 2,078 children with an additional 52 children added in the second year, followed by an additional 20 children in the third year. The final sample size was 2,150 children. Upon recruitment, the mean age of children was 5.59 months (SD = 1.22 months) and 49.3% were female. Approximately 68.8% of mothers and 71.5% of fathers had a junior college degree or higher. The monthly household income ranged from 0 to 13,000,000 Korean Won with a mean of 3,211,430 Won (SD = 1,497,082 Won; On January 16, 2023, 1 U.S. dollar = 1,241 Korean Won).

For the current study, data from Grade 3 (G3; Year 10) and Grade 4 (G4; Year 11) were used. The number of children in G3 who were retained from the initial sample was 1,484, which is approximately 69% of the original sample. In G4, 1,436 children participated in the study. The number of children who had data for at least one focal variable (i.e., ST, EF, school adjustment) in G3 was 1,242. In G3, the mean age of children was 9.39 years (SD = 0.12) and 49% were female. Approximately 72.7% of mothers and 73.2% of fathers had a junior college degree or higher. The average monthly household income was 5,418,140 Korean Won (SD = 4,831,530 Won) ranging from

900,000 to 85,000,000 Won. A more detailed description of the sociodemographic information is provided in Table 1.

Procedures and Design

Recruitment

A stratified sampling method was used by sampling 30 medical institutions from six regions that had more than 500 cases of delivery per year and then recruiting participants from these institutions. Some exclusion criteria were applied such as mothers younger than 18 years old, mothers unable to speak in Korean, mothers or newborns with severe health problems, newborns with a plan of adoption, and twins.

Data Collection

The participants of the PSKC included children, primary caregivers (mostly mothers; 97.2%), and teachers. Data were collected from June to December annually by approximately 40 trained examiners. Various methods were employed for data collection, including paper-and-pencil questionnaires, web-based questionnaires, computer- or tablet-assisted interviews, observations, performance measures, physical examinations, and so on. For the variables included in the current study, paper-and-pencil questionnaires, web-based questionnaires, and computer- or tablet-assisted interviews were used. Paper-and-pencil questionnaires were used for questions to primary caregivers. Questionnaires were sent to their homes and collected by examiners during home visits for interviews, observations, and performance measures that occurred typically two weeks after sending questionnaires. During the home visits, computer- or tablet-assisted interviews were conducted to gather more detailed information. The examiners presented each question on a laptop or a tablet screen to aid participants' understanding and to record their responses. For sensitive questions such as household income and health issues, about which the participants might feel hesitant to respond verbally, the examiners provided the option to type their answers on the computer or tablet by themselves instead of verbally reporting them to the examiner. Web-based questionnaires were utilized to evaluate child characteristics in school. Teachers were provided with a unique link and code to complete the questionnaires at their convenience.

Informed consent was obtained from primary caregivers and teachers online. The PSKC obtained annual IRB approval (G3: KICCEIRB-2017-05; G4: KICCEIRB-2018-02) and does not require additional permission for data use because the data, codebook, and questionnaires are open to the public.

Measures

Screen Time

Children's ST was reported by primary caregivers. During the home visit, primary caregivers were given a computer or tablet and asked to answer questions regarding children's ST. The duration of ST was measured by the average daily hours that children spent on smart devices (e.g., smartphones and tablets) or computers. Regarding content, the extent to which children spent time in different types of content on smart devices or computers was measured on a 4-point Likert scale (1 = Never, 4 = Every day). The types of content included in the questionnaire were gaming, entertainment (i.e., video watching and listening to music), social networking, information-seeking, and learning-related activities. These five types of content were grouped into two – recreational (i.e., gaming, entertainment, social networking) and educational (i.e., information-seeking and learning-related activities) based on the nature of each activity and the results of exploratory factor analyses. The mean score of each content category was used in the analysis.

Executive Function Difficulties

Children's EF difficulties were assessed by primary caregivers using the Executive Function Difficulty Screening Questionnaire (Song, 2014). The paper form was sent to the home before the visit so that primary caregivers could complete it beforehand.

The measure includes 40 items in four subscales (i.e., Plan/Organize, 11 items; Behavior Control, 11 items; Emotional Control, 8 items; and Attention, 10 items). Plan/Organize measures the inability to manage task demands including understanding the task, setting goals, and planning steps (e.g., find it difficult to do things that need to be done step by step in order). Behavioral Control assesses the inability to control one's behaviors appropriately (e.g., have difficulty controlling behaviors). Emotional Control contains items regarding the inability to modulate emotional responses (e.g., overreact to minor things). Attention addresses the inability to focus on a given situation (e.g., tend to forget things easily). All items were rated on a 3-point Likert scale (1 = Never, 3 = Often).

One of the items in the Behavioral Control subscale was removed because the item had low communalities at both time points (.15 in G3 and .13 in G4) and did not load with any other items (i.e., do not care much even if people around them criticize or nag them about their behaviors), resulting in a total of 10 items in the Behavioral Control subscale. The mean score of each subscale was used in the analysis. Because the items concern EF difficulties, a higher score indicates more difficulties in each domain. The internal consistency (Cronbach α) of all subscales was high across all time points (Plan/Organize: .89 and .89; Behavior Control: .84 and 86; Emotional Control: .91 and .90; Attention: .91 and .91; G3 and G4, respectively).

School Adjustment

Teachers were provided an online link and a specific code to complete the School Adjustment Inventory (Chi & Jung, 2006). The questionnaire consists of 35 items in four subscales (i.e., Adjustment to School Life, 11 items; Adjustment to Academic Performance, 11 items; Adjustment to Peers, 8 items; and Adjustment to Teachers, 5 items) on a 5-point Likert scale (1 = Strongly disagree, 5 = Strongly agree). Adjustment to School Life measures the ability to adjust to the overall school environment such as following rules and schedules, sitting still, and focusing on tasks (e.g., follow the classroom rules). Adjustment to Academic Performance contains items regarding the ability to be motivated and actively participate in class (e.g., actively participate in activities during class). Adjustment to Peers is related to the ability to create and maintain healthy peer relationships and perform prosocial behaviors (e.g., popular among peers). Adjustment to Teachers assesses the ability to form close relationships and feel comfortable with teachers (e.g., ask teachers for help when needed).

Since the original labels for the subscales appeared to be ambiguous, I used the following labels to reflect behavioral and social adjustment more clearly and make the interpretations more consistent – Classroom Behaviors, Academic Behaviors, Peer

Relationships, and Teacher Relationships instead of Adjustment to School Life, Adjustment to Academic Performance, Adjustment to Peers, and Adjustment to Teachers, respectively.

After running an exploratory factor analysis, one item from Classroom Behaviors (i.e., act younger than their age; Reverse coded) and another from Teacher Relationships (i.e., excessively fear and feel intimidated by teachers; Reverse coded), were excluded due to low communalities at both time points (.239 and .118 in G3 and .275 and .131 in G4). In addition, two of the items in the Academic Behaviors subscale more strongly loaded onto the Classroom Behaviors subscale, and the content of questions appeared to be consistent with the behaviors measured by the Classroom Behaviors subscale (i.e., do their assignments well and bring their materials prepared; have a strong sense of responsibility for the given tasks). Thus, these two items were moved to the Classroom Behaviors subscale from the Academic Behaviors subscale. As a result of this modification, the total number of items and the number of items in each subscale were slightly changed (i.e., Classroom Behaviors 12 items, Academic Behaviors 9 items, Peer Relationships 8 items, Teacher Relationships 4 items, total 33 items). The mean score of each subscale was used in the analysis. A higher score indicates better adjustment in school settings.

High internal consistency (Cronbach α) was found in all subscales across all time points (Classroom Behaviors: .96 and .97; Academic Behaviors: .94 and .93; Peer Relationships: .94 and .94; Teacher Relationships: .85 and .84; G3 and G4, respectively). The summary of measures is presented in Table 2.

Covariates

Children's age, sex, number of siblings, and SES measured by monthly household income and parents' levels of education were included as time-invariant covariates. This information was obtained from primary caregivers, and data from G3 was used in the analyses.

The average amount of extracurricular learning-related activities (i.e., private tutoring, doing homework, and reading) in hours per week reported by primary caregivers was added as a time-variant covariate. It was included as a covariate due to prior research that reported that learning-related activities were significantly related to ST, EF, and/or school adjustment (e.g., Cosden et al., 2004; Kim et al., 2021; Tomopoulous, Valdez, et al., 2007).

Plan of Analysis

Descriptive statistics, zero-order correlations, and attrition were analyzed in SPSS 27.0. Then, a series of confirmatory factor analyses (CFA) was conducted to examine if the factor structures of EF difficulties and school adjustment differed by time or other confounders. To test the relations of ST with EF difficulties and school adjustment and the mediated effects of ST variables on school adjustment through EF difficulties, a half-longitudinal mediation model was created in a structural equation modeling framework (Figure 1). Latent variables were created for EF difficulties and school adjustment each year, and observed variables were used for ST variables (i.e., overall duration, educational ST, and recreational ST). In addition, four additional models were created for each of the four subscales of school adjustment as an outcome. In these models, each school adjustment subscale was included as an observed construct. Children's age, sex, number of siblings, SES, and hours spent in extracurricular learning-related activities were added as covariates in all models. The full information maximum likelihood (FIML) was used to address missing data. CFA and the mediation model were tested in Mplus 8.8 (Muthén & Muthén, 1998-2017).

The multiple fit indices were employed to evaluate a model fit including the comparative fit index (CFI), the root mean square error of approximation (RMSEA) and its 90% CI, and the standardized root mean square residual (SRMR). Model fit is considered good when CFI is larger than or equal to .95 and RMSEA is less than or equal to .05. Model fit is acceptable when CFI is larger than or equal to .90, RMSEA is less than or equal to .08, and SRMR is less than or equal to .08 (Little, 2013). SRMR was considered for CFAs but not for the half-longitudinal mediation model because SRMR has not been well evaluated in the longitudinal model (Little, 2013). The chi-square statistic (χ^2) was not considered a proper fit index due to the large sample size in the current study considering that the chi-square is sensitive to sample size (Fan et al., 1999).

A half-longitudinal mediation model is a mediation model with two time points (Cole & Maxwell, 2003). Although it has some shortcomings compared to a longitudinal model with more time points (e.g., cannot directly test the stationarity assumption), it has certain advantages over a cross-sectional model. At least two time points enable controlling for prior levels of the mediator and outcome variables and examining the change variance. Because there is no way to directly test stationarity with two time points, the half-longitudinal mediation model assumes the relations between variables would be stable. That is, it assumes that the paths from the predictor to the mediator and from the mediator to the outcome, which are estimated at the same time, would have a time-ordered relation if more than two time points were obtained (Little, 2013).

To test mediation, I followed the steps outlined in Little (2013), which utilize the model comparison method adapted from the steps outlined in Cole and Maxwell (2003). For model comparison, a proper null model should be computed first, in which the measured variables do not covary with each other within and across time points, the variances of the same measured variables are constrained to be equal over time, and the means of the same measured variables are constrained to be equal over time. The null model provides an index of the amount of information in the data, which is represented in the calculation of CFI (Little 2013).

Before testing the relations between the variables, a series of factorial invariance tests should be performed in order to ensure that the constructs, not the measures of the constructs, change across time points. In factorial invariance testing for the measurement model, equality constraints are added to each step so that less restricted and more restricted models can be compared using the chi-square difference testing or CFI difference testing. If the chi-square difference is not significant or the CFI difference is less than or equal to .01, it is considered that imposing constraints does not significantly worsen the model fit, and the model with constraints is retained (Little, 2013). Due to the large sample size of the current study, only the CFI difference was used as an index.

First, the baseline model, which has the factor structure of each latent variable across time, is created. When the measures have the same structure over time, it is considered to have configural invariance (Step 1). Second, when the observed variable has the same relations with the latent factor over time (i.e., each corresponding loading is constrained to be equal over time) as well as configural invariance, weak invariance is established (Step 2). If a score on the latent variable is associated with the same score on the observed indicator over time (i.e., each corresponding intercept is constrained to be equal over time) along with the previous two invariances, strong invariance is achieved (Step 3). Finally, if residual variances of the corresponding indicators are the same over time added to the previous three invariances, it means strict invariance. Strict invariance is often considered overly restrictive. Therefore, strong invariance was desired in the current study.

Once establishing strong invariance by following the steps for the factorial invariance testing described above, several assumptions for longitudinal mediation are tested after adding structural parts. First, the equilibrium, or the homogeneity of the variance-covariance relations among constructs across time points is tested by comparing the strong invariance model to a reduced model in which the variances and covariances in G3 latent variables are constrained to be equal to those in G4 (Step 4). The mediation effects can still be tested even if the equilibrium assumption is violated, but the mediated effect may be confounded. Then, the mean-level stability in the latent variables (i.e., if latent factor means are equal over time) is tested by comparing the model with freely estimated factor means and the one with factor means constrained to be equal over time (Steps 5a and 5b). This test is also non-essential to test mediation but if the model secures the mean-level stability, there is stronger support for mediated effects.

The next step is to test the possibility of added components. It evaluates if there are any omitted variables by creating a saturated model and comparing it to a reduced model without covariances of the disturbances (Steps 6a and 6b). If the disturbances do not covary, it can be assumed that all relevant variables are included in the model, which is highly unlikely in social science. If the disturbances covary, the mediation can be tested but I cannot rule out the potential effects of omitted variables. Next, potential relations other than the hypothesized paths were tested by comparing a reduced model with hypothesized paths only to a saturated model, which includes other significant paths (Step 7). The final mediation model is evaluated by being compared to the saturated model to test whether the indirect effect remains when other significant paths are included (Step 8). When comparing models with structural parts added, the criterion for determining too much loss in fit is a *p*-value for a chi-square difference less than .001 or a CFI change greater than .002 (Little, 2013) but the current study used a CFI change only due to a large sample size.

The mediated effect was calculated by multiplying two coefficients, *a* (for the path from the predictor to the mediator) and *b* (for the path from the mediator to the outcome). The significance of the mediated effects was determined using the *Rmediation* package by Tofighi and Mackinnon (2011), which provides the confidence intervals using a product of coefficients method by MacKinnon et al. (2002) to address the nonnormal distribution of the product of coefficients. If the 95% CI does not include zero, the mediated effect can be considered significant.

CHAPTER 3

RESULTS

Attrition

Among a total of 2,150 from the initial sample, the number of participants who had data for at least one study variable (i.e., ST duration, educational ST, recreational ST, EF difficulties, and school adjustment) in both G3 and G4 were 1,391 (64.7%). The number of participants who had data in G3 but not in G4 was 93 (4.3%). The number of participants who had data in G4 but not in G3 was 45 (2.1%). The number of participants who had no data at both time points was 621 (28.9%); these cases were not included in the analysis.

Several analyses were conducted to assess if the attrition status of G3 or G4 compared to the initial sample was related to sociodemographic variables (i.e., child sex, SES, number of siblings, and residential areas in the initial year; Table 3). First, a dummy variable was created with 1 indicative of having data for at least one study variable in G3 and 0 indicative of having no data in G3. Chi-square tests were performed on categorical variables and *t*-tests were conducted on continuous variables. The results of chi-square tests presented that the attrition status was not related to children's sex ($\chi^2(1) = .076$, $p = .783$) and residential areas (i.e., large, medium, or small city) ($\chi^2(2) = 2.839$, $p = .242$). According to the independent *t*-test, the attrition status was not related to the number of siblings ($t(2070) = -1.511$, $p = .131$), and SES ($t(1067.758) = .890$, $p = .374$). When examining differences in sociodemographic characteristics by attrition status in G4, similar results were found. The attrition status was not associated with children's sex

($\chi^2(1) = .045$, $p = .832$), residential areas ($\chi^2(2) = 1.426$, $p = .490$), the number of siblings ($t(2070) = -1.160$, $p = .246$), and SES ($t(1194.925) = .877$, $p = .381$).

The same steps were followed to test if any sociodemographic variables were related to the attrition status of G4 compared to G3 (i.e., having data on at least one study variable in G3 but not in G4 vs. having data in both G3 and G4; Table 4). The attrition status was not related to children's sex ($\chi^2(1) = .112$, $p = .738$), residential areas ($\chi^2(2) = 1.169$, $p = .557$), the number of siblings ($t(1482) = .233$, $p = .816$), and SES ($t(1481) = -.283$, $p = .777$) according to the results of chi-square tests and *t*-tests. Additional independent *t*-tests were conducted to examine if the attrition status of G4 compared to G3 was related to any of the study variables in G3 (i.e., ST duration, educational ST, recreational ST, EF difficulties subscales, and school adjustment subscales). The results demonstrated that the attrition status was not related to the study variables ($t(631\text{-}1482) = -1.426 – .685$, $p = .154 – .946$) except for the emotional control subscale in EF difficulties ($t(1390) = 2.109$, $p < .05$).

Descriptive Statistics

Descriptive statistics are presented in Table 5. According to the values of skewness (-1.44 – 1.79) and kurtosis (-.57 – 3.49), there were no variables with serious concerns of non-normality because the values of all variables were within the acceptable range (skewness between -2 and 2, Kurtosis between -7 and 7; West et al., 1995). Children spent approximately 1.19 hours (SD = .83) and 1.51 hours (SD = .97) of ST per day in G3 and G4, respectively. The difference in ST duration and educational and recreational ST between G3 and G4 was significant (duration: $t(1365) = -12.504$, p

< .001; educational ST: *t*(1244) = -5.528, *p* < .001; recreational ST: *t*(1245) = -10.593, *p* < .001). Thus, children spent significantly more hours in ST and engaged more frequently in both educational and recreational ST in G4 than they did in G3. The levels of all the EF difficulties subscales were lower in G4 compared to G3 (*t*s(1288 or 1290) = 3.665 – 6.558, *p* < .001). However, all levels of reported school adjustment were not significantly different between G3 and G4 (*t*s(363) = -1.583 – -.457, *p*s = .114 – .648).

Zero-Order Correlations

Correlations Between Covariates and Study Variables

First, correlations between covariates and study variables were examined (Table 6). Boys were less likely to engage in educational ST (*r*(1357) = -.056, *p* < .05) in G3 and tended to have more EF difficulties across all four subscales (G3: *r*s(1390 or 1392) = .076 – .279; G4: *r*s(1358) = .076 – .246, *p*s < .01 or 001) and poorer adjustment to school in every aspect (G3: *r*s(631) = -.286 – -.098; G4: *r*s(691) = -281 – -.105, *p*s < .01 or .001) in both G3 and G4 compared to girls (i.e., Children's sex was coded 0 = female, 1 = male).

Children's age was related to only two study variables (G3 recreational ST: *r*(1335) = .058, *p* < .05; G4 Academic Behaviors: *r*(683) = -.078, *p* < .05) and therefore was not included in further analyses as a covariate.

The number of siblings was significantly correlated with some ST variables (G3 ST duration: *r*(1482) = .053, *p* < .05; G3 educational ST: *r*(1357) = -.111, *p* < .001; G3 recreational ST: *r*(1358) = .058, *p* < .05; G4 recreational ST: *r*(1341) = .082, *p* < .01). Thus, children with more siblings tended to have more ST overall and more frequent engagement in recreational ST while engaging less in educational ST compared to children with fewer siblings.

SES was significantly related to most of the variables. For instance, children from higher SES families had lower hours in ST (G3: $r(1481) = -.227$, G4: $r(1363) = -.193$, ps $< .001$) and less frequent recreational ST consumption (G3: $r(1357) = -.165$, G4: $r(1340) = -.186$, ps $<.001$) than those from lower SES families. In addition, children with higher SES tended to have fewer EF difficulties (G3: rs(1389 or 1391) = -.072 – -.059; G4: rs(1357) = -.076 – -.054, ps < .05 or .01) and better adjustment to school (G3: rs(631) = .088 – .117; G4: rs(691) = .077 – .104, ps < .05 or .01) with a few exceptions (no significant correlations with Attention and Teacher Relationships). Children from higher SES families were also likely to engage in more extracurricular activities (G3: $r(1481) = .181$, G4: $r(1387) = .216$, ps $< .001$).

Children who spent more hours in extracurricular activities tended to engage in fewer hours in ST (rs(1364 – 1384) = -.233 – -.181, ps < .001), less recreational ST (rs(1271 – 1392) = -.275 – -.218, ps < .001), and more educational ST (rs(1270 – 1385) = .103 – .182, ps <.001) than those with fewer hours in extracurricular activities. Moreover, children with more extracurricular activities tended to have fewer EF difficulties (rs(1309 – 1397) = -.178 – -.073, ps < .01 or .001) and better adjustment to school (rs(610 – 707) = .085 – .169, ps <.05, .01, or .001).

Correlations Within Study Variables

The rank-order stability of the variables over time and correlations between ST variables and between the subscales (i.e., EF difficulties and school adjustment) were examined (Tables 7 and 8). For all the variables, children with higher levels in G3 tended to have higher levels in G4 as well because all the correlations between G3 and G4 were significantly positive (*r*s(362 – 1364) = .259 – .727, *p*s < .001). ST duration and recreational ST were related to each other concurrently and longitudinally (*r*s(1250 – 1359) = .306 – .431, *p*s < .001), but educational ST was related to the other two ST variables (i.e., ST duration and recreational ST) only concurrently (*r*s(1357 – 1382) =.083 – .131, *p*s < .01 or .001). In general, children with higher consumption of overall ST tended to engage in recreational ST and educational ST more frequently than children with a lower ST duration. Children with more frequent consumption of educational ST were likely to engage in recreational ST more frequently. EF difficulties subscales were correlated with each other concurrently and longitudinally (*r*s(1287 – 1399) =.287 – .683, *p*s < .001). School adjustment subscales were significantly related to each other concurrently and longitudinally (*r*s(362 – 707) =.108 – .766, *p*s < .05, .01, or .001) except for one marginally significant relation (G3 Classroom Behavior and G4 Teacher Relationships: $r(362) = .096$, $p = .066$). Thus, children with higher scores in one subscale tended to have higher scores in the other subscales in both EF difficulties and school adjustment.

Concurrent Correlations Between Study Variables

Concurrent correlations between study variables relevant to hypothesized relations were explored (Table 7). In G3, ST duration was significantly related to some of the EF difficulties (Plan/Organize: $r(1392) = .067$, $p < .05$; Behavioral Control: $r(1392) = .069$, $p < .05$) and school adjustment subscales (Classroom Behaviors: $r(631) = -.109$, *p*

$< .01$; Academic Behaviors: $r(631) = -.108$, $p < .01$). Thus, children who spent more time engaging in ST were likely to have more difficulties in planning and behavioral control and lower levels of behavioral adjustment in school. Educational ST was associated with all of the EF difficulties subscales (rs(1272 or 1274) = -.141 – -.059, ps < .05 or .001) and one school adjustment subscale (Academic Behaviors: $r(581) = .093$, $p < .05$). More frequent engagement in educational ST was related to fewer difficulties in EF in general and better behaviors regarding academic performance. On the other hand, recreational ST had no significant correlations with the EF difficulties or school adjustment subscales except for the Plan/Organize subscale ($r(1275) = .097$, $p < .001$). EF difficulties subscales were significantly correlated with most of the school adjustment subscales except for the Teacher Relationships subscale (rs(598) = -.344 – -.095, p < .05, .01, or .001), indicating children with more EF difficulties were more likely to poorly adjust to school.

In G4, slightly different patterns were observed. ST duration had significant correlations with all of the EF difficulties subscales (rs(1373) = .055 – .141, ps < .05 or .001) and only one school adjustment subscale (Classroom Behaviors: $r(695) = -.081$, $p < .05$). Thus, children with a longer ST duration tended to have more EF difficulties and poorer behaviors in classroom engagement. Similarly, recreational ST was correlated with all of the EF difficulties subscales (rs(1349) = .055 – .092, ps < .05, .01, or .001) but none of the school adjustment subscales, indicating more involvement in recreational ST was related to more EF difficulties. Conversely, educational ST was related to only one EF difficulties subscale (Plan/Organize: $r(1350) = -.057$, $p < .05$) and most of the school adjustment subscales except for the Teacher Relationships subscale (rs(686) = .080

– .107, *p*s < .05 or .01). Children who more frequently engaged in educational ST were likely to adjust better to school environments and have fewer difficulties in planning. Lastly, correlations between EF difficulties and school adjustment presented similar patterns to those in G3, suggesting more EF difficulties were related to poorer school adjustment (*r*s(695) = -.330 – .090, *p*s < .05, .01, or .001).

Longitudinal Correlations Between Study Variables

Longitudinal correlations between study variables relevant to the hypothesized paths were investigated (Table 8). First, correlations between ST variables in G3 and EF difficulties in G4 were explored. ST duration and recreational ST in G3 were positively related to the Plan/Organize subscale in EF difficulties (*r*(1358) = .072, *p* < .01; *r*(1241) = .061, *p* < .05, respectively), but not to the other three subscales, in G4. Thus, more engagement in the overall duration of ST and recreational ST were related to more difficulties in planning one year later. Educational ST in G3 was negatively related to all of the EF difficulties subscales in G4 (*r*s(1240) = -.161 – -.076, *p*s < .01 or .001), which indicates children with more frequent engagement in educational ST had fewer EF difficulties one year later.

Second, ST variables in G3 had a few significant correlations with school adjustment subscales in G4. For instance, ST duration in G3 was negatively related to Classroom Behaviors in G4 (*r*(691) = -.083, *p* < .05). Recreational ST was negatively related to Academic Behaviors (*r*(629) = -.079, *p* < .05) whereas educational ST was positively associated with it (*r*(629) = .098, *p* < .05). Thus, more engagement in the overall ST duration and recreational ST in G3 was related to poorer classroom behaviors or academic behaviors in G4. On the other hand, more engagement in educational ST was related to better academic behaviors. Only one significant correlation was found between ST variables and Peer Relationships. Educational ST in G3 and Peer Relationships in G4 were significantly correlated ($r(629) = .081$, $p < .05$), indicating higher levels of educational ST engagement were related to better relationships with peers one year later. There were no significant correlations between any of the ST variables in G3 and Teacher Relationships in G4.

Lastly, EF difficulties subscales in G3 were generally related to school adjustment subscales in G4 except one (Teacher Relationships) in a negative direction (r(654 or 655) = -.339 – -.102, ps < .01 or .001). Thus, children with more EF difficulties tended to have poorer classroom behaviors, academic behaviors, and peer relationships one year later.

Preliminary Analyses

Cross-sectional CFAs were conducted to ensure that the factor structures of EF difficulties and school adjustment are the same across time points and to examine which indicator is the best anchor. The measurement models were tested for G3 and G4 separately (Figure 2). The fit of the G4 model was good (CFI = .959; RMSEA = .077, 90% CI [.066, .087]; SRMR = .048), but the model fit of G3 data seemed less acceptable (CFI = .937; RMSEA = .093, 90% CI [.083, .103]; SRMR = .053). Although the value of RMSEA was a bit higher than the criteria for an acceptable fit, the other two indices were acceptable. Thus, both G3 and G4 models were considered to have an acceptable fit. All the loadings had an acceptable magnitude (standardized estimates = .60 – .93; Comrey & Lee, 2013). The best anchors were Plan/Organize for EF difficulties and Peer

Relationships for school adjustment because they had the largest loading among constructs.

Second, a three-group CFA was performed in order to rule out any potential confounds by residential areas (i.e., large, medium, and small cities). Although differences by residential areas were not of theoretical interest to the current study, the infrastructure, local resources, or neighborhood may be different by the size of residential areas, which may contribute to the development of EF or school adjustment. A multilevel approach was not possible because the level-2 unit (i.e., residential areas) did not have sufficient numbers to be treated as a random effect (i.e., between 15 and 30). Instead, each area was treated as a separate group in a multi-group CFA to test whether the differences between areas were trivial enough to ignore (Little, 2013). A three-group CFA, however, did not run properly because the number of participants in the small-city group was too small (n = 47 – 82). Thus, the two-group CFA was performed after combining medium and small cities into one group (i.e., large-city group n = 586, medium-to-small-city group n = 886).

Measurement and structural invariances across residential areas were evaluated using the steps and criteria described above in the Plan of Analysis section (Steps 1 to 5; Table 9). One difference is that a criterion for too much loss in measurement invariance testing here was the change of CFI ≤ .02 because in this case I evaluated the differences across time points and groups whereas the steps described above evaluated the differences across time points only. As a result, strong invariance was obtained, which demonstrates that the measurement of the latent variables of EF difficulties and school adjustment did not differ by residential areas. Furthermore, homogeneity of variances and covariances as well as mean-level stability were achieved, which indicates that the variability and relations between the latent variables of EF difficulties and school adjustment were not different across residential areas. In sum, the differences in the measurement and structural parts by residential areas appeared to be small enough to ignore, and therefore residential areas were not included in further analysis.

Invariance Testing

In measurement invariance testing, the strong invariance of the measurement was established. Thus, loadings and intercepts of the measured EF difficulties and school adjustment variables were considered to be equal over time. However, equilibrium and mean-level stability were not achieved as the CFI change was larger than .002 between a full model and a reduced model. Moreover, I was not able to rule out the possible effects of omitted variables because the CFI change from a saturated model, which includes all possible lags and covariances, to a reduced model without covariances among disturbances was larger than .002. After testing potential relations other than the hypothesized paths by comparing a reduced model with hypothesized paths only to a full model with other significant paths, five additional significant paths were added to the hypothesized model when creating the final model (G3 recreational ST → G4 ST duration, G3 ST duration and educational ST → G4 recreational ST, G3 EF difficulties and recreational ST → G4 extracurricular activities). The final model fit the data well (CFI = .958; RMSEA .038, 90% CI [.035, .041]). The steps and results of testing measurement and structure invariance and creating the final model were summarized in Table 10.

Half-Longitudinal Mediation Model

The results of the final model are displayed in Figure 3. The estimates reported in the descriptions below are standardized estimates where applicable (In Mplus, STDY Standardization Results for estimates related to the sex variable and STDYX Standardization Results for everything else).

First, the autoregressive paths from G3 to G4 were significant for all time-variant variables, which include ST duration, educational ST, recreational ST, EF difficulties, school adjustment, and extracurricular activities (.249 – .767, *p*s < .001). Thus, the rank-order stability within each variable was obtained (e.g., Children spending more hours in ST than others in G3 were more likely to engage in ST for longer hours in G4 than others in G4 as well).

Second, covariances among disturbances were examined. In both G3 and G4, covariances among disturbances of ST duration, educational ST, and recreational ST were all significant (.116 – .423, *p*s < .001). Therefore, children with higher levels of ST duration tended to have more frequent engagement in educational and recreational ST. The levels of engagement in educational and recreational ST were significantly correlated with each other. The disturbance of EF difficulties significantly covaried with the disturbances of educational ST (-.139, $p < .001$) and recreational ST (.081, $p < .01$) in G3, indicating children with more EF difficulties tended to have less engagement in educational ST and more engagement in recreational ST. In G4, the disturbances of EF difficulties covaried with the disturbances of ST duration (.129, p < <.001) and recreational ST (.116, $p < .001$), which means children with more EF difficulties were likely to experience longer ST duration and more recreational ST. Finally, the disturbances of school adjustment covaried with the disturbances of ST duration (-.088, $p < .05$), educational ST (.083, $p < .05$), and EF difficulties (-.266, $p < .001$) in G3 and recreational ST in G4 (.097, $p < .05$). Therefore, children with better school adjustment tended to exhibit lower levels of ST duration and EF difficulties while having higher levels of educational and recreational ST.

Aim 1. Longitudinal Relations of Screen Time with Executive Function Difficulties

Among the cross-lagged paths from early ST variables (i.e., ST duration, educational ST, and recreational ST) to later EF difficulties, only the path from early educational ST to later EF difficulties was significant. Controlling for ST duration, recreational ST, EF difficulties, and covariates in G3, educational ST in G3 negatively predicted EF difficulties in G4 (-.074, $p < .001$). Thus, children with more frequent engagement in educational ST in G3 were likely to have fewer EF difficulties one year later. On the other hand, ST duration and recreational ST were not uniquely related to later EF difficulties.

Aim 2. Longitudinal Relations of Screen Time with School Adjustment

None of the ST variables in G3 was significantly associated with school adjustment one year later. Thus, there was no direct effect of the duration or content of ST on school adjustment.

Aim 3. Mediated Relations Between Screen Time and School Adjustment Through Executive Function Difficulties

First, the path from EF difficulties in G3 to school adjustment in G4 was estimated. EF difficulties in G3 negatively predicted subsequent school adjustment holding constant the effects of early school adjustment, ST variables, and covariates (-.164, $p < .001$). Therefore, children with more EF difficulties in G3 were more likely to show poorer school adjustment one year later.

A mediated relation from early educational ST to later school adjustment through EF difficulties was tested using the estimates of the path from educational ST in G3 to EF difficulties in G4 (*a* path: -.074, SE = .020) and the path from EF difficulties in G3 to school adjustment in G4 (*b* path: -.164, SE = .046). The mediated estimate was .012 and the confidence interval did not include zero (SE = .005, 95% CI [.004, .023]). Thus, EF difficulties significantly mediated the relation between early educational ST and later school adjustment. More frequent engagement in educational ST was related to fewer difficulties in EF one year later, which in turn could lead to better adjustment to school. The effect size regarding the proportion mediated was calculated by dividing the mediated estimate by the total effect, which is the sum of the mediated estimate and the direct effect from the predictor to the outcome (MacKinnon, 2012). The mediated effect explained 21.05% of the total effect of educational ST on school adjustment.

The mediated effects from early ST duration or recreational ST to school adjustment through EF difficulties were not significant because the cross-lagged path from early ST duration or recreational ST to later EF difficulties was not significant.

The model explained a significant proportion of variance in ST duration (G3: R^2 = .055, G4: R^2 = .218, *p*s < .001), educational ST (G3: R^2 = .016, $p < .05$, G4: R^2 = .095, $p < .001$), recreational ST (G3: R^2 = .038, G4: R^2 = .305, *p*s < .001), EF difficulties (G3: R^2 = .079, G4: R^2 = .622, *p*s < .001) and school adjustment (G3: R^2 = .075, G4: R^2 = .154, *p*s < .001) at both time points except for educational ST in G3 (R^2 = .004, p = .229).

Paths from Covariates

Children's sex, the number of siblings, and SES in G3 were included as time-invariant covariates, and hours in extracurricular learning-related activities in both G3 and G4 were added as time-variant covariates (Table 11).

Children's Sex. Children's sex was significantly related to ST duration (.050, $p < .05$), educational ST (-.060, $p < .05$), and recreational ST (-.057, $p < .05$) in G3, EF difficulties in G3 (.267, $p < .001$), school adjustment in both G3 (-.238, $p < .001$) and G4 (-.102, $p < .01$), and extracurricular learning-related activities in G3 (-.068, $p < .05$). Boys had a higher number of overall ST hours, engaged less in both educational and recreational ST, had more EF difficulties, presented poorer school adjustment, and participated less in extracurricular activities compared to girls.

Number of Siblings. The number of siblings was significantly associated with educational ST (-.108, $p < .001$) and extracurricular activities (-.138, $p < .001$) in G3. Thus, children with more siblings tended to engage in educational ST and extracurricular learning-related activities less frequently than those with fewer numbers of siblings.

SES. SES was significantly related to the duration of ST (G3: -.224, $p < .001$; G4: -.082, $p < .01$), recreational ST (G3: -.176, $p < .001$; G4: -.065, $p < .01$), and extracurricular activities (G3: .171, G4: .105, *p*s < .001) at both time points and EF difficulties (-.080, $p < .01$) and school adjustment (.130, $p < .01$) in G3 only. Children from higher SES families spent fewer hours in total ST and recreational ST and spent more time in extracurricular activities than children from lower SES families. They also had fewer EF difficulties and better adjustment to school than children from lower SES families.

Extracurricular Learning-Related Activities. The covariances of the disturbances of extracurricular activities with those of ST duration (G3: -.137, G4: -.103, *p*s < .001), educational ST (G3: .164, G4: .108, *p*s < .001), recreational ST (G3: -.222, G4: -.129, *p*s < .001), EF difficulties (G3: -.150, $p < .001$; G4: -.095, $p < .01$), and school adjustment (G3: .142, $p < .01$) were significant at both time points except for the relation with school adjustment in G4 (.062, $p = .131$). Thus, children who engaged in more hours of extracurricular learning-related activities spent fewer hours in total ST, engaged less in recreational ST, and engaged more in educational ST than those with fewer hours of extracurricular learning-related activities. Additionally, they had fewer difficulties in EF and better adjustment to school. Some significant longitudinal relations were also found between extracurricular activities in G3 and the duration of ST (-.080, $p < .01$) and recreational ST (-.055, $p < .05$) in G4. Children who spent more hours in extracurricular activities in G3 were less likely to engage in ST in general and ST with recreational content one year later. Recreational ST (-.94, $p < .001$) and EF difficulties (-.053, $p < .05$)

in G3 were significantly related to extracurricular activities in G4, indicating children with more frequent engagement in recreational ST and higher levels of EF difficulties tended to spend fewer hours in extracurricular activities one year later. There were no other significant longitudinal relations.

Models with Observed Variables of School Adjustment

Due to some heterogenous correlations between EF or ST variables and school adjustment subscales, four additional mediation analyses were conducted for each school adjustment subscale as an outcome for exploratory purposes (Tables 12 to 15). I followed the same steps described above with the same covariates included. Each school adjustment subscale was included as an observed variable.

The first analysis included Classroom Behaviors as an outcome variable (Figure 4). The final model fit the data well (CFI = .983; RMSEA .031, 90% CI [.027, .036]; Table 12). The results were similar to those from the model with the latent variable of school adjustment. Among *a* paths, which are the paths from G3 ST predictors (i.e., ST duration, educational ST, and recreational ST) to G4 EF difficulties, only the path from educational ST to EF difficulties was significant, controlling for the covariates, ST duration, recreational ST, and the previous level of EF difficulties (-.072, SE = .020). Thus, more frequent engagement in educational ST was related to fewer EF difficulties one year later. The *b* path from EF difficulties in G3 to Classroom Behaviors in G4 was significant such that more EF difficulties were related to subsequent poorer classroom behaviors (-.212, SE = .042). The mediated effect from educational ST to EF difficulties to Classroom Behaviors was significant (.015, SE = .005, 95% CI [.006, .027]). The mediated effect explained 75% of the total effect of educational ST on Classroom Behaviors. The other two ST variables (i.e., ST duration and recreational ST) in G3 were not significantly related to EF difficulties in G4. Therefore, the mediated effects for these two variables were not significant.

The second and third models included Academic Behaviors and Peer Relationships as an outcome respectively, and yielded similar results (Figures 5 and 6). The final models fit the data well (Academic Behaviors: CFI = .984; RMSEA .030, 90% CI [.025, .034], Table 13; Peer Relationships: CFI = .981; RMSEA .030, 90% CI [.026, .035], Table 14) and only educational ST in G3 was related to EF difficulties in G4. Educational ST had a significant mediated effect on Academic Behaviors and Peer Relationships through EF difficulties (Academic Behaviors: .009, SE = .004, 95% CI [.002, .018]; Peer Relationships: .010, SE = .004, 95% CI [.003, .019]). The mediated effect explained 16.67% of the total effect of educational ST on Academic Behaviors and 22.73% of the total effect of educational ST on Peer Relationships.

The fourth analysis included Teacher Relationships as an outcome variable. The model fit was good (CFI = .984; RMSEA .029, 90% CI [.024, .034], Table 15). The mediated effect was not significant (.002, SE = .003, 90% CI [-.004, .009]) because the *b* path from EF difficulties in G3 to Teacher Relationships in G4 was not significant (-.031, SE = .043, $p = .480$; Figure 7). The mediated relations from all models are summarized in Table 16.

The models with observed constructs of each school adjustment subscale demonstrated similar patterns in terms of the relations between covariates and study variables as in the model with a latent variable of school adjustment (Tables 17 – 20). However, a few exceptions were found. For instance, children's sex was related to Academic Behaviors only in G3 (-.147, $p < .001$; G4: -.047, $p = .220$), and SES was not related to Teacher Relationships at both time points. Finally, the disturbance of extracurricular learning-related activities covaried with the disturbances of Classroom Behaviors (.103, $p < .01$) and Academic Behaviors (.078, $p < .05$) in G4.

These four models also explained a significant proportion of variance in ST duration (G3: $R^2 = .055$, G4: $R^2 = .218$, *p*s < .001), educational ST (G3: $R^2 = .016$, $p < .05$, G4: $R^2 = .094 – .098$, $p < .001$), recreational ST (G3: $R^2 = .037$ or .038, G4: $R^2 = .302 – .305$, *p*s < .001), EF difficulties (G3: $R^2 = .077$ or .078, G4: $R^2 = .622 – .625$, *p*s < .001) and school adjustment subscales (G3: $R^2 = .041 – .103$, G4: $R^2 = .089 – .238$, *p*s < .01 or .001). The proportion of variance explained for Teacher Relationships in G3 was not significant ($R^2 = .017$, $p = .101$).

CHAPTER 4

DISCUSSION

Researchers, parents, educators, and policymakers have increasingly directed their attention toward the role of ST in child development given its pervasive presence in children's everyday lives. Although much of the existing literature has predominantly focused on the potential risks associated with excessive ST, it is essential to recognize that ST can function in a variety of ways depending on other factors such as content (Kostyrka-Allchorne et al., 2017). In light of this, the current study explored the longitudinal mediated relations of early ST including its duration and content with later school adjustment through EF difficulties in school-aged children by employing longitudinal data derived from the Panel Study on Korean Children.

The first aim of the current study was to scrutinize if and how ST duration and content are related to EF difficulties. It was hypothesized that more hours in overall ST duration and increased involvement in recreational ST would be related to more EF difficulties. On the other hand, more frequent engagement in educational ST was hypothesized to be associated with fewer EF difficulties. The second aim was to investigate the associations of ST duration and content with school adjustment. More hours in overall ST duration and increased involvement in recreational ST were expected to be related to poorer school adjustment. On the contrary, increased involvement in educational ST would be linked to better school adjustment. The third aim was to explore whether EF difficulties mediate the association between early ST and later school adjustment. The hypothesis posited that the heightened overall ST duration and involvement in recreational ST would be related to more difficulties in EF, which in turn would be associated with poorer school adjustment. In contrast, higher levels of educational ST were expected to be linked to fewer difficulties in EF, contributing to better school adjustment.

I summarized and discussed the following results below: (a) the relations of ST duration and content with EF difficulties, (b) the relations of ST duration and content with school adjustment, (c) the mediated relations of ST duration and content with school adjustment through EF difficulties, and (d) the relations between covariates and study variables.

Relations Between Screen Time and Executive Function Difficulties

The hypotheses concerning the associations between ST variables (i.e., duration and content) and EF difficulties were partly supported. First, the overall duration of ST was not significantly related to EF difficulties. This result is inconsistent with previous findings indicating a link between extended ST duration and more EF difficulties, or conversely, shorter ST duration associated with better EF performances (Kostyrka-Allchorne et al., 2017; Li et al., 2021; McHarg et al., 2020). However, previous findings should be interpreted with caution because many studies focused on younger children. Some researchers have posited that the relation between increased ST duration and poorer EF in young children may be attributed to their limited symbolic awareness (Anderson & Pempek, 2005). Due to a lack of cognitive skills, they may not be able to acquire a comprehensive understanding of the two-dimensional nature of screen content but reactively attend to it, which can prevent them from effectively processing information on screen. Some have even argued that learning from media may not be effective in early childhood for these reasons even if the content is educational (Radesky & Christakis, 2016). With age, however, children become more deliberate in how they process information instead of impulsively responding to ST without goal-directed thought as they acquire advanced cognitive capacities and accumulate experiences with various forms of ST (Kirkorian et al., 2012). Therefore, excessive ST may be less likely to be negatively related to EF development in middle childhood compared to early childhood.

Alternatively, inconsistent findings may underscore the role of diverse ST content as demonstrated in Yang et al. (2017). Given that different types of ST content may contribute differently to EF development, aggregating hours across different ST activities may inadequately capture each activity's unique role, resulting in non-significant associations between ST duration and EF. Supporting this explanation, the current findings demonstrated that recreational ST and educational ST had different relations with EF difficulties. Specifically, recreational ST had no significant relation with EF difficulties, contrary to the hypothesis, whereas educational ST had a significant negative association with EF difficulties, supporting the hypothesis.

Some previous studies including both recreational and educational ST have shown that recreational ST was related to poorer EF performance (Huber et al., 2018; Lillard & Peterson, 2011) with a few exceptions demonstrating non-significant relations (Nathanson et al., 2014). The inconsistent outcome of the current study may be related to the broader definitions of recreational ST. Whereas previous studies focused solely on recreational video viewing (e.g., cartoons, entertainment shows), the current study encompassed gaming, entertainment (e.g., video viewing and listening to music), and social networking within the recreational ST category. Although these activities loaded onto a single factor in exploratory factor analysis, each may have distinct relations with EF difficulties. For example, studies have posited that interactive or cognitively demanding games require skills that can enhance cognitive abilities including EF (e.g., attention switching, object tracking, perspective taking, and memorizing rules) (Chaarani et al., 2022; Gashaj et al., 2021; Yang et al., 2020). However, the current study did not differentiate gaming types due to the lack of relevant data. Like many ST activities, gaming is not a single concept but includes multiple types or forms, which can have different associations with cognitive competence including EF (Bavelier et al., 2011). Thus, future investigations are needed to understand the link between different types of recreational ST and EF considering other factors such as interactivity or cognitive demands.

In addition, developmental changes might also explain the non-significant relation between recreational ST and EF difficulties. Older children may possess enhanced analytical skills which may enable them to assess ST content more comprehensively even if it is recreational and refrain from any risks associated with recreational ST. For instance, Zimmerman and Christakis (2007) raised possible age differences in the association between early entertainment TV viewing and later attentional problems. According to this study, viewing entertainment TV programs before age 3 was significantly associated with attentional problems 5 years later but viewing any type of content at ages 4 and 5 was not related to later attentional problems. Although this research included children younger than the current participants, it suggests potential age-related variations in the link between ST and EF difficulties. Thus, the recreational content of ST may become less influential as children age because they become behaviorally and cognitively more mature, which enables them to more selectively interact with environmental factors.

On the other hand, more frequent engagement in educational ST exhibited significant associations with fewer EF difficulties, aligning with previous findings (Huber et al., 2018; Linebarger et al., 2014; Nathanson et al., 2014). Past studies proposed some possible explanations for the positive role of educational ST. Educational videos, characterized by slower pacing, provide children with additional time for deliberate and active information processing, which may support EF development (Lillard & Peterson, 2011). In addition, reduced fantastical content in educational videos contributes to more effective cognitive processing because children may find it challenging to digest and interpret fantastical content which includes physically impossible situations (Lillard et al., 2015).

Although useful, these explanations may not entirely align with the current findings, as educational ST in the current study included a broader spectrum beyond educational videos, including information-seeking and learning activities. For instance, educational ST in the current study involved activities such as searching for information on websites, watching educational programs, or participating in online courses, which demand intentional engagement and active attention. Therefore, the positive role of educational ST observed in the current study may be attributed to the deliberate and intentional nature of children's involvement in educational ST. When children engage in ST, they make judgments about the mental effort required to assess and interpret on-screen information and increased mental effort is likely to enhance information processing (Salomon, 1983). Compared to recreational ST, educational ST in the current study is more likely to necessitate goal-directed attention and intentional behaviors, engaging children in using more mental efforts, actively reprocessing information, and coordinating various prefrontal cortex regions. These processes contribute to the active utilization of different EF skills, fostering positive EF development (Zelazo, 2020). Thus, educational ST may help children practice the skills needed for better EF, resulting in a decrease in EF difficulties.

Relations Between Screen Time and School Adjustment

Inconsistent with previous research, neither the duration nor content of ST showed significant relations with school adjustment in the current study. Extensive research has consistently reported negative associations between ST duration and adaptive school adjustment indicators, including classroom engagement, learning-related activities, peer relationships, and social skills (e.g., Jeong et al., 2020; Pagani et al., 2010, 2013; Rocha et al., 2021; Sanders et al., 2019; Shiue, 2015; Yang et al., 2017) and positive relations between ST duration and problem behaviors such as inattention, hyperactivity, impulsivity, aggression, and peer problems (e.g., Gentile et al., 2012; McArthur et al., 2022; Özmert et al., 2002; Sharif et al., 2010; Shiue, 2015; Pagani et al., 2010; Tamana et al., 2019). However, some mixed findings, as observed in the current study, also exist (Byun & Kim, 2007; Hu et al., 2020; Tansriratanawong et al., 2017). In these studies, no significant relations were found between the duration of ST and school adjustment, problem behaviors, or social skills.

The absence of a significant relation between ST duration and school adjustment in the current study may suggest potential cultural differences between Eastern and Western countries. Notably, research with non-significant findings listed above was all conducted in Eastern countries such as South Korea, China, and Thailand. It is often observed that Asian parents are characterized by a tendency to exert greater control over their children, and Asian children are generally perceived as more compliant and obedient to established rules (Chen et al., 2003; Huang & Lamb, 2014). Thus, it is plausible that Asian parents have more strict ST rules and Asian children tend to better adhere to them although it is crucial to recognize that the dynamics can be more complex depending on other individual and contextual factors.

Cross-national research comparing ST consumption in children from different countries is limited, but a study exploring racial and ethnic differences in adhering to specific healthy lifestyle recommendations (e.g., fruit and vegetable consumption, ST, physical activities, sugar-sweetened beverages consumption; Rogers et al., 2013) may support this explanation (Haughton et al., 2016). The study found variations among children and adolescents ages 6 to 11 years old in the U.S. by race or ethnicity. For example, non-Hispanic Asian youth were more likely to meet ST recommendations (i.e., less than 2 hours per day) compared to non-Hispanic white, non-Hispanic black, and Hispanic youth. The current findings might also be interpreted in light of the Goldilocks hypothesis, which states ST lower than a certain threshold may exhibit no or even positive associations with adaptive developmental outcomes (Przybylski & Weinstein, 2017). In this manner, ST consumption in South Korean children might not have exceeded this threshold, resulting in no significant relations between ST duration and school adjustment. Indeed, the daily average of ST in the current study (e.g., 1.19 or 1.51 hours) was lower than the average hours of using computers and mobile devices among 8- to 12-year-olds in the U.S. (e.g., 2 to 3 hours; Rideout et al., 2022) although a direct comparison is not possible due to differences in the measurement, age range, and context (e.g., pre- and post-pandemic).

The hypothesis that different types of ST content would have distinct relations with school adjustment was not supported. A little research on the relations between ST and school adjustment has considered factors beyond duration even though different types of content can have different relations with children's adjustment. However, some studies have demonstrated that more consumption of recreational or non-educational ST tended to be related to poorer behavioral and social adjustment albeit not specific to school settings (Conners-Burrow et al., 2011; Park et al., 2019; Sanders et al., 2019; Tomopoulos, Dreyer, et al., 2007). However, child behavioral and social adjustment may be different in school settings. Several studies raised the possibility of inconsistency in child behaviors across contexts because children can perceive and react differently to the same situations depending on their expectations of a given context (Sy et al., 2003; Tisak et al., 2007). Thus, in school settings, where rules are more explicit and relationships are more complex, children may demonstrate higher compliance and better social competence, potentially yielding less variable outcomes in school adjustment.

Although no significant longitudinal relations were found, the current results revealed some significant concurrent relations between ST variables and school adjustment even after controlling for the effects of covariates. For instance, ST duration and educational ST were significantly related to school adjustment in G3, and recreational ST had a significant concurrent relation with school adjustment in G4. These results suggest that ST and school adjustment may exhibit reciprocal relations concurrently, but there may be no enduring associations across time.

Another possibility is that longitudinal relations can exist, but a more extended period between early ST exposure and later school adjustment may be necessary for significant results. In a longitudinal study that followed participants from first grade to fourth grade, for example, ST duration predicted school adjustment two years later but not one year later (Lee & Lee, 2022). It may indicate that some amount of time, which is probably longer than one year, is required for the relations between early ST and later school adjustment to be manifested. To further explore these explanations about significant concurrent relations without longitudinal relations or longitudinal relations with a more prolonged period, research with data from more than two time points is needed.

The models with observed variables had similar patterns of non-significant relations between ST variables and school adjustment subscales, except for the Academic Behaviors subscale. In this specific model, the frequency of recreational ST was negatively related to children's academic behaviors one year later. Thus, more frequent engagement in recreational ST in Grade 3 was associated with better behavioral adjustment related to academic performance. This result aligns with previous findings regarding negative associations between recreational ST and academic achievement (Adelantado-Renau et al., 2019; Ishii et al., 2020). Previous research explained such relations with the time displacement hypothesis, a decrease in mental effort, or an increase in arousal (Shin, 2004). The latter two are unlikely in the current study due to non-significant relations between recreational ST and EF difficulties but the time displacement hypothesis may be likely because more engagement in recreational ST was significantly related to fewer hours in extracurricular learning-related activities. Thus, further research exploring the specific path is warranted.

Mediated Relations Between Screen Time and School Adjustment Through Executive Function Difficulties

The third hypothesis was partially supported, as significant mediation was observed only for the relation between educational ST and school adjustment via EF difficulties. Higher levels of engagement in educational ST were related to fewer difficulties in EF, which in turn was associated with better school adjustment. However, the mediated relations from the overall duration of ST and recreational ST were not significant, as the paths from the predictors (i.e., ST duration and recreational ST) to the mediator (i.e., EF difficulties) did not reach significance.

The significant mediated relation provides initial support for the developmental cascades model (Masten & Cicchetti, 2010) and the iterative reprocessing model (Cunningham & Zelazo, 2007; Zelazo, 2015). According to the developmental cascades model, cascading effects can explain why adaptive or maladaptive skills in one area can spill over into adaptive or maladaptive skills in another area. In this study, the cascading effects from environmental factors (i.e., educational ST) to cognitive competence (i.e., EF difficulties), which were spilled over into children's behavioral and social functioning in the school context, were examined.

The specific cascading paths from educational ST to EF difficulties to school adjustment can be supported by the hypothetical processes following the flow in the iterative reprocessing model (e.g., enhanced reflection through goal-directed problem-solving encourages EF development, which contributes to adaptive learning and adjustment; Cunningham & Zelazo, 2007; Zelazo, 2015). Educational ST in the current study appears to require active attention and deliberative information processing, which can encourage reflection or an elaborative reprocessing of information in the prefrontal cortex, leading to reduced EF difficulties (Zelazo, 2020). Since EF assists children in controlling and managing attention and behaviors toward specific goals, which are essential skills for adaptive learning and adjustment, reduced EF difficulties subsequently foster adaptive behavioral and social functioning at school (Zelazo et al., 2016). Although no study has investigated brain activities by ST content, a study with 9– to 10-year-old children found that not all ST-related brain structures uniformly exhibit negative consequences on cognitive performance, highlighting the complexity of determining ST effects on brain activities (Paulus et al., 2019). Future studies on brain functions related to various ST activities are necessary for a comprehensive and systematic understanding of why educational ST is related to a decrease in EF difficulties.

Interestingly, the mediated relation between educational ST and school adjustment through EF difficulties was significant, even though the direct path from educational ST to school adjustment was not. According to the traditional Baron and Kenny (1986) approach to mediation, a significant effect of a predictor on an outcome is a primary requirement for mediation. However, it is not uncommon to have a significant mediated relation without a significant direct relation when the mediated effect and the total effect are similar (O'Rourke & MacKinnon, 2018). The statistical power to detect mediation is greater than the power to detect the total effect, particularly with large sample sizes and small effects for the *a* path (from a predictor to a mediator) and the *b* path (from a mediator to an outcome). Moreover, when the absolute value of the *b* path is larger than the *a* path, the statistical power to test mediation becomes even greater (Kenny & Judd, 2014; O'Rourke & MacKinnon, 2015). These conditions correspond to the current findings. To illustrate, the mediated effect (.012) and the total effect (.057) differed by only .045, making the direct effect nearly zero. Furthermore, both the *a* and *b* paths had small effects with a large sample size, and the *b* path (-.164) was greater than the *a* path (-.074).

The models with observed variables of each subscale from the school adjustment measure demonstrated similar results except for the one with teacher relationships as an outcome. Thus, greater engagement in educational ST was related to fewer difficulties in EF, which in turn was linked to better adjustment in classroom behaviors, academic behaviors, and peer relationships. Unlike the other models, however, the model with teacher relationships did not exhibit a significant relation between EF difficulties and the outcome. This result is inconsistent with previous findings regarding significant concurrent and longitudinal relations between EF or self-regulation and relationships with teachers (McKinnon et al., 2018; Portilla et al., 2014; Rudasill, 2011; Valiente et al., 2012). The mixed findings may stem from different ways of measuring teacher-child relationships. In previous studies, teacher-child relationships were assessed by teacher-child conflict and closeness, and EF or self-regulation was more closely related to conflict than closeness (Portilla et al., 2014; Rudasill, 2011). Conflict with teachers was reported to be more stable over time than closeness and more driven by children's individual characteristics. On the other hand, closeness with teachers was more variable over time, suggesting it is more likely to be influenced by other factors (Jerome et al., 2009). In the current study, children's relationships with teachers were primarily evaluated based on their positive behaviors toward teachers (e.g., Ask teachers for help when needed). Thus, the teacher relationships subscale in the current study might have been influenced by factors other than children's individual EF difficulties, such as teacher characteristics. Thus, future research with consideration of teacher characteristics would provide a more comprehensive understanding of the associations between EF and various school adjustment aspects.

Relations with Covariates

The current study incorporated several time-variant and time-invariant covariates such as children's sex, SES, number of siblings, and hours of extracurricular learning-related activities. First, children's sex was related to ST variables in Grade 3 but not in Grade 4. Specifically, boys tended to spend more time on overall ST compared to girls but the frequency of the engagement in both educational and recreational ST was lower in boys than girls. Gender difference in ST duration is consistent with previous findings across multiple countries, which repeatedly demonstrated higher ST in boys than girls (Ishtiaq et al., 2021; LeBlanc et al., 2015). Interestingly, the results regarding the content of ST contradicted this pattern, as both educational and recreational ST were lower in boys. This discrepancy might stem from different parental perceptions of their children's ST between genders. Whereas ST duration was measured in average daily hours, the assessment of each content relied on Likert scale ratings of children's engagement, which is more susceptible to parental perceptions. Parents with male children may be more likely to believe that their children use ST less than their peers compared to parents with female children, influencing their subjective estimates of children's levels of ST engagement.

Children's biological sex was also significantly related to the levels of EF difficulties and school adjustment. Boys tended to exhibit more difficulties in EF and poorer school adjustment compared to girls. These results echo the findings from a systematic review of EF development in children and adolescents across countries, which found girls outperformed boys on both EF tasks and parent- or teacher-ratings of EF in most Western and East Asian countries (Schirmbeck et al., 2020). In addition, it is well-documented that boys are more prone to display behavioral and social problems compared to girls (Chen, 2010; Hajovsky et al., 2022; Kristoffersen et al., 2015; Yang et al., 2008). These gender disparities may reflect genuine differences in EF difficulties and school adjustment between boys and girls, but they may mirror gender-differentiated perceptions among parents and teachers, such as the perception that girls are more calm, compliant, and prosocial than boys (Bouchard et al., 2020).

Second, the number of siblings was expected to be related to ST variables, but it was related to educational ST only. Children with siblings are likely to be exposed to more ST due to the sharing of ST experiences among siblings either directly or indirectly (Domoff et al., 2019). However, the current study focused on mobile devices and computers, which are less amenable to sharing among multiple individuals. Alternatively, the effects of a sibling's ST may diminish as children age. Research on the resemblance of ST among peers or siblings during childhood and adolescence indicated that peer resemblance increased whereas sibling resemblance decreased with age (Bogl et al., 2020). As the importance of peer interactions and the time spent with peers increase, children's ST may become more closely tied to peers' ST whereas the association with siblings' ST may relatively weaken.

Third, family SES was related to ST duration and recreational ST but not educational ST. Higher SES was related to lower levels of the overall ST duration and less engagement in recreational ST. These results are consistent with a recent report, which showed children from lower-income families tended to spend more time on mobile ST and engage in more recreational activities using mobile media devices such as watching videos and playing games (Rideout & Robb, 2020). Compared to children in higher SES families, those in lower SES families may lack opportunities for alternative activities, as reflected in the positive relations between SES and hours spent in extracurricular learning-related activities in the current findings. In addition, parents in lower SES families might have less availability to control and manage their children's ST due to work or other demands (Ribner et al., 2017). On the other hand, the frequency of educational ST was not related to SES. This observation may suggest parents' perceptions toward utilization of educational ST do not differ across SES groups. It may imply that parents, irrespective of SES, believe in the role of ST as an educational resource. According to a recent report, 72% of parents of children aged between 0 to 8 believed that ST is helpful for their children's learning and 78% of parents answered that they let their children use ST for learning (Rideout & Robb, 2020).

Lastly, hours in extracurricular learning-related activities demonstrated both concurrent and prospective relations with ST variables. Children who engaged in more hours of extracurricular learning-related activities tended to spend fewer hours on overall ST duration and engage less frequently in recreational ST. These findings supported the time displacement hypothesis (Neuman, 1988), suggesting that ST displaces time for learning activities. On the other hand, more hours in extracurricular activities were related to more frequent engagement in educational ST. This could imply that children interested in learning activities are more likely to engage in various types of learning, including those facilitated through media devices.

Implications

The implications drawn from the current study hold valuable insights for refining guidelines and interventions related to ST among school-aged children. Traditionally, adhering to a 2-hour limit per day was perceived as the norm for children's ST guidelines (American Academy of Pediatrics, 2001). However, the practicality and efficacy of this

2-hour restriction have been questioned among parents, children, educators, and researchers as ST constitutes a significant part of children's daily activities since the emergence of mobile devices (e.g., Minges et al., 2015; Sanders et al., 2016). Acknowledging the inadequacy of strict time limits, contemporary guidelines now emphasize consistent rules and the cultivation of healthy ST habits without specific time limits (American Academy of Child and Adolescent Psychiatry, 2020; Council on Communication and Media et al., 2016). The current findings question the effectiveness of strict time limits by presenting the non-significant relations between ST duration and children's cognitive, behavioral, and social functions. Instead, ST content should be considered when setting ST rules in the development of ST guidelines to encourage healthy habits.

Although children are surrounded by various media devices, it does not guarantee critical utilization, highlighting the need to assist children in developing healthy ST habits. While numerous interventions have aimed to guide healthy ST use, the majority focused on reducing ST hours. The previous interventions included a variety of programs including parental education, family counseling, classroom curricula, community-based programs, and physical education classes (e.g., Maniccia et al., 2011; Jones et al., 2021; Wu et al., 2016). The randomized controlled trials of such interventions demonstrated significant results in reducing ST hours during and after interventions.

However, some challenges have been proposed, particularly when dealing with older children or adolescents, such as non-significant intervention effects, a longer period needed for meaningful effects to be presented, or non-sustained effects after program discontinuity (e.g., Andrade et al., 2015; Babic et al., 2016). It may imply the necessity for early interventions to maximize the effects of interventions. In addition, it can highlight the use of age-appropriate strategies tailored to developmental stages. For older children, restricting ST duration may be less effective due to increasing independence and autonomy. Indeed, parents of older children often find it difficult to monitor and supervise their children's ST and are less likely to intervene (Sanders et al., 2016). Furthermore, ST engagement may not be as detrimental as parents are worried about, especially when directed toward educational purposes, as children become equipped with more mature self-regulation skills.

Therefore, for older children, improving children's internal motivation to control their own ST using specific rules and open conversations discussing the effects of different types of ST content on learning and adaptation may be an effective strategy rather than restricting their ST engagement. A qualitative meta-synthesis of ST barriers and facilitators among 11- to 18-year-olds revealed that explicit rules were perceived as facilitators to reduce ST, whereas harsh restrictions were considered barriers (Minges et al., 2015). Moreover, youth thought family ST rules were unfair when set without their participation in decision-making. School-aged children and adolescents can monitor and observe their own ST, perceive the danger of excessive ST, and have a desire to control their ST (Minges et al., 2015). Indeed, individuals are more likely to change their behaviors and maintain them when they perceive the behavior change strategies are self-driven rather than imposed by others (Ryan & Deci, 2000). Thus, child-centered rules considering both benefits and risks and various ST aspects including not only its duration but content could be developed at home to encourage children to regulate their ST independently.

More broadly, cultivating media literacy can be a promising alternative to rigid ST duration limits in order to encourage healthy ST habits and informed engagement with digital media in school-aged children. Defined as the ability to analyze and evaluate messages delivered through media, understand their influences, and take appropriate behaviors (Schmidt et al., 2008), media literacy is crucial for children to critically assess the effects of ST, make informed choices regarding their ST consumption, and eventually develop positive behaviors. Although children in contemporary society are often considered *digital natives*, educators perceive students' limitations in media literacy abilities, emphasizing the need for deliberate cultivation of these skills (Schmidt, 2013). Evidence from a meta-analysis highlights the efficacy of media literacy programs as they had significant effects on various outcomes. These outcomes encompass not only media-related aspects such as knowledge, criticism, and awareness of influences of media but also behavioral-related factors like attitudes toward risky or antisocial behaviors and self-efficacy to avoid them (Jeong et al., 2012). Thus, fostering children's media literacy can be helpful for overall adaptation as well as healthy ST use.

Developing media literacy is especially important in this era where distinctions between media producers and consumers blur, which requires children to be equipped with skills and responsibilities for both roles (Hobbs & Jensen, 2009). Recognizing the diverse nature of ST, it is essential to acknowledge that a one-size-fits-all approach is untenable (Rasi et al., 2019). Therefore, future ST interventions should move beyond strict duration limitations and prioritize media literacy, considering the multiple aspects of ST including both duration and content, the varied roles imposed on children, and the influence of different contextual and individual factors.

Another important implication of the current findings is providing a foundational basis for EF interventions targeting better school adjustment. According to the developmental cascades model (Masten & Cicchetti, 2010), interventions that interrupt negative cascades or encourage positive cascades can be effective because they can cut the negative spillover from problems in one domain to other problems or increase the possibility of better performance in one domain from improvements in competence in other domains. Thus, interventions targeting the mediator can be efforts to focus on the cascades from the mediator to the outcome (Cicchetti & Hinshaw, 2002). That is, EF interventions can improve school adjustment by encouraging positive cascades from higher levels of EF and more adaptive school function and suppressing negative cascades from lower levels of EF and poorer school adjustment.

Interventions on EF have been repeatedly reported to be effective due to the malleability and plasticity of EF (Bernier et al., 2012; Zelazo et al., 2016). Preschool years and the transition to adolescence have been suggested as a target period of EF interventions because those are sensitive periods for EF development in terms of neural development and contextual changes (Zelazo & Carlson, 2012). Although these periods can be of particularly practical importance in intervention efforts, it does not necessarily mean that interventions during other developmental periods are not useful.

Plenty of studies have confirmed that different approaches to EF interventions were effective in school-aged children. For instance, computerized training, physical activities (e.g., aerobic and martial arts), art activities (e.g., music, drama, and play), and mindfulness meditation were reported to be effective in improving children's EF (Diamond & Lee, 2011; Takacs & Kassai, 2019). In addition, school curricula that include full-time programs targeting EF improvements such as *Tools of Mind* and *Montessori,* or integration of some strategies into existing curricula can be an effective and efficient way to implement EF interventions (Diamond & Lee, 2011).

An important question is whether EF interventions can improve school adjustment as well as EF itself. Based on the theoretical framework depicted in the developmental cascades model and a significant mediating role of EF in linking the relations between educational ST and school adjustment found in the current study, it is expected that EF interventions can be effective in encouraging children's positive and adaptive behaviors and relationships in school settings. However, one meta-analysis about the near- and far-transfer effects of EF interventions concluded that EF interventions have a significant near-transfer effect but not a far-transfer effect (Kassai et al., 2019). It suggested that training in EF may be effective in improving targeted EF components but not be successful in enhancing more distantly related features such as social skills and academic performance.

Nevertheless, training multiple EF components at the same time (e.g., cognitive flexibility, working memory, and inhibitory control) could be more practical and promising (Kassai et al., 2019). For instance, a study that explored the effects of computerized gaming interventions on various EF components including working memory, planning, and inhibitory control demonstrated that interventions were effective in improving not only EF but also school performance such as math and literacy performance (Goldin et al., 2014). Another study that examined the effects of school-readiness interventions integrated into Head Start programs found that interventions improved EF skills and EF mediated the effects of intervention on school readiness (Bierman et al., 2008). Thus, the far-transfer effects of EF interventions can be feasible if the efforts encompass various aspects of EF. More intervention studies targeting multiple EF components should be conducted to investigate the far-transfer effects of EF interventions on school adjustment.

Strengths and Limitations

The current study exhibits several notable strengths. Firstly, it explored relatively understudied facets of ST by concentrating on contemporary ST devices such as computers and smart devices and different ST content. The shift from static and passive forms of engagement (e.g., TV viewing) to more interactive and mobile modes (e.g., smart devices) underscores the need to investigate how newer types of ST contribute to children's development. However, not many studies have been conducted with newer types of ST devices. Considering the importance of ST in children’s everyday lives has rapidly increased over the past few years due to the development of new technologies and will increase far more, it is timely to update previous research by examining how more contemporary types of ST serve in children’s development. Moreover, the current study incorporated not only the duration but also the content of ST. Although the relations of

ST with children's developmental outcomes should be understood in a complex and sophisticated manner considering various aspects of ST, many studies have focused on the duration of ST. Thus, the current study attempted to enrich the existing literature by highlighting the unique and significant role of ST content, particularly in relation to children's EF difficulties and school adjustment.

Another strength of the current study lies in the investigation of the underlying mechanism linking ST to school adjustment. Despite continuous calls for more longitudinal research on the mechanism explaining how ST is related to developmental outcomes (e.g., Kostyrka-Allchorne et al., 2017), little is known. Although several studies have explored hypotheses about the link between ST and school adjustment, very few studies have attempted to empirically examine the mechanisms explaining this link (Cerniglia et al., 2021; Linebarger et al., 2014; Park et al., 2021; Sharif et al., 2010). By exploring EF difficulties as a potential mechanism, the current study aimed to elucidate the intricate interplay between ST, EF difficulties, and school adjustment and offer a foundational basis for interventions aimed at enhancing children's functioning in school settings.

Third, the current study attempted to include various personal and contextual covariates potentially related to children's ST, EF, or school adjustment such as sex, age, SES, number of siblings, and extracurricular learning-related activities. Including proper covariates is important to scrutinize the sophisticated relations between ST, EF, and school adjustment. For instance, some studies have demonstrated that negative relations between ST and developmental outcomes disappeared when including other factors such as SES, age, and home environment (e.g., Foster & Watkins, 2010; Jusienė et al., 2020; Stevens & Mulsow, 2006). In addition, the current study controlled for the prior levels of the outcomes (i.e., EF and school adjustment). Although evidence has suggested that early behavioral traits can be related to later behavioral outcomes or even ST (e.g., Radesky et al., 2014), many studies did not include the earlier levels of the outcomes in their models. Thus, the current study employing a cross-lagged panel model with data for two consecutive years and several covariates can better explain the unique relations between ST, EF, and school adjustment above and beyond other potentially relevant factors.

Lastly, the current study contributes to the diversity of ST research by focusing on an underrepresented population, namely South Korean school-aged children. Although the impact of ST is a global concern, studies on the relations between ST, EF, and school adjustment have predominantly originated from North America or Western Europe with some exceptions (e.g., Li et al., 2021; Yang et al., 2017). Considering that South Korea is a country where ST is prevalent even among very young children, a lack of publications in the South Korean context is surprising. To my knowledge, this is the first that explored the longitudinal mediated relations between ST, EF, and school adjustment. The current study with South Korean school-aged children broadens the scope of ST research and brings diversity, confirming that certain findings from North America or Western Europe (e.g., a positive role of educational ST in EF development; Huber et al., 2018; Linebarger et al., 2014) apply in diverse cultural settings.

Despite several important implications and strengths of the current study, it is not without limitations. First, the inclusion of educational and recreational ST may overlook other potentially influential types of content. For instance, the role of communication other than social networking, such as calling, texting, or video chatting, was not included in the questionnaires used in PSKC. Given the participants' age, however, they might have used such communication methods more frequently than social networking. Thus, future research should incorporate more types of content to explore their associations with children's EF and school adjustment for a more nuanced understanding of the unique role of ST content.

Second, some methodological constraints exist in the measurement of ST. The reliance on parent reports for the average daily hours of ST exposure provides only a rough approximation of ST duration, and as children become more independent in middle childhood, parental reports may become less accurate. Furthermore, the assessment of each content type using Likert scales depends on subjective parental evaluations. Therefore, future research with more objective measurement methods, such as daily diaries or ecological momentary assessments, can enhance the reliability of recall and reporting (Shiffman et al., 2008) and provide more accurate insights into children's ST consumption.

Furthermore, the large sample size of the PSKC project led to the practical use of parent reports for measuring children's EF. While the employed EF measurement demonstrated reliability and validity in prior research (Song, 2014), the exclusive reliance on behavioral ratings may raise concerns. Some researchers have argued that performance-based EF measures may better reflect children's capacities than behavioral ratings (Buchanan, 2016) and the lack of correlation between performance-based measures and behavioral ratings of EF (Toplak et al., 2013). Therefore, future research integrating both performance-based assessments and behavioral ratings is needed to verify the replicability of the study's findings.

Third, the design of the current study using a half-longitudinal mediation model introduces limitations. Inconsistency in the assessments used and the effects of the pandemic constrained the investigation to only two time points, despite the availability of data for Grade 5 and Grade 6 in PSKC. Although a half-longitudinal mediation model offers advantages over a cross-sectional model, it has limitations. For instance, the half-longitudinal mediation model assumes stationarity, a condition seldom met in social science research because it is not uncommon that human behaviors and their relations with other factors change over time (Little, 2013). While the violation of the stationarity assumption is often considered acceptable in longitudinal research involving more than two time points, it may compromise the assumptions underlying the half-mediation longitudinal model. Furthermore, mediation results based on only two time points may lack the robustness required to strongly support the potential benefits of intervention on a mediator. Thus, future studies incorporating more than two time points could enhance the reliability of results and strengthen the implications drawn from the findings.

Another limitation is the representativeness of the sample. Despite recruiting participants from nationwide hospitals, PSKC was restricted to those with more than 500 cases of delivery per year. This approach may inadvertently exclude children and families from smaller rural regions or those experiencing poverty. Indeed, the levels of monthly household income of families who participated in the project (5,418,140 Korean Won) exceeds the national average (4,754,166 Korean Won; Statistics Korea et al., 2022), underscoring potential sampling bias. In addition, only 7% of children belonged to the low-income class as per the national criteria (below 50% of the median income with consideration of the number of household members; Statistics Korea, 2023). Therefore, the current sample might not properly represent the characteristics of children from under-resourced families. Future research should aim for more representative samples, incorporating children from lower-income families or rural areas, to ensure the generalizability of findings to the broader population.

Conclusion

In conclusion, the current study aimed to investigate the intricate dynamics of ST among school-aged children, with a focus on both duration and content, and explored its associations with EF difficulties and school adjustment. The investigation revealed that the duration and content of ST played distinctive roles in shaping children's EF difficulties and school adjustment. In particular, educational ST emerged as a positive contributor, demonstrating a significant association with reduced EF difficulties, subsequently enhancing school adjustment. This provides initial evidence in support of the developmental cascades model and the iterative reprocessing model and highlights the need for more longitudinal research.

The current findings challenge the conventional belief that ST is negatively related to children's cognitive and behavioral outcomes and emphasize the importance of considering the purpose and nature of ST activities when guiding children's ST use. The acknowledgment of the positive role of educational ST prompts a reconsideration of rigid duration limitations, advocating for a more nuanced approach to guideline development such as encouraging media literacy. The significant mediated relation between educational ST and school adjustment via EF difficulties highlights the need for a comprehensive understanding of the mechanisms linking ST to children's behavioral and social functions in school settings and offers an empirical foundation to develop EF interventions to enhance school adjustment.

In sum, the current study contributes a novel perspective to the ongoing discourse on children's ST, emphasizing the need to move beyond duration restrictions but consider the content of ST activities. By recognizing the diverse roles ST plays in children's lives and the implications, parents, educators, and researchers can better support children in navigating ST use to promote balanced development and successful adaptation. As technology continues to constitute a large part of children's daily lives, the current findings provide valuable insights for informed decision-making, policy formulation, and the development of interventions that align with the evolving landscape of the digital world.

REFERENCES

Adelantado-Renau, M., Moliner-Urdiales, D., Cavero-Redondo, I., Beltran-Valls, M. R., Martínez-Vizcaíno, V., & Álvarez-Bueno, C. (2019). Association between screen media use and academic performance among children and adolescents: A systematic review and meta-analysis. *JAMA pediatrics, 173*(11), 1058-1067. https://doi.org/10.1001/jamapediatrics.2019.3176

Ahn, S., Kang, B., & Lee, K. (2017). Structural relationships among children's duration of media use, behavior problems, and school adjustment. *Korean Journal of Child Study, 38*(2), 191-204. https://doi.org/10.5723/kjcs.2017.38.2.191

American Academy of Child & Adolescent Psychiatry (2020). Screen time and children. *AACAP.org*. https://www.aacap.org/AACAP/Families_and_Youth/Facts_for_Families/FFF-Guide/Children-And-Watching-TV-054.aspx#:~:text=Between%2018%20and%2024%20months,limit%20activities%20that%20include%20screens

American Academy of Pediatrics (2001). American Academy of Pediatrics: Children, adolescents, and television. *Pediatrics, 107,* 423–426. http://doi.org/10.1542/peds.107.2.423

Anderson, D. R., Huston, A. C., Schmitt, K. L., Linebarger, D. L., Wright, J. C., & Larson, R. (2001). Early childhood television viewing and adolescent behavior: The recontact study. *Monographs of the Society for Research in Child Development*, 66(1), i-viii+1-154.

Anderson, D. R., & Pempek, T. A. (2005). Television and very young children. *American Behavioral Scientist, 48*(5), 505-522. https://doi.org/10.1177/0002764204271506

Andrade, S., Verloigne, M., Cardon, G., Kolsteren, P., Ochoa-Avilés, A., Verstraeten, R., Donoso, S., & Lachat, C. (2015). School-based intervention on healthy behaviour among Ecuadorian adolescents: Effect of a cluster-randomized controlled trial on screen-time. *BMC Public Health, 15*, 1-11. https://doi.org/10.1186/s12889-015-2274-4

Anthony, C. J., & Ogg, J. (2020). Executive function, learning-related behaviors, and science growth from kindergarten to fourth grade. *Journal of Educational Psychology, 112*(8), 1563–1581. https://doi.org/10.1037/edu0000447

Babic, M. J., Smith, J. J., Morgan, P. J., Lonsdale, C., Plotnikoff, R. C., Eather, N., Skinner, G., Baker, A. L., Pollock, E., & Lubans, D. R. (2016). Intervention to reduce recreational screen-time in adolescents: Outcomes and mediators from the 'Switch-Off 4 Healthy Minds'(S4HM) cluster randomized controlled trial. *Preventive Medicine*, *91*, 50-57. http://doi.org/10.1016/j.ypmed.2016.07.014

Baggetta, P., & Alexander, P. A. (2016). Conceptualization and operationalization of executive function. *Mind, Brain, and Education*, *10*(1), 10-33. https://doi.org/10.1111/mbe.12100

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173-1182. https://doi.org/10.1037/0022-3514.51.6.1173

Barr, A. L., Zack, E., & Calvert, S. L. (2010). Infant and early childhood exposure to adult-directed and child-directed television programming: Relations with cognitive skills at age four. *Merrill-Palmer Quarterly, 56*(1), 21–48. https://doi.org/10.1353/mpq.0.0038

Bavelier, D., Green, C., Han, D., Renshaw, P. F., Merzenich, M. M. & Gentile, D. A. (2011). Brains on video games. *Nature Reviews Neuroscience, 12*, 763–768. https://doi.org/10.1038/nrn3135

Baydar, N., Kağitçibaşi, Ç., Küntay, A. C., & Gökşen, F. (2008). Effects of an educational television program on preschoolers: Variability in benefits. *Journal of Applied Developmental Psychology*, *29*(5), 349–360. https://doi.org/10.1016/j.appdev.2008.06.005

Belton, S., Issartel, J., Behan, S., Goss, H., & Peers, C. (2021). The differential impact of screen time on children's wellbeing. *International Journal of Environmental Research and Public Health*, *18*(17), 9143. https://doi.org/10.3390/ijerph18179143

Bernier, A., Carlson, S. M., Deschênes, M., & Matte-Gagné, C. (2012). Social factors in the development of early executive functioning: A closer look at the caregiving environment. *Developmental Science*, *15*(1), 12–24. https://doi.org/10.1111/j.1467-7687.2011.01093.x

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review, 29*(3), 180-200. https://doi.org/10.1016/j.dr.2009.05.002

Bierman, K., Nix, R., Greenberg, M., Blair, C., & Domitrovich, C. (2008). Executive functions and school readiness intervention: Impact, moderation, and mediation in the Head Start REDI program. *Development and Psychopathology, 20*(3), 821-843. https://doi.org/10.1017/S0954579408000394

Blankson, A. N., O'Brien, M., Leerkes, E. M., Calkins, S. D., & Marcovitch, S. (2015). Do hours spent viewing television at ages 3 and 4 predict vocabulary and executive functioning at age 5? *Merrill-Palmer Quarterly*, *61*(2), 264-289. https://doi.org/10.13110/merrpalmquar1982.61.2.0264

Bogl, L. H., Mehlig, K., Ahrens, W., Gwozdz, W., De Henauw, S., Molnár, D., Moreno, L., Pigeot, I., Russo, P., Solea, A., Veidebaum, T., Kaprio, J., Lissner, L., & Hebestreit, A. (2020). Like me, like you–relative importance of peers and siblings on children's fast food consumption and screen time but not sports club participation depends on age. *International Journal of Behavioral Nutrition and Physical Activity*, *17*, 1-11. https://doi.org/10.1186/s12966-020-00953-4

Bouchard, C., Sylvestre, A., & Forget-Dubois, N. (2020). Why are boys perceived as less prosocial than girls by their early childhood educators? The role of pragmatic skills in preschool and kindergarten children. *Educational Psychology, 40*(10), 1190-1210. https://doi.org/10.1080/01443410.2020.1742875

Brock, L. L., Rimm-Kaufman, S. E., Nathanson, L., & Grimm, K. J. (2009). The contributions of 'hot' and 'cool' executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten. *Early Childhood Research Quarterly*, *24*(3), 337–349. https://doi.org/10.1016/j.ecresq.2009.06.001

Buchanan, T. (2016). Self-report measures of executive function problems correlate with personality, not performance-based executive function measures in nonclinical samples. *Psychological Assessment, 28*, 372-385. https://doi.org/10.1037/pas0000192

Butcher, J. (2016). Can tablet computers enhance learning in further education? *Journal of Further and Higher Education, 40*(2), 207-226. https://doi.org/10.1080/0309877X.2014.938267

Byun, S., & Kim, J. (2007). The relationships among children's/adolescents' frequency levels of playing internet games, motives for playing internet games and adaptation to school. *Journal of Korean Home Management Association, 25*(2), 47-58.

Caemmerer, J. M., & Keith, T. Z. (2015). Longitudinal, reciprocal effects of social skills and achievement from kindergarten to eighth grade. *Journal of School Psychology*, *53*(4), 265–281. https://doi.org/10.1016/j.jsp.2015.05.001

Carrera, P., Jiménez-Morago, J. M., Román, M., & León, E. (2019). Caregiver ratings of executive functions among foster children in middle childhood: Associations with early adversity and school adjustment. *Children and Youth Services Review, 106*, 104495. https://doi.org/10.1016/j.childyouth.2019.104495

Carlson, S. M., Zelazo, P. D., & Faja, S. (2013). Executive function. In P. D. Zelazo (Ed.), *The Oxford handbook of developmental psychology (Vol. 1): Body and mind* (pp. 706–743). Oxford University Press.

Cerniglia, L., Cimino, S., & Ammaniti, M. (2021). What are the effects of screen time on emotion regulation and academic achievements? A three-wave longitudinal study on children from 4 to 8 years of age. *Journal of Early Childhood Research*, *19*(2), 145–160. https://doi.org/10.1177/1476718X20969846

Chaarani, B., Ortigara, J., Yuan, D., Loso, H., Potter, A., & Garavan, H. P. (2022). Association of video gaming with cognitive performance among children. *JAMA Network Open, 5*(10), e2235721. https://doi.org/10.1001/jamanetworkopen.2022.35721

Chen, J. J. L. (2010). Gender differences in externalising problems among preschool children: Implications for early childhood educators. *Early Child Development and Care, 180*(4), 463-474. https://doi.org/10.1080/03004430802041011

Chen, X., Rubin, K. H., Liu, M., Chen, H., Wang, L., Li, D., Gao, X., Cen, G., Gu, H., & Li, B. (2003). Compliance in Chinese and Canadian toddlers: A cross-cultural study. *International Journal of Behavioral Development*, *27*(5), 428-436. https://doi/org/10.1080/01650250344000046

Chi, S., & Jung, D. (2006). Validation of school adjustment inventory for first grade elementary school students. *Korean Journal of Child Studies, 27*(1),1-15.

Cho, Y., & Ha, E. (2020). Classification of executive function types of children with latent profile analysis and relationship between school adjustment, academic performance, and problem behavior. *Sookmyung Journal of Child Study, 32*(1), 46-66.

Cicchetti, D., & Hinshaw, S. P. (2002). Prevention and intervention science: Contributions to developmental theory. *Development and Psychopathology*, *14*(4), 667-671. https://doi.org/10.1017.S0954579402004017

Cole, D. A., & Maxwell, S. E. (2003). Testing mediational models with longitudinal data: Questions and tips in the use of structural equation modeling. *Journal of abnormal psychology, 112*(4), 558 –577. https://doi.org/10.1037/0021-843X.112.4.558.

Comrey, A. L., & Lee, H. B. (2013). *A first course in factor analysis*. Psychology press.

Conners-Burrow, N. A., McKelvey, L. M., & Fussell, J. J. (2011). Social outcomes associated with media viewing habits of low-income preschool children. *Early Education and Development*, *22*(2), 256–273. https://doi.org/10.1080/10409289.2011.550844

Cosden, M., Morrison, G., Gutierrez, L., & Brown, M. (2004). The effects of homework programs and after-school activities on school success. *Theory into Practice*, *43*(3), 220-226. https://doi.org/10.1207/s15430421tip4303_8

Council on Communications and Media, Hill, D., Ameenuddin, N., Chassiakos, Y. R., Cross, C., Radesky, J., Hutchinson, J., Levine, A., Boyd, R., Mendelson, R., Moreno, M., Swanson, W. S., & MBE. (2016). Media use in school-aged children and adolescents. *Pediatrics, 138*(5), e20162592. https://doi.org/10.1542/peds.2016-2592

Cunningham, W. A., & Zelazo, P. D. (2007). Attitudes and evaluations: A social cognitive neuroscience perspective. *Trends in Cognitive Sciences*, *11*(3), 97–104. https://doi.org/10.1016/j.tics.2006.12.005

Diamond, A. (2006). Early development of executive functions. In E. Bialystok & F. I. M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 70-95). Oxford University Press.

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*, *64,* 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*(6045), 959-964. https://doi.org/10.1126/science.1204529

Domoff, S. E., Radesky, J. S., Harrison, K., Riley, H., Lumeng, J. C., & Miller, A. L. (2019). A naturalistic study of child and family screen media and mobile device use. *Journal of Child and Family Studies*, *28*, 401-410. https://doi.org/10.1007/s10826-018-1275-1

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology, 43,* 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428

Fabes, R. A., Martin, C. L., & Hanish, L. D. (2009). Children's behaviors and interactions with peers. In K. H. Rubin, W. M. Bukowski, & B. Laursen (Eds.), *Handbook of peer interactions, relationships, and groups* (pp. 45–62). The Guilford Press.

Fan, X., Thompson, B., & Wang, L. (1999). Effects of sample size, estimation methods, and model specification on structural equation modeling fit indexes. *Structural equation modeling: A multidisciplinary journal, 6*(1), 56-83. https://doi.org/10.1080/10705519909540119.

Foster, E. M., & Watkins, S. (2010). The value of reanalysis: TV viewing and attention problems. *Child Development*, *81*(1), 368–375. https://doi.org/10.1111/j.1467-8624.2009.01400.x

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, *134*(1), 31–60. https://doi.org/10.1037/0033-2909.134.1.31

Gashaj, V., Dapp, L. C., Trninic, D., & Roebers, C. M. (2021). The effect of video games, exergames and board games on executive functions in kindergarten and 2nd grade: An explorative longitudinal study. *Trends in Neuroscience and Education, 25*, 100162. https://doi.org/10.1016/j.tine.2021.100162

Gentile, D. A., Swing, E. L., Lim, C. G., & Khoo, A. (2012). Video game playing, attention problems, and impulsiveness: Evidence of bidirectional causality. *Psychology of Popular Media Culture*, *1*(1), 62–70. https://doi.org/10.1037/a0026969

Gioia, G. A., Espy, K. A., & Isquith, P. K. (2003). *Behavior Rating Inventory of Executive Function–Preschool version*. Psychological Assessment Resources.

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). *BRIEF: Behavior rating inventory of executive function*. Psychological Assessment Resources.

Goh, E., & Jeon, H. (2020). Investigating predictors of first graders' school adjustment in Korean elementary school using latent profile analysis and machine learning. *Korean Journal of Child Studies, 41*(4), 75-90. https://doi.org/10.5723/kjcs.2020.41.4.75

Goldin, A. P., Hermida, M. J., Shalom, D. E., Elias Costa, M., Lopez-Rosenfeld, M., Segretin, M. S., Fernández-Slezak, D., Lipina, S. J., & Sigman, M. (2014). Far transfer to language and math of a short software-based gaming intervention. *Proceedings of the National Academy of Sciences, 111*(17), 6443-6448. https://doi.org/10.1073/pnas.1320217111

Goodman, R. (1997). The Strengths and Difficulties Questionnaire: A research note. *Journal of Child Psychology and Psychiatry, 38*(5), 581-586. https://doi.org/10.1111/j.1469-7610.1997.tb01545.x.

Hajovsky, D. B., Caemmerer, J. M., & Mason, B. A. (2022). Gender differences in children's social skills growth trajectories. *Applied Developmental Science, 26*(3), 488-503. https://doi.org/10.1080/10888691.2021.1890592

Haughton, C. F., Wang, M. L., & Lemon, S. C. (2016). Racial/ethnic disparities in meeting 5-2-1-0 recommendations among children and adolescents in the United States. *The Journal of Pediatrics, 175*, 188-194. https://doi.org/10.1016/j.jpeds.2016.03.055

Hobbs, R., & Jensen, A. (2009). The past, present, and future of media literacy education. *Journal of Media Literacy Education, 1*(1), 1-11. https://doi.org/10.23860/jmle-1-1-1

Holmes, C. J., Kim-Spoon, J., & Deater-Deckard, K. (2016). Linking executive function and peer problems from early childhood through middle adolescence. *Journal of*

Abnormal Child Psychology, 44(1), 31–42. https://doi.org/10.1007/s10802-015-0044-5

Horowitz-Kraus, T., & Hutton, J. S. (2018). Brain connectivity in children is increased by the time they spend reading books and decreased by the length of exposure to screen-based media. *Acta Paediatrica, 107*(4), 685-693. https://doi.org/10.1111/apa.14176

Hu, B. Y., Johnson, G. K., Teo, T., & Wu, Z. (2020). Relationship between screen time and Chinese children's cognitive and social development. *Journal of Research in Childhood Education*, *34*(2), 183–207. https://doi.org/10.1080/02568543.2019.1702600

Huang, C. Y., & Lamb, M. E. (2014). Are Chinese children more compliant? Examination of the cultural difference in observed maternal control and child compliance. *Journal of Cross-Cultural Psychology, 45*(4), 507-533. https://doi.org/10.1177/0022022113513652

Huber, B., Yeates, M., Meyer, D., Fleckhammer, L., & Kaufman, J. (2018). The effects of screen media content on young children's executive functioning. *Journal of Experimental Child Psychology*, *170*, 72–85. https://doi.org/10.1016/j.jecp.2018.01.006

Hughes, C., & Ensor, R. (2008). Does executive function matter for preschoolers' problem behaviors? *Journal of Abnormal Child Psychology, 36*, 1-14. https://doi.org/10.1007/s10802-007-9107-6

Hughes, C., & Ensor, R. (2011). Individual differences in growth in executive function across the transition to school predict externalizing and internalizing behaviors and self-perceived academic success at 6 years of age. *Journal of Experimental Child Psychology, 108*(3), 663-676. https://doi.org/10.1016/j.jecp.2010.06.005

Huttenlocher, P. R. (2002). *Neural plasticity: The effects of environment on the development of the cerebral cortex*. Harvard University Press.

Hutton, J. S., Dudley, J., Horowitz-Kraus, T., DeWitt, T., & Holland, S. K. (2020). Associations between screen-based media use and brain white matter integrity in preschool-aged children. *JAMA Pediatrics, 174*(1), e193869-e193869. https://doi.org/10.1001/jamapediatrics.2019.3869

Ishii, K., Aoyagi, K., Shibata, A., Javad Koohsari, M., Carver, A., & Oka, K. (2020). Joint associations of leisure screen time and physical activity with academic performance in a sample of Japanese children. *International Journal of Environmental Research and Public Health*, *17*(3), 757. https://doi.org/10.3390/ijerph17030757

Ishtiaq, A., Ashraf, H., Iftikhar, S., & Baig-Ansari, N. (2021). Parental perception on screen time and psychological distress among young children. *Journal of Family Medicine and Primary Care, 10*(2), 765-772. https://doi.org/10.4103/jfmpc.jfmpc_1720_20

Jang, Y. J., & Kim, S. (2008). The impact of computer use on adolescents' social relationship and school adjustment: An analysis of Korean Youth Panel Survey data. *Journal of Communication Research*, *45*(1), 67-96. https://doi.org/10.22174/jcr.2008.45.1.67

Jeong, H. (2020). Structural relationships among media exposure, parental interaction, and school readiness in early childhood. *International Journal of Early Childhood Education, 26*(1), 97-113. http://doi.org/10.18023/ijece.2020.26.1.006

Jeong, S. H., Cho, H., & Hwang, Y. (2012). Media literacy interventions: A meta-analytic review. *Journal of communication*, *62*(3), 454-472. https://doi.org/10.1111/j.1460-2466.2012.01643.x

Jerome, E. M., Hamre, B. K., & Pianta, R. C. (2009). Teacher-child relationships from kindergarten to sixth grade: Early childhood predictors of teacher-perceived conflict and closeness. *Social Development, 18,* 915–945. https://doi.org/10.1111/j.1467-9507.2008.00508.x

Jimerson, S. R., Campos, E., & Greif, J. L. (2003). Toward an understanding of definitions and measures of school engagement and related terms. *The California School Psychologist, 8,* 7-27. https://doi.org/10.1007/BF03340893

Jones, A., Armstrong, B., Weaver, R. G., Parker, H., von Klinggraeff, L., & Beets, M. W. (2021). Identifying effective intervention strategies to reduce children's screen time: A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity, 18,* 1-20. https://doi.org/10.1186/s12966-021-01189-6

Jusienė, R., Rakickienė, L., Breidokienė, R., & Laurinaitytė, I. (2020). Executive function and screen-based media use in preschool children. *Infant and Child Development*, *29*(1). https://doi.org/10.1002/icd.2173

Kassai, R., Futo, J., Demetrovics, Z., & Takacs, Z. K. (2019). A meta-analysis of the experimental evidence on the near-and far-transfer effects among children's executive function skills. *Psychological Bulletin, 145*(2), 165-188. https://doi.org/10.1037/bul0000180

Kenny, D. A., & Judd, C. M. (2014). Power anomalies in testing mediation. *Psychological Science, 25,* 334–339. https://doi.org/10.1177/0956797613502676

Kim, A., Nam, M., & Choi, Y. (2021). Exploring the relationship between digital device usage, executive functions, and reading time and preference in 4th to 6th graders. *Korean Journal of Developmental Psychology, 34*(4), 109-131. https://accesson.kr/jkdp/v.34/4/109/18480

Kim, B., & Shin, H. (2019). The relationship between young children's media use time, self-regulation, and problem behaviors. *Korean Journal of Human Ecology, 28*(6), 567-581. https://doi.org/10.5934/kjhe.2019.28.6.567

Kirkorian, H. L., & Anderson, D. R. (2009). Learning from educational media. In S. L. Calvert and B. J. Wilson (Eds.), *The handbook of children, media, and development* (pp. 188–213). John Wiley & Sons.

Kirkorian, H. L., Anderson, D. R., & Keen, R. (2012). Age differences in online processing of video: An eye movement study. *Child Development, 83*(2), 497-507. https://doi.org/10.1111/j.1467-8624.2011.01719.x

Korkman, M., Kirk, U., & Kemp, S. (2007). *NEPSY-II*. Pearson.

Kostyrka-Allchorne, K., Cooper, N. R., & Simpson, A. (2017). The relationship between television exposure and children's cognition and behaviour: A systematic review. *Developmental Review, 44*, 19–58. https://doi.org/10.1016/j.dr.2016.12.002

Kristoffersen, J. H., Obel, C., & Smith, N. (2015). Gender differences in behavioral problems and school outcomes. *Journal of Economic Behavior & Organization, 115*, 75-93. http://doi.org/10.1016/j.jebo.2014.10.006

LeBlanc, A. G., Katzmarzyk, P. T., Barreira, T. V., Broyles, S. T., Chaput, J. P., Church, T. S., Fogelholm, M., Harrington, D. M., Hu, G., Kuriyan, R., Kurpad, A., Lambert, E. V., Maher, C., Maia, J., Mtsudo, V., Olds, T., Onywera, V., Sarmiento, O. L., Standage, M., … & ISCOLE Research Group. (2015). Correlates of total sedentary time and screen time in 9–11 year-old children around the world: The international study of childhood obesity, lifestyle and the environment. *PloS One*, *10*(6), e0129622. https://doi.org/10.1371/journal.pone.0129622

Lee, K. (2021a). A longitudinal study of changes in media use time and gender differences from preschoolers to lower grades of elementary school. *Journal of Korean Council for Children & Rights, 25*(3), 379-399. http://doi.org/10.21459/kccr.2021.25.3.379

Lee, K. (2021b). Causal longitudinal analysis between media usage time trajectories and school adaptation trajectories for low grade elementary school children. *Journal of Open Parent Education, 12*(1), 105-124. http://doi.org/10.36431/JPE.12.1.6

Lee, J., Do, N., & Oh, Y. (2013). *Current status and protective measures of young children's exposure to media devices*. Korea Institute of Child Care and Education.

Lee, J., Kang, S., Lee, K., & Yi, S. (2015). The effects of parenting practice on the trajectories of change in the school adjustment of upper elementary students. *Korean Journal of Child Studies, 36*(4), 91-110. https://doi.org/10.5723/KJCS.2015.36.4.91

Lee, H. & Kim, H. (2019). The effectiveness of smartphone addiction prevention program for upper elementary students. *Korean Journal of Child Psychotherapy, 14*(2), 37-57. http://doi.org/10.23931/kacp.2019.14.2.37

Lee, K., & Lee, M. (2022). Longitudinal relationships of media time uses, self esteem, and school adjustment from 8 to 11 years old: Applying autoregressive cross-lagged modeling analysis. *Journal of Open Parent Education*, *14*(2), 89-112. http://doi.org/10.36431/JPE.14.2.5s

Lee, J., Park, W., & Um, J. (2021). *A study on policy measures to optimize the media use of infants and young children.* Korea Institute of Child Care and Education.

Lezak, M. D. (1982). The problem of assessing executive functions. *International Journal of Psychology*, *17*(1–4), 281–297. https://doi.org/10.1080/00207598208247445

Lezak, M. D., Howieson, D. B., Loring, D. W., & Fischer, J. S. (2004). *Neuropsychological assessment*. Oxford University Press.

Li, H., Wu, D., Yang, J., Luo, J., Xie, S., & Chang, C. (2021). Tablet use affects preschoolers' executive function: FNIRS evidence from the dimensional change card sort task. *Brain Sciences*, *11*(5), 567. https://doi.org/10.3390/brainsci11050567

Lillard, A. S., Drell, M. B., Richey, E. M., Boguszewski, K., & Smith, E. D. (2015). Further examination of the immediate impact of television on children's executive function. *Developmental Psychology, 51*(6), 792–805. https://doi.org/10.1037/a0039097

Lillard, A. S., & Peterson, J. (2011). The immediate impact of different types of television on young children's executive function. *Pediatrics, 128*(4), 644-649. https://doi.org/ 10.1542/peds.2010-1919

Linebarger, D. L., Barr, R., Lapierre, M. A., & Piotrowski, J. T. (2014). Associations between parenting, media use, cumulative risk, and children's executive functioning. *Journal of Developmental & Behavioral Pediatrics, 35*(6), 367–377. https://doi.org/10.1097/DBP.0000000000000069

Little, T. D. (2013). *Longitudinal structural equation modeling*. Guilford Press.

MacKinnon, D. (2012). *Introduction to statistical mediation analysis*. Routledge.

MacKinnon, D. P., Lockwood, C. M., Hoffman, J. M., West, S. G., & Sheets, V. (2002). A comparison of methods to test mediation and other intervening variable effects. *Psychological Methods, 7*(1), 83 –104. https://doi-org/10.1037/1082-989X.7.1.83.

Maniccia, D. M., Davison, K. K., Marshall, S. J., Manganello, J. A., & Dennison, B. A. (2011). A meta-analysis of interventions that target children's screen time for reduction. *Pediatrics, 128*(1), e193-e210. https://doi.org/10.1542/peds.2010-2353

Mares, M. L., & Woodard, E. (2005). Positive effects of television on children's social interactions: A meta-analysis. *Media Psychology, 7*(3), 301–322. https://doi.org/10.1207/S1532785XMEP0703_4

Masten, A. S., & Cicchetti, D. (2010). Developmental cascades. *Development and Psychopathology, 22*(3), 491-495. https://doi.org/10.1017/S0954579410000222

Masten, A. S., Herbers, J. E., Desjardins, C. D., Cutuli, J. J., McCormick, C. M., Sapienza, J. K., Long, J. D., & Zelazo, P. D. (2012). Executive function skills and school success in young children experiencing homelessness. *Educational Researcher, 41*(9), 375–384. https://doi.org/10.3102/0013189X12459883

McArthur, B. A., Tough, S., & Madigan, S. (2022). Screen time and developmental and behavioral outcomes for preschool children. *Pediatric Research, 91*(6), 1616-1621. https://doi.org/10.1038/s41390-021-01572-w

McHarg, G., Ribner, A. D., Devine, R. T., & Hughes, C. (2020). Screen time and executive function in toddlerhood: A longitudinal study. *Frontiers in Psychology, 11*, 570392. https://doi.org/10.3389/fpsyg.2020.570392

McKinnon, R. D., Blair, C., & The Family Life Project Investigators. (2018). Does early executive function predict teacher–child relationships from kindergarten to second grade? *Developmental Psychology, 54*(11), 2053–2066. https://doi.org/10.1037/dev0000584

McNeill, J., Howard, S. J., Vella, S. A., & Cliff, D. P. (2019). Longitudinal associations of electronic application use and media program viewing with cognitive and psychosocial development in preschoolers. *Academic Pediatrics, 19*(5), 520–528. https://doi.org/10.1016/j.acap.2019.02.010

Minges, K. E., Owen, N., Salmon, J., Chao, A., Dunstan, D. W., & Whittemore, R. (2015). Reducing youth screen time: Qualitative metasynthesis of findings on barriers and facilitators. *Health Psychology, 34*(4), 381-397. https://doi.org/10.1037/hea0000172

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology, 41*(1), 49-100. https://doi.org/10.1006/cogp.1999.0734

Moilanen, K. L., Shaw, D. S., & Maxwell, K. L. (2010). Developmental cascades: Externalizing, internalizing, and academic competence from middle childhood to early adolescence. *Development and Psychopathology, 22*(3), 635-653. https://doi.org/10.1017/S0954579410000337

Muthén, L.K. and Muthén, B.O. (1998-2017). *Mplus user’s guide* (8th edition). Muthén & Muthén

Mutz, D. C., Roberts, D. F., & Vuuren, D. V. (1993). Reconsidering the displacement hypothesis: Television's influence on children's time use. *Communication Research, 20*(1), 51-75. https://doi.org/10.1177/009365093020001003

Nathanson, A. I., Aladé, F., Sharp, M. L., Rasmussen, E. E., & Christy, K. (2014). The relation between television exposure and executive function among preschoolers. *Developmental Psychology, 50*(5), 1497–1506. https://doi.org/10.1037/a0035714

Nelson, T. D., Nelson, J. M., James, T. D., Clark, C. A. C., Kidwell, K. M., & Espy, K. A. (2017). Executive control goes to school: Implications of preschool executive performance for observed elementary classroom learning engagement. *Developmental Psychology, 53*(5), 836–844. https://doi.org/10.1037/dev0000296

Neophytou, E., Manwell, L. A., & Eikelboom, R. (2021). Effects of excessive screen time on neurodevelopment, learning, memory, mental health, and neurodegeneration: A scoping review. *International Journal of Mental Health and Addiction*, *19*(3), 724–744. https://doi.org/10.1007/s11469-019-00182-2

Neuenschwander, R., Röthlisberger, M., Cimeli, P., & Roebers, C. M. (2012). How do different aspects of self-regulation predict successful adaptation to school? *Journal of Experimental Child Psychology*, *113*(3), 353–371. https://doi.org/10.1016/j.jecp.2012.07.004

Neuman, S. B. (1988). The displacement effect: Assessing the relation between television viewing and reading performance. *Reading Research Quarterly, 23*, 414–440. https://doi.org/10.2307/747641

OECD (2022). *Information and communication technology (ICT)*. OECDiLibrary. https://doi.org/10.1787/69c2b997-en

O’Rourke, H. P., & MacKinnon, D. P. (2015). When the test of mediation is more powerful than the test of the total effect. *Behavior Research Methods, 47*, 424–442. https://doi.org/10.3758/s13428-014-0481-z

O'Rourke, H. P., & MacKinnon, D. P. (2018). Reasons for testing mediation in the absence of an intervention effect: A research imperative in prevention and intervention research. *Journal of Studies on Alcohol and Drugs, 79*(2), 171-181. https://doi.org/10.15288/jsad.2018.79.171

Özmert, E., Toyran, M., & Yurdakök, K. (2002). Behavioral correlates of television viewing in primary school children evaluated by the Child Behavior Checklist. *Archives of Pediatrics & Adolescent Medicine, 156*(9), 910–914. https://doi.org/10.1001/archpedi.156.9.910

Pagani, L. S., Fitzpatrick, C., & Barnett, T. A. (2013). Early childhood television viewing and kindergarten entry readiness. *Pediatric Research, 74*(3), 350–355. https://doi.org/10.1038/pr.2013.105

Pagani, L. S., Fitzpatrick, C., Barnett, T. A., & Dubow, E. (2010). Prospective associations between early childhood television exposure and academic, psychosocial, and physical well-being by middle childhood. *Archives of Pediatrics & Adolescent Medicine*, *164*(5). 425-431. https://doi.org/10.1001/archpediatrics.2010.50

Park, Y., Park, J., Kim, D., Seo, J., & Choi, N. (2019). The mediating effect of sleep duration on the relationship between electronic media usage time of four-year-olds and third-grader's peer attachment: Longitudinal analysis using latent variable modeling. *Journal of Korea Open Association for Early Childhood Education, 24*(3), 317-338. http://doi.org/10.20437/KOAECE24-3-13

Park, E., Sim, B., Kim, Y., & Kang, M. (2021). Longitudinal effects of media usage by early school-age children and maternal parenting stress on school adjustment: Mediating effect of executive function difficulty. *Family and Environment Research, 59*(2), 233-243. https://doi.org/10.6115/fer.2021.017

Paulus, M. P., Squeglia, L. M., Bagot, K., Jacobus, J., Kuplicki, R., Breslin, F. J., Bodurka, J., Morris, A. S., Thompson, W. K., Bartsch, H., & Tapert, S. F. (2019). Screen media activity and brain structure in youth: Evidence for diverse structural correlation networks from the ABCD study. *Neuroimage, 185*, 140-153. https://doi.org/10.1016/j.neuroimage.2018.10.040

Perry, K. E., & Weinstein, R. S. (1998). The social context of early schooling and children's school adjustment. *Educational Psychologist, 33*(4), 177-194. https://doi.org/10.1207/s15326985ep3304_3

Portilla, X. A., Ballard, P. J., Adler, N. E., Boyce, W. T., & Obradović, J. (2014). An integrative view of school functioning: Transactions between self-regulation, school engagement, and teacher–child relationship quality. *Child Development, 85*(5), 1915-1931. https://doi.org/10.1111/cdev.12259

Przybylski, A. K., & Weinstein, N. (2017). A large-scale test of the Goldilocks hypothesis: Quantifying the relations between digital-screen use and the mental well-being of adolescents. *Psychological Science*, *28*(2), 204–215. https://doi.org/10.1177/0956797616678438

Radesky, J. S., & Christakis, D. A. (2016). Increased Screen Time. *Pediatric Clinics of North America*, *63*(5), 827–839. https://doi.org/10.1016/j.pcl.2016.06.006

Radesky, J. S., Silverstein, M., Zuckerman, B., & Christakis, D. A. (2014). Infant self-regulation and early childhood media exposure. *Pediatrics*, *13*(5), e1172–e1178. https://doi.org/10.1542/peds.2013-2367

Rasi, P., Vuojärvi, H., & Ruokamo, H. (2019). Media literacy education for all ages. *Journal of Media Literacy Education*, *11*(2), 1-19. https://doi.org/10.23860/JMLE-2019-11-2-1

Ribner, A., Fitzpatrick, C., & Blair, C. (2017). Family socioeconomic status moderates associations between television viewing and school readiness skills. *Journal of Developmental & Behavioral Pediatrics*, *38*(3), 233-239. https://doi.org/10.1097/DBP.0000000000000425

Rideout, V., Peebles, A., Mann, S., & Robb, M. B. (2022). *Common Sense census: Media use by tweens and teens, 2021*. Common Sense.

Rideout, V., & Robb, M. B. (2020). *The Common Sense census: Media use by kids age zero to eight, 2020*. Common Sense.

Riggs, N. R., Jahromi, L. B., Razza, R. P., Dillworth-Bart, J. E., & Mueller, U. (2006). Executive function and the promotion of social–emotional competence. *Journal of Applied Developmental Psychology*, *27*(4), 300–309. https://doi.org/10.1016/j.appdev.2006.04.002

Rocha, H. A. L., Correia, L. L., Leite, Á. J. M., Machado, M. M. T., Lindsay, A. C., Rocha, S. G. M. O., Campos, J. S., Cavalcante e Silva, A., & Sudfeld, C. R. (2021). Screen time and early childhood development in Ceará, Brazil: A population-based study. *BMC Public Health*, *21*(1), 1-8. https://doi.org/10.1186/s12889-021-12136-2

Rogers, V. W., Hart, P. H., Motyka, E., Rines, E. N., Vine, J., & Deatrick, D. A. (2013). Impact of let's go! 5-2-1-0: A community-based, multisetting childhood obesity prevention program. *Journal of Pediatric Psychology*, *38*(9), 1010-1020. https://doi.org/10.1093/jpepsy/jst057

Rosenqvist, J., Lahti-Nuuttila, P., Holdnack, J., Kemp, S. L., & Laasonen, M. (2016). Relationship of TV watching, computer use, and reading to children's neurocognitive functions. *Journal of Applied Developmental Psychology*, *46*, 11-21. https://doi.org/10.1016/j.appdev.2016.04.006

Rudasill, K. M. (2011). Child temperament, teacher–child interactions, and teacher–child relationships: A longitudinal investigation from first to third grade. *Early Childhood Research Quarterly, 26*, 147–156. https://doi.org/10.1016/j.ecresq.2010.07.002

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68-78. https://doi.org/10.1037/0003-066X.55.1.68

Salomon, G. (1983). Television watching and mental effort: A social psychological view. In J. Bryant & D. R. Anderson (Eds.), *Children's understanding of television: Research on attention and comprehension* (pp. 35–68). Academic Press.

Sameroff, A. J., & Haith, M. M. (1996). *The five to seven year shift*. University of Chicago Press.

Sanders, W., Parent, J., Forehand, R., Sullivan, A. D., & Jones, D. J. (2016). Parental perceptions of technology and technology-focused parenting: Associations with youth screen time. *Journal of Applied Developmental Psychology, 44*, 28-38. https://doi.org/10.1016/j.appdev.2016.02.005

Sanders, T., Parker, P. D., del Pozo-Cruz, B., Noetel, M., & Lonsdale, C. (2019). Type of screen time moderates effects on outcomes in 4013 children: Evidence from the longitudinal study of Australian children. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 117. https://doi.org/10.1186/s12966-019-0881-7

Sasser, T. R., Bierman, K. L., & Heinrichs, B. (2015). Executive functioning and school adjustment: The mediational role of pre-kindergarten learning-related behaviors. *Early Childhood Research Quarterly*, *30*, 70-79. https://doi.org/10.1016/j.ecresq.2014.09.001

Schirmbeck, K., Rao, N., & Maehler, C. (2020). Similarities and differences across countries in the development of executive functions in children: A systematic review. *Infant and Child Development*, *29*(1), e2164. https://doi.org/10.1002/icd.2164

Schmidt, H. C. (2013). Media literacy education from kindergarten to college: A comparison of how media literacy is addressed across the educational system. *Journal of Media Literacy Education*, *5*(1), 295-309. https://doi.org/10.23860/jmle-5-1-3

Schmidt, M. E., Bickham, D. S., Branner, A., & Rich, M. (2008). Media-related policies of professional health organizations. In S. L. Calvert & B. J. Wilson (Eds.), *The handbook of children, media, and development* (pp. 503-526). Blackwell Publishing.

Sharif, I., Wills, T. A., & Sargent, J. D. (2010). Effect of visual media use on school performance: A prospective study. *Journal of Adolescent Health*, *46*(1), 52–61. https://doi.org/10.1016/j.jadohealth.2009.05.012

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual Review of Clinical Psychology*, *4,* 1-32. https://doi.org/10.1146/annurev.clinpsy.3.022806.091415

Shin, N. (2004). Exploring pathways from television viewing to academic achievement in school age children. *The Journal of Genetic Psychology*, *165*(4), 367–382. https://doi.org/10.3200/GNTP.165.4.367-382

Shiue, I. (2015). Duration of daily TV/screen watching with cardiovascular, respiratory, mental and psychiatric health: Scottish Health Survey, 2012–2013. *International Journal of Cardiology*, *186*, 241–246. https://doi.org/10.1016/j.ijcard.2015.03.259

Skalická, V., Wold Hygen, B., Stenseng, F., Kårstad, S. B., & Wichstrøm, L. (2019). Screen time and the development of emotion understanding from age 4 to age 8: A community study. *British Journal of Developmental Psychology*, *37*(3), 427–443. https://doi.org/10.1111/bjdp.12283

Skvarc, D. R., Penny, A., Harries, T., Wilson, C., Joshua, N., & Byrne, L. K. (2021). Type of screen time and academic achievement in children from Australia and New Zealand: Interactions with socioeconomic status. *Journal of Children and Media*, *15*(4), 509–525. https://doi.org/10.1080/17482798.2021.1878045

Song, H. (2014). Validity of child-adolescent self-reported executive function difficulty screening questionnaire. *Korean Journal of Clinical Psychology, 33*(1), 121-137.

Statistics Korea. (2023). Household trend survey. *Statistics Korea.* https://www.index.go.kr/potal/main/EachDtlPageDetail.do?idx_cd=2762

Statistics Korea, Bank of Korea, and Financial Supervisory Service (2022). Household finances and welfare survey: Household income by income quintile by household characteristics. *KOSIS*. https://kosis.kr/statHtml/statHtml.do?orgId=101&tblId=DT_1HDAB02&conn_path=I2

Stevens, T., & Mulsow, M. (2006). There is no meaningful relationship between television exposure and symptoms of attention-deficit/hyperactivity disorder. *Pediatrics*, *117*(3), 665–672. https://doi.org/10.1542/peds.2005-0863

Sung, E. (2013). The effects of mobile phone use on early adolescence in school adjustment. *Journal of Educational Information and Media*, *19*(2), 253-281.

Sy, S. R., DeMeis, D. K., & Scheinfield, R. E. (2003). Pre-school children's understanding of the emotional consequences for failures to act prosocially. *British Journal of Developmental Psychology, 21*(2), 259-272. https://doi.org/10.1348/026151003765264075

Takacs, Z. K., & Kassai, R. (2019). The efficacy of different interventions to foster children's executive function skills: A series of meta-analyses. *Psychological Bulletin*, *145*(7), 653–697. https://doi-org /10.1037/bul0000195

Tamana, S. K., Ezeugwu, V., Chikuma, J., Lefebvre, D. L., Azad, M. B., Moraes, T. J., Subbarao, P., Becker, A. B., Turvey, S. E., Sears, M. R., Dick, B. D., Carson, V., Rasmussen, C., Investigators, C. study, Pei, J., & Mandhane, P. J. (2019). Screen-time is associated with inattention problems in preschoolers: Results from the CHILD birth cohort study. *PLOS ONE*, *14*(4), e0213995. https://doi.org/10.1371/journal.pone.0213995

Tansriratanawong, S., Louthrenoo, O., Chonchaiya, W., & Charnsil, C. (2017). Screen viewing time and externalizing problems in preschool children in northern Thailand. *Journal of Child and Adolescent Mental Health, 29*(3), 245–252. https://doi.org/10.2989/17280583.2017.1409226.

Tisak, M. S., Holub, S. C., & Tisak, J. (2007). What nice things do boys and girls do? Preschoolers' perspectives of peers' behaviors at school and at home. *Early Education and Development*, *18*(2), 183-199. https://doi.org/10.1080/10409280701282686

Tofighi, D. & MacKinnon, D. P. (2011). RMediation: An R package for mediation analysis confidence intervals. *Behavior Research Methods, 43,* 692-700. https://doi.org/10.3758/s13428-011-0076-x

Tomopoulos, S., Dreyer, B. P., Valdez, P., Flynn, V., Foley, G., Berkule, S. B., & Mendelsohn, A. L. (2007). Media content and externalizing behaviors in Latino toddlers. *Ambulatory Pediatrics*, *7*(3), 232–238. https://doi.org/10.1016/j.ambp.2007.02.004

Tomopoulos, S., Valdez, P. T., Dreyer, B. P., Fierman, A. H., Berkule, S. B., Kuhn, M., & Mendelsohn, A. L. (2007). Is exposure to media intended for preschool children associated with less parent-child shared reading aloud and teaching activities? *Ambulatory Pediatrics*, *7*(1), 18–24. https://doi.org/10.1016/j.ambp.2006.10.005

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct*? Journal of Child Psychology and Psychiatry, 54*(2), 131-143. https://doi.org/10.1111/jcpp.12001

Valiente, C., Swanson, J., & Lemery-Chalfant, K. (2012). Kindergartners' temperament, classroom engagement, and student–teacher relationship: Moderation by effortful control. *Social Development, 21*(3), 558-576. https://doi.org/10.1111/j.1467-9507.2011.00640.x

Verlinden, M., Veenstra, R., Ghassabian, A., Jansen, P. W., Hofman, A., Jaddoe, V. W. V., Verhulst, F. C., & Tiemeier, H. (2014). Executive functioning and non-verbal intelligence as predictors of bullying in early elementary school. *Journal of Abnormal Child Psychology, 42*(6), 953–966. https://doi.org/10.1007/s10802-013-9832-y

Wentzel, K. R. (2013). School adjustment. In I. B. Weiner (Ed.), *Handbook of psychology* (pp. 235-258). John Wiley & Sons.

West, S. G., Finch, J. F., & Curran, P. J. (1995). *Structural equation modeling: Concepts, issues and applications*. SAGE Publications.

Wu, L., Sun, S., He, Y., & Jiang, B. (2016). The effect of interventions targeting screen time reduction: A systematic review and meta-analysis. *Medicine, 95*(27). e4029. https://doi.org/10.1097/MD.0000000000004029

Yang, X., Chen, Z., Wang, Z., & Zhu, L. (2017). The relations between television exposure and executive function in Chinese preschoolers: The moderated role of parental mediation behaviors. *Frontiers in Psychology*, *8*, 1833. https://doi.org/10.3389/fpsyg.2017.01833

Yang, Y., Li, H., Zhang, Y., Tein, J. Y., & Liu, X. (2008). Age and gender differences in behavioral problems in Chinese children: Parent and teacher reports. *Asian Journal of Psychiatry, 1*(2), 42-46. https://doi.org/10.1016/j.ajp.2008.09.005

Yang, X., Wang, Z., Qiu, X., & Zhu, L. (2020). The relation between electronic game play and executive function among preschoolers. *Journal of Child and Family Studies*, *29*(10), 2868–2878. https://doi.org/10.1007/s10826-020-01754-w

Zahedi, S., Jaffer, R., & Iyer, A. (2021). A systematic review of screen-time literature to inform educational policy and practice during COVID-19. *International Journal of Educational Research Open, 2*, 100094. https://doi.org/10.1016/j.ijedro.2021.100094

Zelazo, P. D. (2015). Executive function: Reflection, iterative reprocessing, complexity, and the developing brain. *Developmental Review*, *38*, 55–68. https://doi.org/10.1016/j.dr.2015.07.001

Zelazo, P. D. (2020). Executive function and psychopathology: A neurodevelopmental perspective. *Annual Review of Clinical Psychology*, *16*, 431-454. https://doi.org/10.1146/annurev-clinpsy-072319-024242

Zelazo, P. D., Blair, C. B., & Willoughby, M. T. (2016). *Executive function: Implications for education. NCER 2017-2000*. National Center for Education Research.

Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and plasticity. *Child Development Perspectives, 6*(4), 354-360. https://doi.org/10.1111/j.1750-8606.2012.00246.x

Zimmerman, F. J., & Christakis, D. A. (2007). Associations between content types of early media exposure and subsequent attentional problems. *Pediatrics*, *120*(5), 986–992. https://doi.org/10.1542/peds.2006-3322

Zorza, J. P., Marino, J., & Acosta Mesas, A. (2016). Executive functions as predictors of school performance and social relationships: Primary and secondary school students. *The Spanish Journal of Psychology*, *19*, E23. https://doi.org/10.1017/sjp.2016.23

APPENDIX A

TABLES

Table 1.

Sociodemographic Information

Variables	Grade 3		Grade 4	
	M (SD) or Percentage (Number of Participants)	Valid Number of Participants	M (SD) or Percentage (Number of Participants)	Valid Number of Participants
Child Age in Years	9.39 (.12)	1,460	10.33 (.11)	1,414
Percentage of Boys	51% (757)	1,484	50.9% (731)	1,436
Number of Siblings	1.21 (.69)	1,484	1.21 (.69)	1,434
Mother Education		1,467		1,415
Elementary School	.1% (1)		.1% (1)	
Middle School	.3% (5)		.3% (4)	
High School	26.9% (395)		26.3% (372)	
Junior College	28.5% (418)		29.0% (410)	
College	38.0% (557)		38.0% (537)	
Graduate College	6.2% (91)		6.4% (91)	
Father Education		1,474		1,424
Elementary School	.1% (1)		0% (0)	
Middle School	.5% (8)		.6% (8)	
High School	26.2% (386)		26.5% (378)	
Junior College	20.1% (297)		20.6% (293)	
College	41.7% (614)		40.8% (581)	
Graduate College	11.4% (168)		11.5% (164)	
Monthly Household Income in Korean Won	5,418,140 (4,831,530)	1,335	5,649,540 (5,242,366)	1,293

Note. M = mean, SD = standard deviation.

Table 2.

Summary of Measurements

Variables	Measures	Scale	Reporter
ST Duration	Time spent on smart devices and computers	Hours/day	Primary Caregivers
Recreational ST	Gaming, Entertainment (i.e., video watching and listening to music), Social networking	4-point Likert	Primary Caregivers
Educational ST	Searching for information, Learning activities	4-point Likert	Primary Caregivers
EF Difficulties	Executive Function Difficulty Screening Questionnaire (Song, 2014) Subscales: Plan/Organize, Behavioral Control, Emotional Control, Attention	3-point Likert	Primary Caregivers
School Adjustment	School Adjustment Inventory (Chi & Jung, 2006) Subscales: Classroom Behaviors, Academic Behaviors, Peer Relationships, Teacher Relationships	5-point Likert	Teachers

Note. ST = screen time, EF = executive function.

Table 3.

Attrition in Grades 3 and 4 Compared to Initial Year

Variables in Initial Sample	G3 Included (n = 1,484) n or M (SD)	G3 Attrited (n = 666) n or M (SD)	*t* or χ^2	G4 Included (n = 1,436) n or M (SD)	G4 Attrited (n = 714) n or M (SD)	*t* or χ^2
Child Sex						
Male	756	335	.076 p = .783	731	360	.045 p =.832
Female	728	331		705	354	
Residential Areas						
Large	578	284	2.839 p = .242	563	299	1.426 p = .490
Medium	602	249		575	276	
Small	304	132		297	139	
Number of Siblings	.665 (.718)	.614 (.706)	-1.511 p = .131	.662 (.712)	.624 (.722)	-1.160 p = .246
SES	-.015 (.758)	.021 (.854)	.890 p = .374	-.015 (.753)	.019 (.866)	.877 p = .381

Note. M = mean, SD = standard deviation, G3 = Grade 3, G4 = Grade 4, SES = socioeconomic status.

Table 4.

Attrition in Grade 4 Compared to Grade 3

Variables in Grade 3	Included (n = 1,391) n or M (SD)	Attrited (n = 93) n or M (SD)	*t* or χ^2
Child Sex			
Male	683	44	.112, *p* = .738
Female	708	49	
Residential Areas			
Large	553	36	
Medium	759	54	1.169, *p* = .557
Small	79	3	
Number of Siblings	1.211 (.686)	1.194 (.696)	.233, *p* = .816
SES	-.006 (.750)	.017 (.753)	-.283, *p* = .777
ST Duration	1.181 (.819)	1.306 (.876)	-1.426, *p* = .154
Educational ST	2.079 (.749)	1.994 (.753)	1.015, *p* = .310
Recreational ST	2.329 (.763)	2.419 (.740)	-1.062, *p* = .289
EFD PN	1.642 (.433)	1.608 (.410)	.685, *p* = .494
EFD BC	1.266 (.306)	1.288 (.287)	-.624, *p* = .533
EFD EC	1.448 (.452)	1.339 (.414)	2.109, *p* = .035
EFD AT	1.546 (.457)	1.519 (.418)	.518, *p* = .604
SA CB	4.236 (.823)	4.146 (.948)	.482, *p* = .630
SA AB	3.994 (.803)	3.968 (.735)	.144, *p* = .886
SA PR	4.087 (.790)	4.075 (.796)	.068, *p* = .946
SA TR	4.056 (.745)	4.060 (.649)	-.023, *p* = .491

Note. M = mean, SD = standard deviation, SES = socioeconomic status, ST = screen time, EFD = executive function difficulties, PN = plan/organize, BC = behavioral control, EC = emotional control, AT = attention, SA = school adjustment, CB = classroom behaviors, AB = academic behaviors, PR = peer relationships, TR = teacher relationships.

Table 5.

Descriptive Statistics

	EX	ST Dur	Edu ST	Rec ST	EFD PN	EFD BC	EFD EC	EFD AT	SA CB	SA AB	SA PR	SA TR
Grade 3												
M	3.24	1.19	2.07	2.33	1.64	1.27	1.44	1.54	4.24	3.94	4.09	4.03
SD	1.16	.83	.75	.76	.43	.32	.45	.45	.84	.83	.79	.80
Range	0 – 8.43	0– 6	1– 4	1– 4	1– 3	1– 3	1– 3	1– 3	1– 5	1– 5	1– 5	1– 5
Skewness	.25	1.34	.47	.37	.65	1.64	1.09	.81	-1.30	-.71	-.91	-.81
Kurtosis	.60	3.49	-.19	-.57	.00	3.17	.89	.35	1.26	.12	.54	.52
N	1,484	1,484	1,359	1,360	1,394	1,394	1,392	1,392	633	633	633	633
Grade 4												
M	3.30	1.51	2.21	2.54	1.59	1.23	1.41	1.51	4.28	3.96	4.08	4.05
SD	1.20	.97	.75	.77	.43	.31	.43	.45	.83	.85	.78	.76
Range	0 – 7.43	0– 7	1– 4	1– 4	1– 3	1– 2.80	1– 3	1– 3	1.17 – 5	1– 5	1– 5	1– 5
Skewness	.29	1.33	.48	.11	.67	1.79	1.05	.79	-1.44	-.86	-1.06	-.95
Kurtosis	.21	2.87	-.18	-.64	-.10	3.36	.76	.11	1.74	.36	1.51	1.34
N	1,434	1,409	1,387	1,386	1,401	1,401	1,401	1,401	709	709	709	709

Note. M = mean, SD = standard deviation, SES = socioeconomic status, EX = extracurricular learning-related activities, ST = screen time, Dur = duration, Edu = educational, Rec = recreational, EFD = executive function difficulties, PN = plan/organize, BC = behavioral control, EC = emotional control, AT = attention, SA = school adjustment, CB = classroom behaviors, AB = academic behaviors, PR = peer relationships, TR = teacher relationships.

Table 6.

Correlations Between Covariates and Study Variables

	ST Dur	Edu ST	Rec ST	EFD PN	EFD BC	EFD EC	EFD AT	SA CB	SA AB	SA PR	SA TR
Grade 3											
Sex	.048†	-.056*	-.050†	.176***	.279***	.076**	.185***	-.286***	-.130**	-.195***	-.098*
Age	.012	.020	.058*	-.027	.016	-.005	.006	.033	-.034	.009	-.003
N Sib	.053*	-.111***	.058*	-.051†	-.027	-.004	-.063*	.000	-.045	.038	-.030
SES	-.227***	.037	-.165***	-.072**	-.059*	-.068*	.002	.095*	.117**	.088*	.028
G3 EX	-.181***	.182***	-.251***	-.103***	-.178***	-.132***	-.076**	.129**	.168***	.119**	.136***
G4 EX	-.192***	.126***	-.231***	-.116***	-.149***	-.122***	-.098***	.036	.137***	.028	.099*
Grade 4											
Sex	.039	-.048†	-.042	.186***	.246***	.076**	.159***	-.281***	-.105**	-.176***	-.139***
Age	.033	.022	.006	.014	.038	.021	-.005	-.045	-.078*	-.073†	-.044
N Sib	.028	-.030	.082**	-.038	-.006	.019	-.051†	-.062	-.050	.026	-.014
SES	-.193***	.050†	-.186***	-.076**	-.021	-.054*	.010	.104**	.077*	.077*	-.026
G3 EX	-.194***	.103***	-.218***	-.073**	-.136***	-.119***	-.021	.112**	.085*	.065†	.019
G4 EX	-.233***	.150***	-.275***	-.148***	-.132***	-.116***	-.083**	.169***	.149***	.088*	.054

Note. N Sib = number of siblings, G3 = Grade 3, G4 = Grade 4, EX = extracurricular learning-related activities, ST = screen time, Dur = duration, Edu = educational, Rec = recreational, EFD = executive function difficulties, PN = plan/organize, BC = behavioral control, EC = emotional control, AT = attention, SA = school adjustment, CB = classroom behaviors, AB = academic behaviors, PR = peer relationships, TR = teacher relationships. Children's sex was coded 0 = female and 1 = male.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 7.

Concurrent Correlations

	ST Dur	Edu ST	Rec ST	EFD PN	EFD BC	EFD EC	EFD AT	SA CB	SA AB	SA PR	SA TR
ST Dur	-	.083**	.431***	.141***	.113***	.055*	.104***	-.081*	-.054	-.015	.036
Edu ST	.100***	-	.127***	-.057*	-.042	-.018	.002	.107**	.086*	.080*	.038
Rec ST	.418***	.131***	-	.092***	.075**	.055*	.082**	-.012	-.043	.071†	-.005
EDF PN	.067*	-.141***	.097***	-	.669***	.467***	.609***	-.250***	-.210***	-.168***	-.090*
EFD BC	.069*	-.122***	.035	.683***	-	.539***	.521***	-.330***	-.196***	-.228***	-.072†
EFD EC	.001	-.114***	.025	.441***	.544***	-	.394***	-.185***	-.099**	-.158***	-.031
EFD AT	.029	-.059*	.045	.587***	.561***	.395***	-	-.240***	-.138***	-.163***	-.044
SA CB	-.109**	.052	-.027	-.223***	-.344***	-.140***	-.217***	-	.641***	.726***	.455***
SA AB	-.108**	.093*	-.021	-.224***	-.215***	-.095*	-.131**	.629***	-	.766***	.663**
SA PR	-.059	.057	.042	-.183***	-.243***	-.155***	-.152***	.753***	.732***	-	.617***
SA TR	-.036	.067	-.034	-.051	-.066	-.025	-.035	.441***	.721***	.598***	-

Note. ST = screen time, Dur = duration, Edu = educational, Rec = recreational, EFD = executive function difficulties, PN = plan/organize, BC = behavioral control, EC = emotional control, AT = attention, SA = school adjustment, CB = classroom behaviors, AB = academic behaviors, PR = peer relationships, TR = teacher relationships.

Correlations below a diagonal are from Grade 3 and those above a diagonal are from Grade 4.

$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 8.

Longitudinal Correlations

G3 \ G4	ST Dur	Edu ST	Rec ST	EFD PN	EFD BC	EFD EC	EFD AT	SA CB	SA AB	SA PR	SA TR
ST Dur	.430***	.035	.352***	.072**	.052†	.014	.018	-.083*	-.070†	-.011	.041
Edu ST	.011	.295***	-.005	-.161***	-.161***	-.124***	-.076**	.074†	.098*	.081*	.074†
Rec ST	.306***	.028	.509***	.061*	.013	.014	.039	-.025	-.079*	-.005	-.002
EDF PN	.105***	-.068*	.059*	.703***	.509***	.354***	.491***	-.215***	-.171***	-.140***	-.059
EFD BC	.066*	-.068*	.042	.542***	.673***	.424***	.435***	-.339***	-.180***	-.236***	-.025
EFD EC	.000	-.049†	.010	.346***	.407***	.649***	.287***	-.196***	-.102**	-.148***	-.047
EFD AT	.069*	-.011	.047†	.496***	.410***	.317***	.727***	-.231***	-.109**	-.162***	-.042
SA CB	-.126**	.046	-.049	-.250***	-.330***	-.185***	-.240***	.383***	.160**	.275***	.096†
SA AB	-.107**	.041	-.104*	-.210***	-.196***	-.099**	-.138***	.216***	.304***	.238***	.254***
SA PR	-.074†	.027	-.007	-.168***	-.228***	-.158***	-.163***	.310***	.212***	.334***	.176**
SA TR	-.042	.071†	-.054	-.090*	-.072†	-.031	-.044	.108*	.188***	.170**	.259***

Note. G3 = Grade 3, G4 = Grade 4, ST = screen time, Dur = duration, Edu = educational, Rec = recreational, EFD = executive function difficulties, PN = plan/organize, BC = behavioral control, EC = emotional control, AT = attention, SA = school adjustment, CB = classroom behaviors, AB = academic behaviors, PR = peer relationships, TR = teacher relationships.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 9.

Tests for Evaluating Differences in the Model by Residential Areas

	χ^2	*df*	$\Delta\chi^2$	Δdf	*p*	CFI	ΔCFI	Pass	RMSEA [90% CI]
0. Null model	10483.64	288	-	-	-	-	-	-	-
1. Configural Invariance	554.178	180	-	-	-	.963	-	-	.053 [.048, .058]
2. Weak invariance	582.966	198	38.788	18	.004	.962	.001	Yes	.051 [.047, .056]
3. Strong invariance	635.567	218	52.601	20	< .001	.959	.003	Yes	.051 [.046, .056]
4. Homogeneity var/cov	647.545	231	11.978	13	.529	.959	.000	Yes	.049 [.045, .054]
5. Mean-level stability	664.981	222	29.414	4	< .001	.957	.002	Yes	.052 [.048, .057]

Note. For measurement invariance testing, the criterion of a change in CFI ≤ .02 was used (from Step 1 to Step 3) to compare models. For the structure part (Step 4 and Step 5), the criterion of a change in CFI ≤ .002 was used.

Table 10.

Tests Related to the Mediated Effect of Screen Time on School Adjustment Through Executive Function Difficulties

	χ^2	*df*	$\Delta\chi^2$	Δdf	*p*	CFI	ΔCFI	Pass	RMSEA [90% CI]
0. Null model	13345.85	367	-	-	-	-	-	-	-
1. Configural Invariance	769.164	222	-	-	-	.958	-	-	.040 [.037, .043]
2. Weak invariance	785.914	228	16.750	6	.010	.957	.001	Yes	.040 [.037, .043]
3. Strong invariance	791.409	234	5.495	6	.482	.957	.000	Yes	.039 [.036, .043]
4. Homogeneity var/cov	843.586	239	52.171	5	< .001	.953	.004	No	.041 [.038, .044]
5a. Mean-level stability (unconstrained)	791.409	234	-	-	-	.957	-	-	-
5b. Mean-level stability (constrained)	841.586	236	50.177	2	< .001	.953	.004	No	.041 [.038, .044]
6a. Omitted variables (full)	781.332	235	-	-	-	.958	-	-	-
6b. Omitted variables (reduced)	1049.261	251	267.929	16	< .001	.938	.019	No	.046 [.043, .048]
7. Other causal effects	877.324	253	95.992	18	< .001	.952	.006	No	.040 [.037, .043]
8. Final model	797.500	248	16.168	13	.240	.958	.000	Yes	.038 [.035, .041]

Note. var/cov = variances/covariances. For measurement invariance testing (from Step 1 to Step 3), the criterion of a change in CFI ≤ .01 was used to compare models. For the structure part (Step 4 and Step 5), the criterion of a change in CFI ≤ .002 was used.

Table 11.

Significant Relations Between Covariates and Study Variables in Model with School Adjustment Latent Variables

Relations Between Variables		Standardized Estimates (SE)
From	**To**	
Sex	G3 EX	$-.068^{*}$ (.026)
	G3 ST Duration	$.050^{*}$ (.025)
	G3 Educational ST	$-.060^{*}$ (.027)
	G3 Recreational ST	$-.057^{*}$ (.026)
	G3 EF Difficulties	$.267^{***}$ (.026)
	G3 School Adjustment	$-.238^{***}$ (.038)
	G4 School Adjustment	$-.102^{**}$ (.039)
Number of Siblings	G3 EX	$-.138^{***}$ (.025)
	G3 Educational ST	$-.108^{***}$ (.026)
SES	G3 EX	$.171^{***}$ (.025)
	G3 ST Duration	$-.224^{***}$ (.025)
	G3 Recreational ST	$-.176^{***}$ (.026)
	G3 EF Difficulties	$-.080^{**}$ (.028)
	G3 School Adjustment	$.130^{**}$ (.039)
	G4 EX	$.105^{***}$ (.023)
	G4 ST Duration	$-.082^{**}$ (.025)
	G4 Recreational ST	$-.065^{**}$ (.024)
G3 EX	G4 ST Duration	$-.080^{**}$ (.025)
	G4 Recreational ST	$-.055^{*}$ (.027)
G3 Recreational ST	G4 EX	$-.094^{***}$ (.023)
G3 EF Difficulties		$-.053^{*}$ (.025)
Covariances Between Disturbances		
SES	Number of Siblings	$-.073^{**}$ (.026)
G3 EX	G3 ST Duration	$-.137^{***}$ (.025)
	G3 Educational ST	$.164^{***}$ (.026)
	G3 Recreational ST	$-.222^{***}$ (.026)
	G3 EF Difficulties	$-.150^{***}$ (.028)
	G3 School Adjustment	$.142^{**}$ (.042)
G4 EX	G4 ST Duration	$-.103^{***}$ (.027)
	G4 Educational ST	$.108^{***}$ (.027)
	G4 Recreational ST	$-.129^{***}$ (.027)
	G4 EF Difficulties	$-.095^{**}$ (.032)

Note. SE = standard error, G3 = Grade 3, G4 = Grade 4, EX = extracurricular learning-related activities, ST = screen time, EF = executive function.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 12.

Tests Related to the Mediated Effect of Screen Time on Classroom Behaviors Through Executive Function Difficulties

	χ^2	*df*	$\Delta\chi^2$	Δdf	*p*	CFI	ΔCFI	Pass	RMSEA [90% CI]
0. Null model	9812.100	218	-	-	-	-	-	-	-
1. Configural Invariance	244.379	93	-	-	-	.984	-	-	.033 [.028, .038]
2. Weak invariance	259.396	96	15.017	3	.002	.983	.001	Yes	.033 [.029, .038]
3. Strong invariance	262.263	99	2.867	3	.413	.983	.000	Yes	.033 [.028, .038]
4. Homogeneity var/cov	314.163	101	51.900	2	< .001	.978	.005	No	.037 [.033, .042]
5a. Mean-level stability (unconstrained)	262.263	99	-	-	-	.983	-	-	-
5b. Mean-level stability (constrained)	312.410	100	50.147	1	< .001	.978	.005	No	.037 [.033, .042]
6a. Omitted variables (full)	263.915	100	-	-	-	.983	-	-	-
6b. Omitted variables (reduced)	526.405	115	262.49	15	< .001	.957	.026	No	.048 [.044, .053]
7. Other causal effects	365.583	118	101.668	18	< .001	.974	.009	No	.037 [.033, .041]
8. Final model	275.815	111	11.900	11	.371	.983	.000	Yes	.031 [.027, .036]

Note. var/cov = variances/covariances. For measurement invariance testing (from Step 1 to Step 3), the criterion of a change in CFI ≤ .01 was used to compare models. For the structure part (Step 4 and Step 5), the criterion of a change in CFI ≤ .002 was used.

Table 13.

Tests Related to the Mediated Effect of Screen Time on Academic Behaviors Through Executive Function Difficulties

	χ^2	*df*	$\Delta\chi^2$	Δdf	*p*	CFI	ΔCFI	Pass	RMSEA [90% CI]
0. Null model	9649.302	218	-	-	-	-	-	-	-
1. Configural Invariance	231.273	93	-	-	-	.985	-	-	.031 [.026, .036]
2. Weak invariance	246.137	96	14.864	3	.002	.984	.001	Yes	.032 [.027, .037]
3. Strong invariance	249.000	99	2.863	3	.414	.984	.000	Yes	.031 [.027, .036]
4. Homogeneity var/cov	300.586	101	51.586	2	< .001	.979	.005	No	.036 [.031, .041]
5a. Mean-level stability (unconstrained)	249.000	99	-	-	-	.984	-	-	-
5b. Mean-level stability (constrained)	298.952	100	49.952	1	< .001	.979	.005	No	.036 [.031, .041]
6a. Omitted variables (full)	249.497	100	-	-	-	.984	-	-	-
6b. Omitted variables (reduced)	498.311	115	248.814	15	< .001	.959	.025	No	.047 [.043, .051]
7. Other causal effects	342.520	118	93.023	18	< .001	.976	.008	No	.035 [.031, .040]
8. Final model	267.228	114	17.731	14	.219	.984	.000	Yes	.030 [.025, .034]

Note. var/cov = variances/covariances. For measurement invariance testing (from Step 1 to Step 3), the criterion of a change in CFI ≤ .01 was used to compare models. For the structure part (Step 4 and Step 5), the criterion of a change in CFI ≤ .002 was used.

Table 14.

Tests Related to the Mediated Effect of Screen Time on Peer Relationships Through Executive Function Difficulties

	χ^2	*df*	$\Delta\chi^2$	Δdf	*p*	CFI	ΔCFI	Pass	RMSEA [90% CI]
0. Null model	9680.413	218	-	-	-	-	-	-	-
1. Configural Invariance	233.149	93	-	-	-	.985	-	-	.031 [.026, .036]
2. Weak invariance	247.698	96	14.549	3	.002	.984	.001	Yes	.032 [.027, .037]
3. Strong invariance	250.582	99	2.884	3	.410	.984	.000	Yes	.032 [.031, .041]
4. Homogeneity var/cov	302.067	101	51.485	2	< .001	.979	.005	No	.036 [.032, .041]
5a. Mean-level stability (unconstrained)	250.582	99	-	-	-	.984	-	-	-
5b. Mean-level stability (constrained)	300.371	100	49.789	1	< .001	.979	.005	No	.036 [.032, .041]
6a. Omitted variables (full)	253.418	100	-	-	-	.984	-	-	-
6b. Omitted variables (reduced)	514.953	115	261.535	15	< .001	.958	.026	No	. 048 [.044, .052]
7. Other causal effects	352.546	118	99.128	18	< .001	.975	.009	No	.036 [.032, .040]
8. Final model	272.739	113	19.321	13	.113	.981	.000	Yes	.030 [.026, .035]

Note. var/cov = variances/covariances. For measurement invariance testing (from Step 1 to Step 3), the criterion of a change in CFI ≤ .01 was used to compare models. For the structure part (Step 4 and Step 5), the criterion of a change in CFI ≤ .002 was used.

Table 15.

Tests Related to the Mediated Effect of Screen Time on Teacher Relationships Through Executive Function Difficulties

	χ^2	*df*	$\Delta\chi^2$	Δdf	*p*	CFI	ΔCFI	Pass	RMSEA [90% CI]
0. Null model	9558.981	218	-	-	-	-	-	-	-
1. Configural Invariance	227.544	93	-	-	-	.986	-	-	.031 [.026, .036]
2. Weak invariance	242.001	96	14.457	3	.002	.984	.001	Yes	.032 [.027, .037]
3. Strong invariance	244.895	99	2.894	3	.408	.984	.000	Yes	.031 [.026, .036]
4. Homogeneity var/cov	296.172	101	51.277	2	< .001	.979	.005	No	.036 [.031, .040]
5a. Mean-level stability (unconstrained)	244.895	99	-	-	-	.984	-	-	-
5b. Mean-level stability (constrained)	294.557	100	49.662	1	< .001	.979	.005	No	.036 [.031, .040]
6a. Omitted variables (full)	244.978	100	-	-	-	.984	-	-	-
6b. Omitted variables (reduced)	492.938	115	247.960	15	< .001	.960	.025	No	.046 [.042, .051]
7. Other causal effects	336.586	118	91.608	18	< .001	.977	.008	No	.035 [.030, .039]
8. Final model	260.274	114	15.296	14	.579	.984	.000	Yes	.029 [.024, .034]

Note. var/cov = variances/covariances. For measurement invariance testing (from Step 1 to Step 3), the criterion of a change in CFI ≤ .01 was used to compare models. For the structure part (Step 4 and Step 5), the criterion of a change in CFI ≤ .002 was used.

Table 16.

Summary of Mediated Relations

Mediated Relations	*a* β (SE)	*b* β (SE)	*ab* β (SE) [95% CI]	Effect Size (%)
Significant Mediated Relations				
Edu ST → EFD → School Adjustment	$-.074^{***}$ (.020)	$-.164^{***}$ (.046)	.012 (.005) [.004, .023]	21.05
Edu ST → EFD → Classroom Behaviors	$-.072^{***}$ (.020)	$-.212^{***}$ (.042)	.015 (.005) [.006, .027]	75.00
Edu ST → EFD → Academic Behaviors	$-.073^{***}$ (.020)	$-.117^{**}$ (.044)	.009 (.004) [.002, .018]	16.67
Edu ST → EFD → Peer Relationships	$-.073^{***}$ (.020)	$-.134^{**}$ (.044)	.010 (.004) [.003, .019]	22.73
Non-Significant Mediated Relations				
Edu ST → EFD → Teacher Relationships	$-.070^{**}$ (.020)	-.031 (.043)	.002 (.003) [-.004, .009]	-
ST Dur → EFD → School Adjustment	.006 (.023)	$-.164^{***}$ (.046)	-.001 (.004) [-.009, .007]	-
ST Dur → EFD → Classroom Behaviors	.010 (.023)	$-.212^{***}$ (.042)	.002 (.005) [-.008, .012]	-
ST Dur → EFD → Academic Behaviors	.006 (.023)	$-.117^{**}$ (.044)	-.001 (.003) [-.007, .005]	-
ST Dur → EFD → Peer Relationships	.006 (.023)	$-.134^{**}$ (.044)	-.001 (.003) [-.008, .006]	-
ST Dur → EFD → Teacher Relationships	.006 (.023)	-.031 (.043)	0 (.001) [-.003, .002]	-
Rec ST → EFD → School Adjustment	.006 (.020)	$-.164^{***}$ (.046)	-.001 (.003) [-.008, .006]	-
Rec ST → EFD → Classroom Behaviors	.002 (.020)	$-.212^{***}$ (.042)	0 (.004) [-.008, .009]	-
Rec ST → EFD → Academic Behaviors	.005 (.019)	$-.117^{**}$ (.044)	-.001 (.002) [-.006 .004]	-
Rec ST → EFD → Peer Relationships	.005 (.020)	$-.134^{**}$ (.044)	-.001 (.003) [-.007, .005]	-
Rec ST → EFD → Teacher Relationships	.004 (.020)	-.031 (.043)	0 (.001) [-.003, .002]	-

Note. SE = standard error, CI = confidence interval, ST = screen time, EFD = executive function difficulties. Edu = educational, Dur = duration, Rec = recreational. Standardized estimates are reported. Effect size is the proportion of the total effect explained by the indirect effect.
$^{**}p < .01$. $^{***}p < .001$.

Table 17.

Significant Relations Between Covariates and Study Variables in Model with Observed Variables of Classroom Behaviors

Relations Between Variables		Standardized Estimates (SE)
From	**To**	
Sex	G3 EX	$-.068^{**}$ (.026)
	G3 ST Duration	$.050^{*}$ (.025)
	G3 Educational ST	$-.060^{*}$ (.027)
	G3 Recreational ST	$-.057^{*}$ (.026)
	G3 EF Difficulties	$.265^{***}$ (.027)
	G3 Classroom Behaviors	$-.300^{***}$ (.034)
	G4 Classroom Behaviors	$-.161^{**}$ (.036)
Number of Siblings	G3 EX	$-.137^{***}$ (.025)
	G3 Educational ST	$-.108^{***}$ (.026)
SES	G3 EX	$.171^{***}$ (.025)
	G3 ST Duration	$-.224^{***}$ (.025)
	G3 Recreational ST	$-.176^{***}$ (.026)
	G3 EF Difficulties	$-.079^{**}$ (.028)
	G3 Classroom Behaviors	$.112^{**}$ (.036)
	G4 EX	$.106^{***}$ (.023)
	G4 ST Duration	$-.081^{**}$ (.025)
	G4 Recreational ST	$-.064^{**}$ (.024)
G3 EX	G4 ST Duration	$-.080^{**}$ (.025)
	G4 Recreational ST	$-.056^{*}$ (.025)
G3 Recreational ST		$-.073^{**}$ (.026)
G3 EF Difficulties	G4 EX	$-.078^{**}$ (.028)
G3 Classroom Behaviors		$-.091^{*}$ (.038)
Covariances Between Disturbances		
SES	Number of Siblings	$-.073^{**}$ (.026)
G3 EX	G3 ST Duration	$-.137^{***}$ (.025)
	G3 Educational ST	$.164^{***}$ (.026)
	G3 Recreational ST	$-.222^{***}$ (.026)
	G3 EF Difficulties	$-.150^{***}$ (.028)
	G3 Classroom Behaviors	$.113^{**}$ (.040)
G4 EX	G4 ST Duration	$-.106^{***}$ (.027)
	G4 Educational ST	$.111^{***}$ (.027)
	G4 Recreational ST	$-.129^{***}$ (.027)
	G4 EF Difficulties	$-.097^{**}$ (.032)
	G4 Classroom Behaviors	$.103^{**}$ (.039)

Note. SE = standard error, G3 = Grade 3, G4 = Grade 4, EX = extracurricular learning-related activities, ST = screen time, EF = executive function, SES = socioeconomic status.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 18.

Significant Relations Between Covariates and Study Variables in Model with Observed Variables of Academic Behaviors

Relations Between Variables		Standardized Estimates (SE)
From	**To**	
Sex	G3 EX	-.068** (.025)
	G3 ST Duration	.050* (.025)
	G3 Educational ST	-.060* (.027)
	G3 Recreational ST	-.057* (.026)
	G3 EF Difficulties	.265*** (.027)
	G3 Academic Behaviors	-.147*** (.037)
Number of Siblings	G3 EX	-.137*** (.025)
	G3 Educational ST	-.108*** (.026)
SES	G3 EX	.171*** (.025)
	G3 ST Duration	-.224*** (.025)
	G3 Recreational ST	-.176*** (.026)
	G3 EF Difficulties	-.079** (.028)
	G3 Academic Behaviors	.140*** (.037)
	G4 EX	.108*** (.023)
	G4 ST Duration	-.082** (.025)
	G4 Recreational ST	-.065** (.024)
G3 EX	G4 ST Duration	-.080** (.025)
	G4 Recreational ST	-.057* (.025)
G3 Recreational ST	G4 EX	-.097*** (.023)
Covariances Between Disturbances		
SES	Number of Siblings	-.073** (.026)
G3 EX	G3 ST Duration	-.137*** (.025)
	G3 Educational ST	.164*** (.026)
	G3 Recreational ST	-.222*** (.026)
	G3 EF Difficulties	-.149*** (.028)
	G3 Academic Behaviors	.143** (.040)
G4 EX	G4 ST Duration	-.105*** (.027)
	G4 Educational ST	.109*** (.027)
	G4 Recreational ST	-.129*** (.027)
	G4 EF Difficulties	-.099** (.032)
	G4 Academic Behaviors	.078* (.039)

Note. SE = standard error, G3 = Grade 3, G4 = Grade 4, EX = extracurricular learning-related activities, ST = screen time, EF = executive function, SES = socioeconomic status.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 19.

Significant Relations Between Covariates and Study Variables in Model with Observed Variables of Peer Relationships

Relations Between Variables		Standardized Estimates (SE)
From	**To**	
Sex	G3 EX	-.068** (.025)
	G3 ST Duration	.050* (.025)
	G3 Educational ST	-.060* (.027)
	G3 Recreational ST	-.056* (.026)
	G3 EF Difficulties	.265*** (.027)
	G3 Peer Relationships	-.211*** (.037)
	G4 Peer Relationships	-.084* (.038)
Number of Siblings	G3 EX	-.137*** (.025)
	G3 Educational ST	-.108*** (.026)
SES	G3 EX	.171*** (.025)
	G3 ST Duration	-.224*** (.025)
	G3 Recreational ST	-.176*** (.026)
	G3 EF Difficulties	-.078** (.028)
	G3 Peer Relationships	.104** (.037)
	G4 EX	.105*** (.023)
	G4 ST Duration	-.082** (.025)
	G4 Recreational ST	-.066** (.024)
G3 EX	G4 ST Duration	-.080** (.025)
	G4 Recreational ST	-.056* (.025)
G3 Recreational ST	G4 EX	-.095*** (.023)
G3 EF Difficulties		-.053* (.025)
Covariances Between Disturbances		
SES	Number of Siblings	-.073** (.026)
G3 EX	G3 ST Duration	-.137*** (.025)
	G3 Educational ST	.164*** (.026)
	G3 Recreational ST	-.222*** (.026)
	G3 EF Difficulties	-.149*** (.028)
	G3 Peer Relationships	.104* (.040)
G4 EX	G4 ST Duration	-.103*** (.027)
	G4 Educational ST	.108*** (.027)
	G4 Recreational ST	-.129*** (.027)
	G4 EF Difficulties	-.094** (.032)

Note. SE = standard error, G3 = Grade 3, G4 = Grade 4, EX = extracurricular learning-related activities, ST = screen time, EF = executive function, SES = socioeconomic status.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 20.

Significant Relations Between Covariates and Study Variables in Model with Observed Variables of Teacher Relationships

Relations Between Variables		Standardized Estimates (SE)
From	**To**	
Sex	G3 EX	-.068* (.025)
	G3 ST Duration	.050* (.025)
	G3 Educational ST	-.060* (.027)
	G3 Recreational ST	-.057* (.026)
	G3 EF Difficulties	.265*** (.027)
	G3 Teacher Relationships	-.112** (.039)
	G4 Teacher Relationships	-.107** (.039)
Number of Siblings	G3 EX	-.137*** (.025)
	G3 Educational ST	-.108*** (.026)
SES	G3 EX	.171*** (.025)
	G3 ST Duration	-.224*** (.025)
	G3 Recreational ST	-.175*** (.026)
	G3 EF Difficulties	-.078** (.028)
	G4 EX	.105*** (.023)
	G4 ST Duration	-.082** (.025)
	G4 Recreational ST	-.066** (.024)
G3 EX	G4 ST Duration	-.080** (.025)
	G4 Recreational ST	-.066* (.024)
G3 Recreational ST	G4 EX	-.094*** (.023)
Covariances Between Disturbances		
SES	Number of Siblings	-.073** (.026)
G3 EX	G3 ST Duration	-.137*** (.025)
	G3 Educational ST	.165*** (.026)
	G3 Recreational ST	-.222*** (.026)
	G3 EF Difficulties	-.149*** (.028)
	G3 Teacher Relationships	.128** (.041)
G4 EX	G4 ST Duration	-.103*** (.027)
	G4 Educational ST	.108*** (.027)
	G4 Recreational ST	-.131*** (.027)
	G4 EF Difficulties	-.093** (.032)

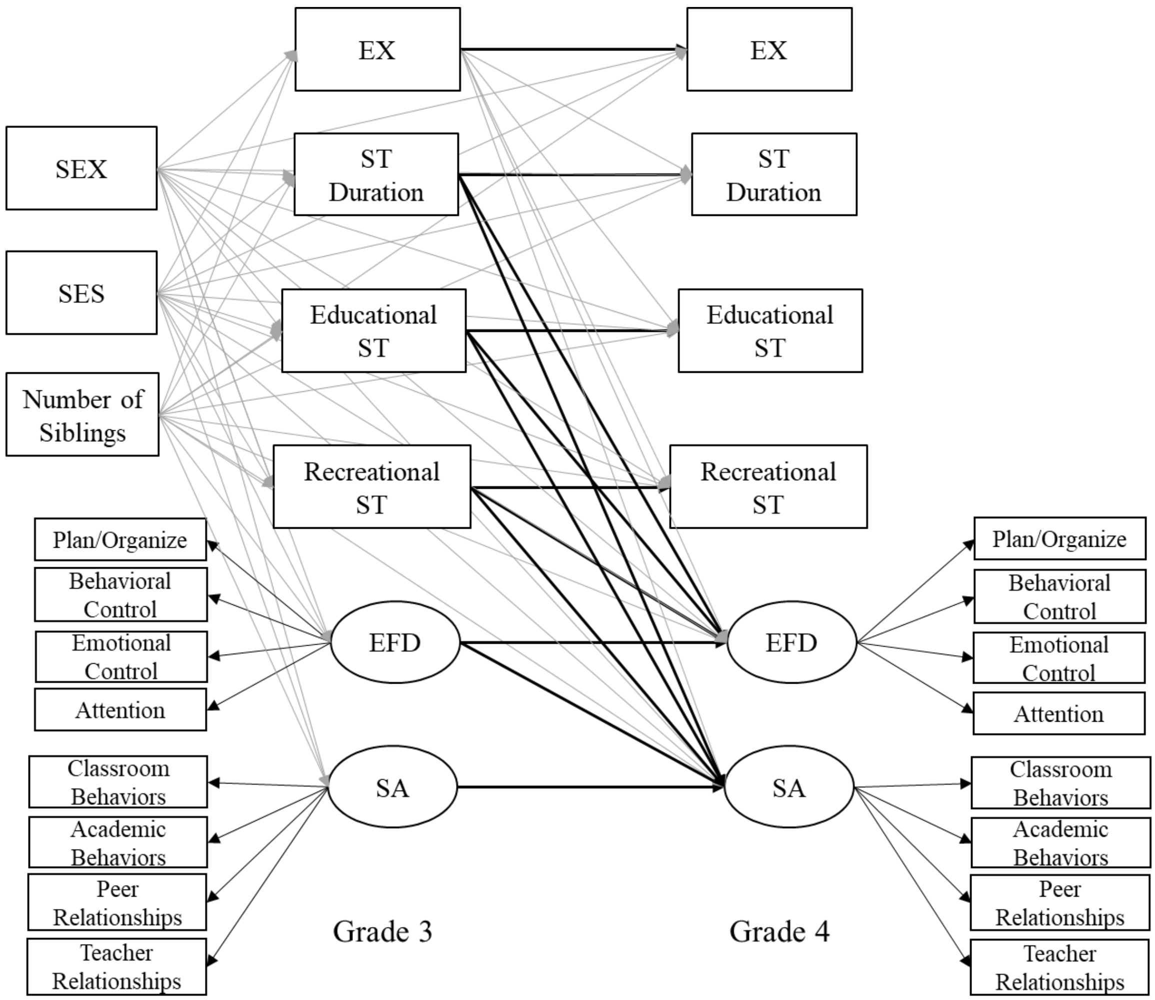
Note. SE = standard error, G3 = Grade 3, G4 = Grade 4, EX = extracurricular learning-related activities, ST = screen time, EF = executive function, SES = socioeconomic status.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

APPENDIX B

FIGURES

Figure 1.

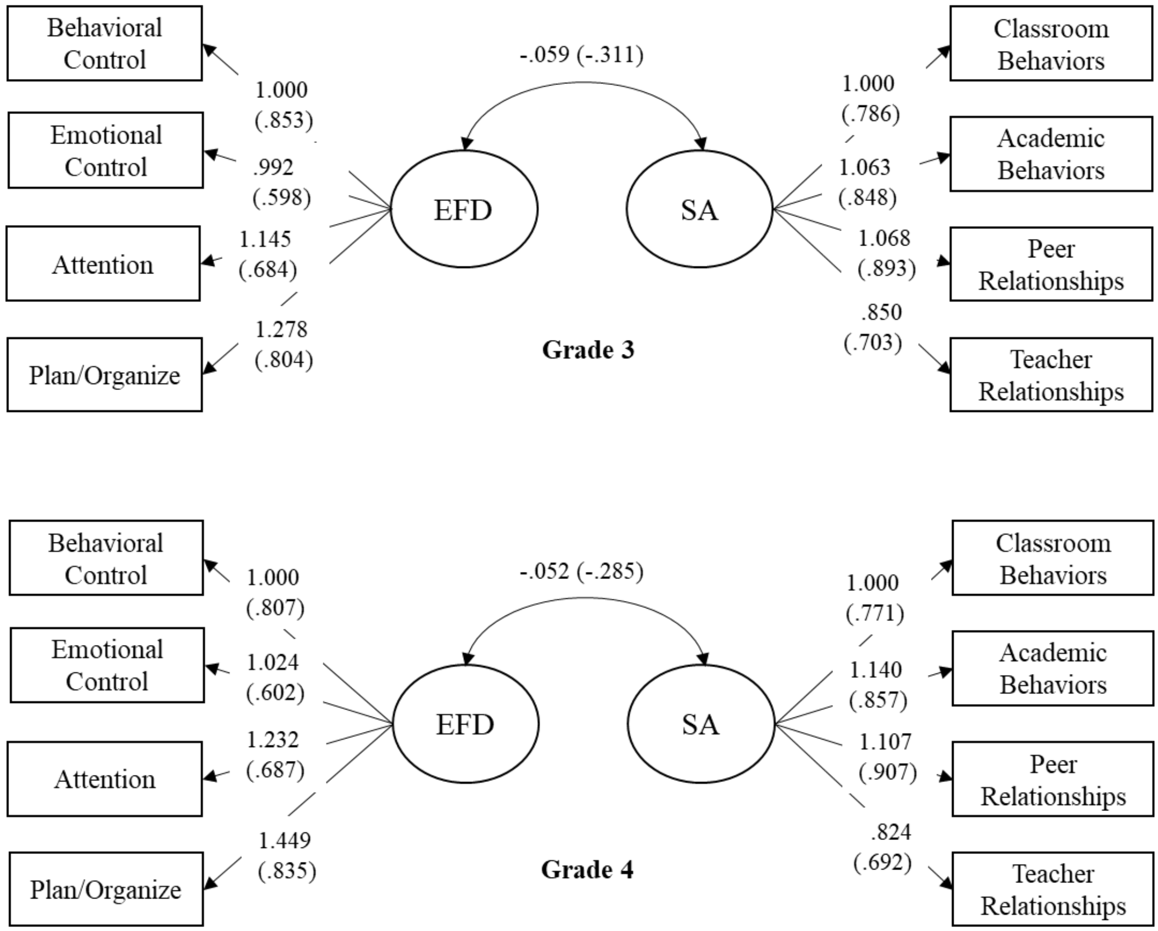
Hypothesized Model Illustrating the Mediated Effect of Screen Time on School Adjustment Through Executive Function Difficulties



Note. EX = extracurricular learning-related activities, ST = screen time, EFD = executive function difficulties, SA = school adjustment. Black lines represent hypothesized paths between study variables. Grey lines represent hypothesized paths from covariates to study variables. Covariances between uniqueness, covariances between exogenous variables, and covariances between disturbances of endogenous variables were included in the analysis but not depicted in the figure for clarity.

Figure 2.

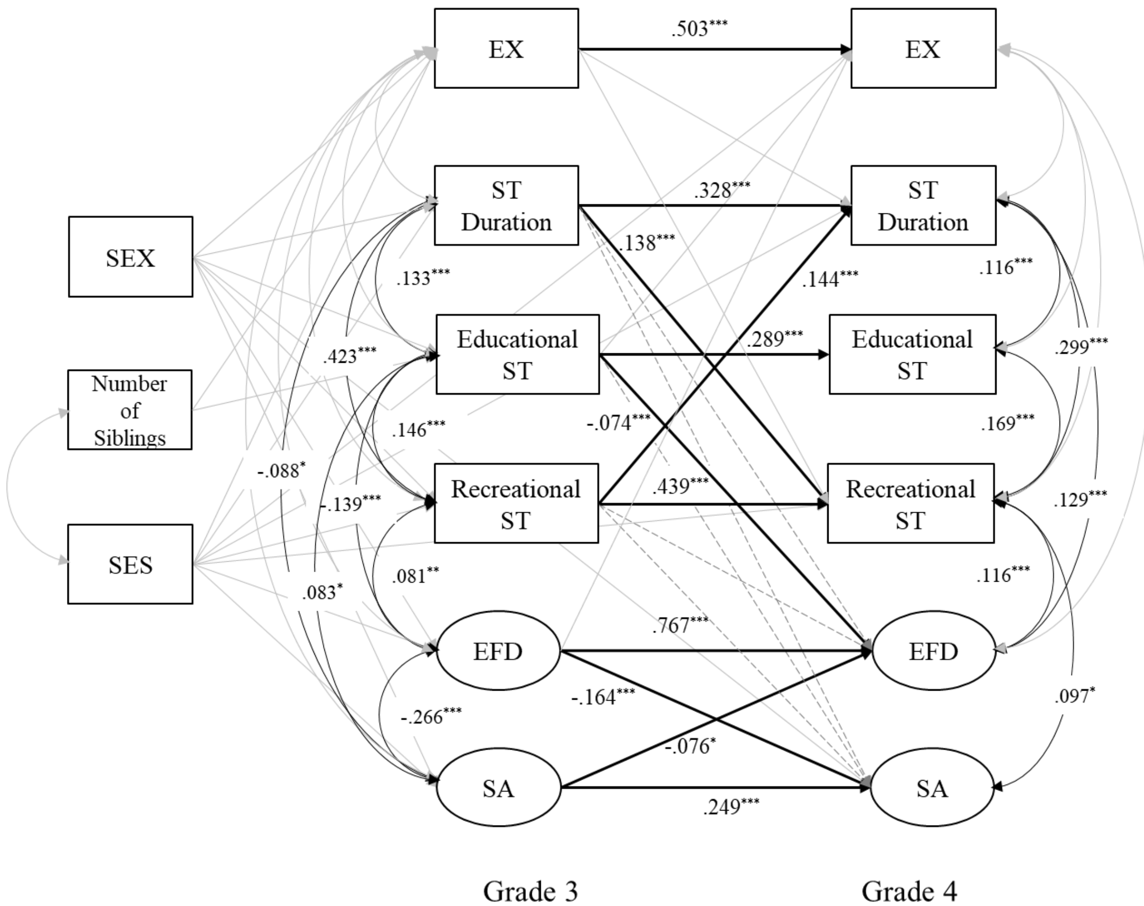
Measurement Models for Executive Function Difficulties and School Adjustment



Note. EFD = executive function difficulties, SA = school adjustment. Both unstandardized and standardized estimates are presented and standardized estimates are in parentheses. All values are significant at $p < .001$.

Figure 3.

Mediated Relations Between Screen Time and School Adjustment Through Executive Function Difficulties

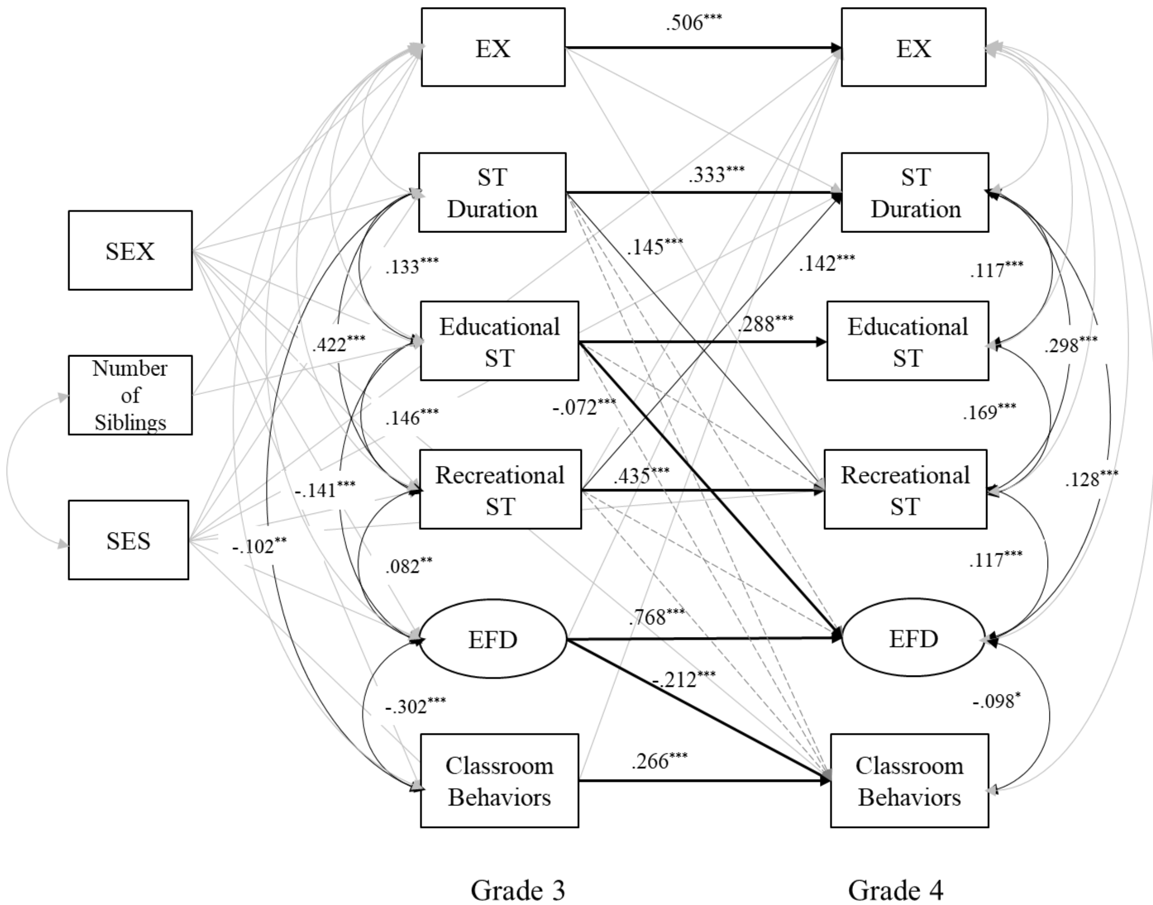


Note. ST = screen time, EFD = executive function difficulties, SA = school adjustment. Standardized estimates are presented. Measurement parts for EFD and SA were not depicted in the figure for clarity. For the paths related to covariates and covariances between disturbances of endogenous variables, only significant paths were presented. Solid grey lines represent significant paths to, from, or between covariates. Dashed grey lines represent non-significant hypothesized paths.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Figure 4.

Mediated Relation Between Screen Time and Classroom Behaviors Through Executive Function Difficulties

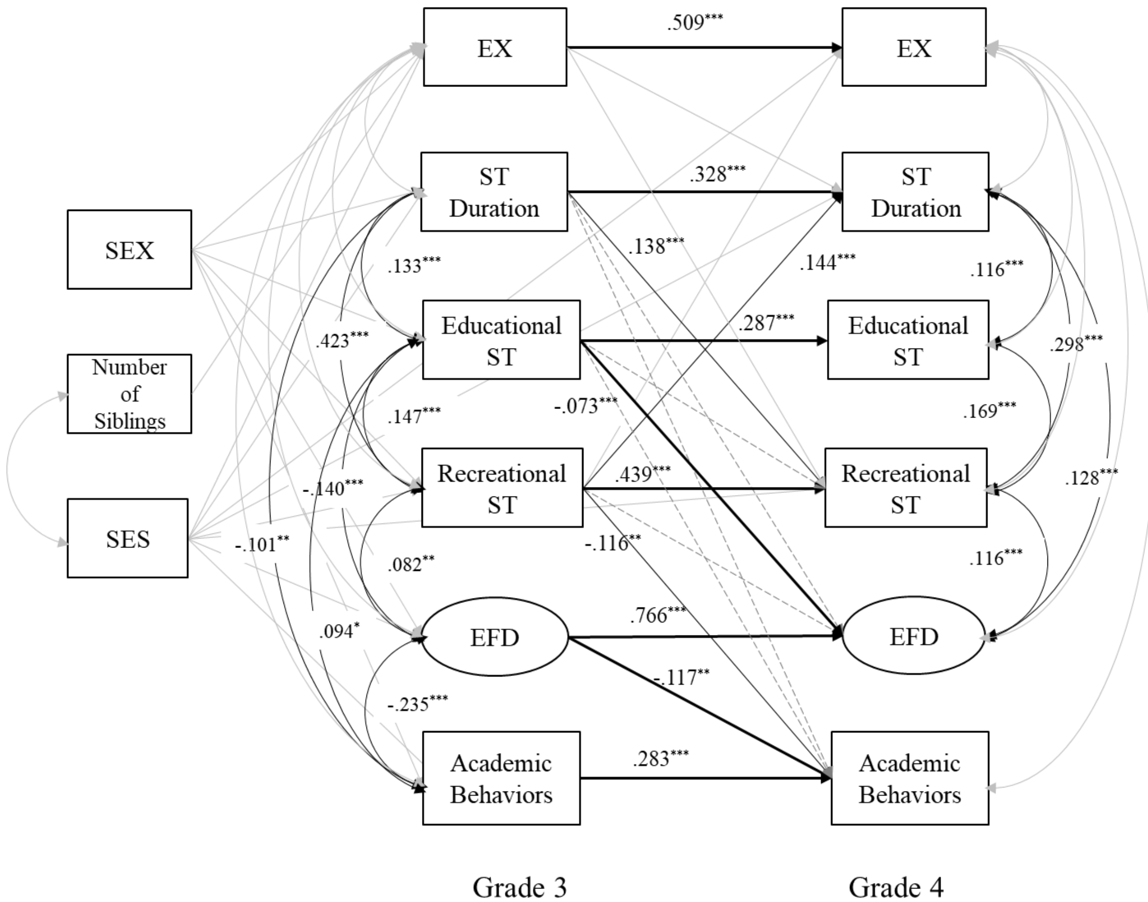


Note. ST = screen time, EFD = executive function difficulties. Standardized estimates are presented. Measurement parts for EFD and SA were not depicted in the figure for clarity. For the paths related to covariates and covariances between disturbances of endogenous variables, only significant paths were presented. Solid grey lines represent significant paths to, from, or between covariates. Dashed grey lines represent non-significant hypothesized paths.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Figure 5.

Mediated Relation Between Screen Time and Academic Behaviors Through Executive Function Difficulties

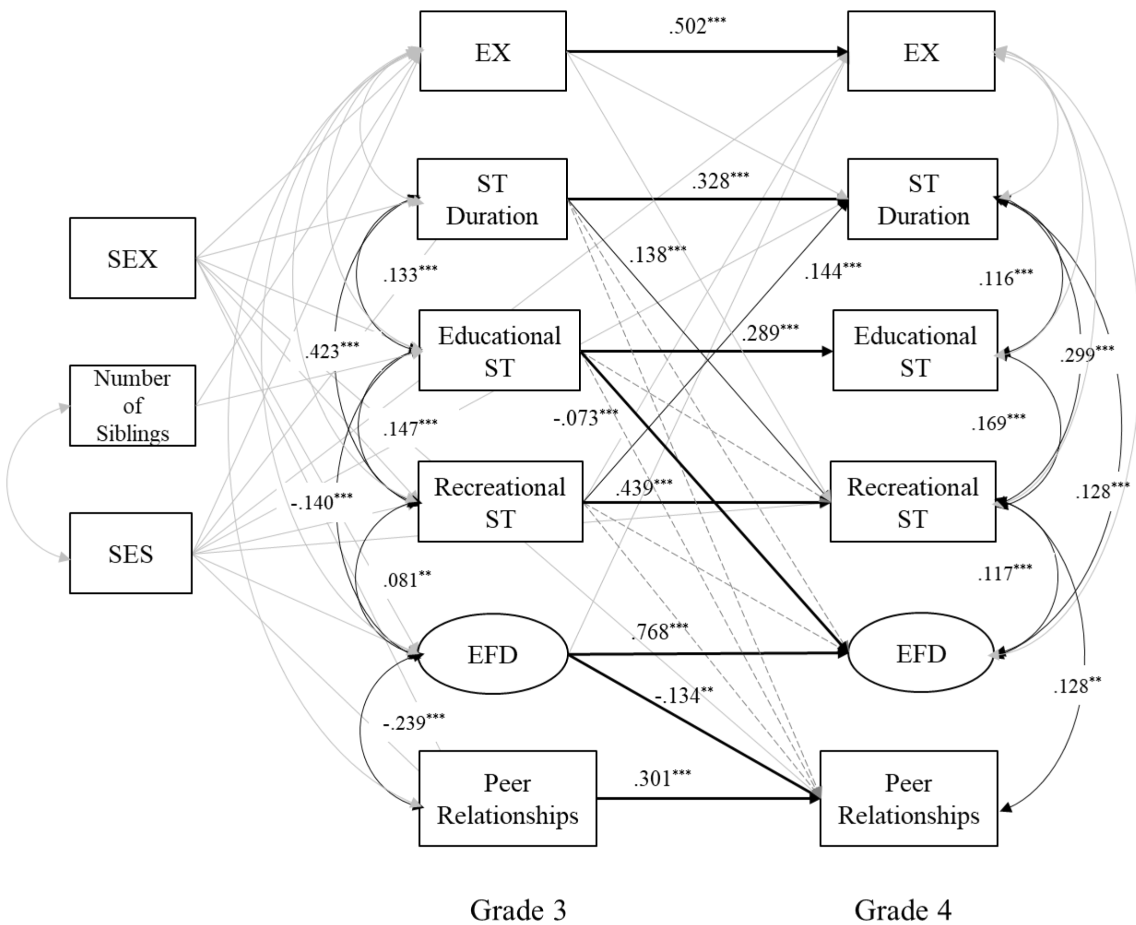


Note. ST = screen time, EFD = executive function difficulties. Standardized estimates are presented. Measurement parts for EFD and SA were not depicted in the figure for clarity. For the paths related to covariates and covariances between disturbances of endogenous variables, only significant paths were presented. Solid grey lines represent significant paths to, from, or between covariates. Dashed grey lines represent non-significant hypothesized paths.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Figure 6.

Mediated Relation Between Screen Time and Peer Relationships Through Executive Function Difficulties

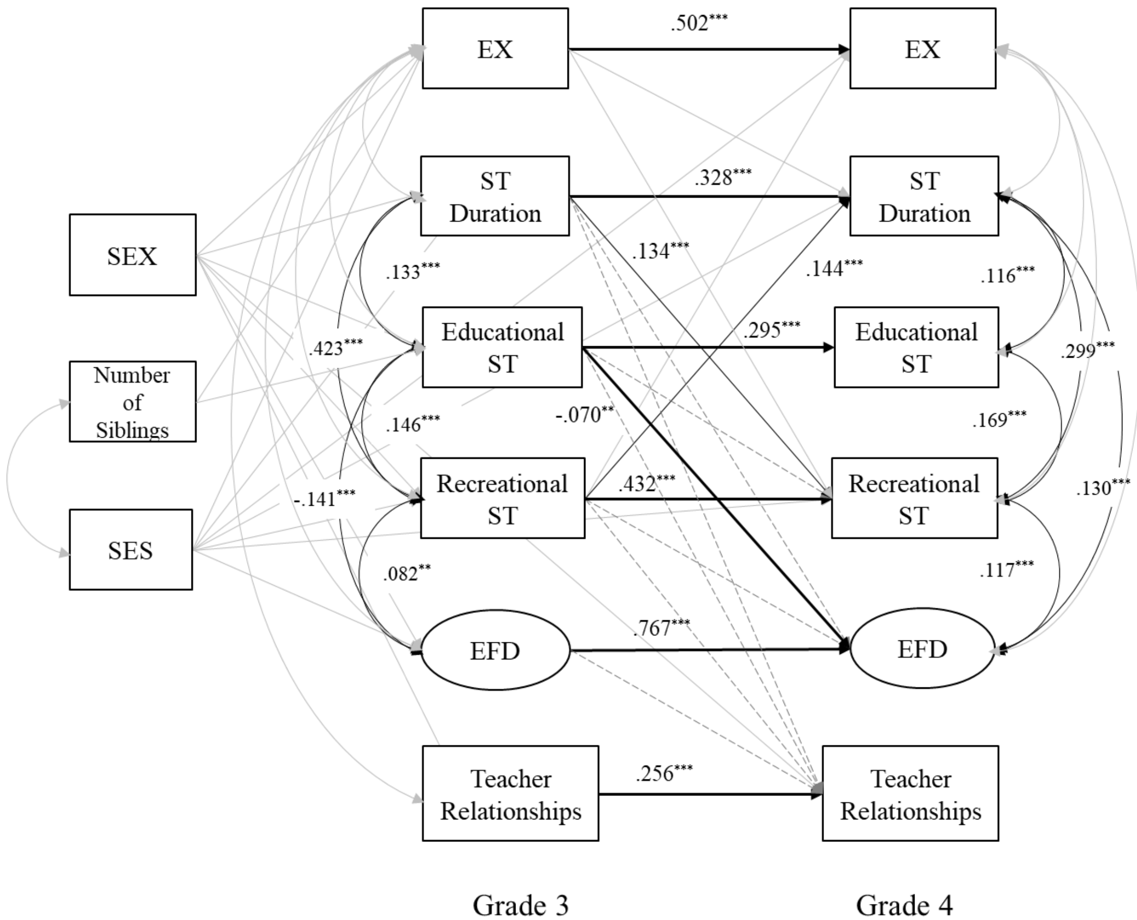


Note. ST = screen time, EFD = executive function difficulties. Standardized estimates are presented. Measurement parts for EFD and SA were not depicted in the figure for clarity. For the paths related to covariates and covariances between disturbances of endogenous variables, only significant paths were presented. Solid grey lines represent significant paths to, from, or between covariates. Dashed grey lines represent non-significant hypothesized paths.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Figure 7.

Mediated Relation Between Screen Time and Teacher Relationships Through Executive Function Difficulties



Note. ST = screen time, EFD = executive function difficulties. Standardized estimates are presented. Measurement parts for EFD and SA were not depicted in the figure for clarity. For the paths related to covariates and covariances between disturbances of endogenous variables, only significant paths were presented. Solid grey lines represent significant paths to, from, or between covariates. Dashed grey lines represent non-significant hypothesized paths.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

APPENDIX C

QUESTIONNAIRES

Executive Function Difficulty Screening Questionnaire (Song, 2014)

	Items	Subscale
1.	Feel hard to start anything.	Plan/ Organize
2.	When there is a lot to do (e.g., homework, studying, errands, etc.), they get confused about what to do.	
3.	Tend to procrastinate tasks almost until the last minute.	
4.	Find it difficult to do things that need to be done step by step in order.	
5.	Cannot predict in advance how much time it will take to complete a task.	
6.	Can make a plan, but they struggle with putting it into action.	
7.	Find it difficult to set goals and take actual steps to achieve them.	
8.	Cannot understand the crucial key points although they seem to partly understand the content.	
9.	Cannot take the lead and initiate things on their own.	
10.	Find it challenging to plan and execute tasks in a systematic and orderly manner.	
11.	Cannot concentrate well when doing tasks like homework, studying, or errands.	
12.	Compared to peers, they seem to have more difficulty regulating their actions.	Behavioral Control
13.	Have difficulty controlling behaviors.	
14.	Tend to act too impulsively.	
15.	Without adult supervision and assistance, it is difficult for them to do tasks like homework, studying, or errands on their own.	
16.	Struggle with writing.	
17.	Disrupt others.	
18.	Find it hard to stay in their seat when they need to sit down and concentrate.	
19.	When they need to stand in line, they wander off instead of staying in place.	
20.	Are not very aware of whether their behavior is bothering others or not.	

21.	Unless someone is watching, they cannot consistently sit down and focus on tasks like homework or studying.	
22.	Do not care much even if people around them criticize or nag them about their behaviors.	
23.	Easily explode in anger over trivial matters.	Emotional Control
24.	Mood changes drastically depending on the situation.	
25.	Struggle to tolerate things and often lose their temper.	
26.	Frequently burst into tears.	
27.	Complain and grumble even when it is unnecessary.	
28.	Overreact to minor things.	
29.	Get instantly angry if there are changes in the original plans	
30.	Experience intense mood swings	
31.	Do not take care of their belongings and leave them scattered around.	Attention
32.	Struggle to find items like clothes, glasses, socks, toys, books, pencils, etc.	
33.	Cannot keep their room tidy.	
34.	Forget to submit completed homework to the teacher even if it is done.	
35.	Frequently lose belongings or homework.	
36.	Tend to forget things easily.	
37.	Forget tasks that need to be done.	
38.	Keep their room consistently messy.	
39.	Have difficulty finding items in their room or on the desk.	
40.	Create a mess with belongings and in the room, needing others to clean up.	

Note. Item 22 was excluded from the analysis due to low communalities at both time points.

School Adjustment Inventory (Chi & Jung, 2006)

	Items	Subscale
1.	Find it difficult to sit still during class (Reverse coded).	Classroom Behaviors
2.	Maintain good order at school.	
3.	Follow the classroom rules.	
4.	Maintain order during outdoor activities.	
5.	Handle tasks with patience in given situations.	
6.	During class, they don't engage in other activities or play around.	
7.	Organize their belongings well and help keep the classroom tidy.	
8.	Adhere well to the teacher's guidance and instructions.	
9.	Punctual at school arrival time, class time, and break time.	
10.	Pay attention and listen well during class.	
11.	Act younger than their age.	
12.	Enthusiastic about everything.	Academic Behaviors
13.	Show clear expressions.	
14.	Express their thoughts and opinions willingly and confidently.	
15.	Perform assignments well and bring necessary materials.	
16.	Take the lead in play and activities at school.	
17.	Have a strong desire to think and explore.	
18.	Actively participate in activities during class.	
19.	Exhibit bright and cheerful expressions.	
20.	Actively engage in group activities and class activities.	

21.	Show a strong sense of responsibility towards assigned tasks.	
22.	When faced with difficult problems, they don’t easily get discouraged and don’t give up midway.	
23.	Share and play with toys with peers.	Peer Relationships
24.	Help peers well.	
25.	When peers forget textbooks or materials, they share or lend them.	
26.	Comfort peers when they are sad.	
27.	Resolve conflicts with peers using positive approaches.	
28.	Are popular among peers.	
29.	Get along well with peers.	
30.	Demonstrate leadership in interactions with peers.	
31.	Excessively fear and feel intimidated by teachers (Reverse coded).	Teacher Relationships
32.	Freely talk with teachers anytime.	
33.	Want to discuss their home life or personal matters with teachers.	
34.	Greet teachers well.	
35.	Ask teachers for help when needed.	

Note. Items 11 and 31 were excluded from the analysis due to low communalities at both time points. Items 15 and 21 were moved to Classroom Behaviors from Academic Behaviors.