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Article

Screen Time and Attention Subdomains in Children Aged 6 to 10 Years

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Abstract: Using digital media has become the most popular leisure activity for children and adolescents. The effects of digital media use on the developing brain and cognitive processes of children are subject to debate. Here, we examine the effect of digital media use on attention subdomains in children aged 6 to 10 years. In total, 77 children participated in the study. Selective and divided attention as well as switching between attentional demands were quantified by the SwAD task. Parents were asked to assess the screen time of their children (TV, smartphone, laptop/PC, game console, tablet). Results show no main or interaction effects of screen time on any of the attention conditions investigated. Based on the present findings, as well as previous studies, we suggest a possible non-linear relationship between the amount of screen time and attention function. Furthermore, we emphasize the relevance of considering the socio-economic background of children and a need for longitudinal studies.

Keywords: children; digital media; attention; development; cognition

1. Introduction

More than half a century ago, televisions entered the households of children around the globe, followed by game consoles in the 1970s. Today, more than a third of children have their own smartphone or tablet device (McNeill et al., 2019; Radesky et al., 2015; Twenge & Campbell, 2018), with younger children being among the strongest users of digital media applications (Fischer-Grote et al., 2019). However, their developmental vulnerability makes it necessary to critically consider the effects of screen time, especially in this age group. In available literature, effects have been heatedly discussed in different areas, such as mental and physical health (Lissak, 2018), social skills (Hinkley et al., 2018), as well as cognitive functions (Sauce et al., 2022). Findings show consistent evidence about negative effects mainly depending on both the duration and content of media use (Chassiakos et al., 2016; Walsh et al., 2020).

In earlier research, effects of using digital media on cognitive abilities have been discussed controversial (Kostyrka-Allchorne et al., 2017; Paulus et al., 2019; Sauce et al., 2021; Walsh et al., 2020). This topic is further complicated because cognitive abilities comprise a variety of mental processes such as attention, perception, inhibition, and decision making. Therefore, in addition to the duration and content, individual cognitive functions need to be considered specifically, in order to get a better understanding of the effects of using digital media. Our focus in the present study is on the effects of screen time on attention: the ability to sort and focus on relevant stimuli. As a multidimensional construct, attention itself consists of multiple interacting subcomponents developing at different times across childhood (Goldberg et al., 2001).

Previous studies on watching television in early childhood identified a negative relation between watching television and attention skills, especially when watching programmes created for adults (Kostyrka-Allchorne et al., 2017). With regard to attention problems some identified a relation with watching television (Lingineni et al., 2012; Özmert et al., 2002; van Egmond-Fröhlich et al., 2012) while others did not (Ferguson, 2011; Foster & Watkins, 2010; Parkes et al., 2013; Schmiedeler et al., 2014). In those who identified significant relations, the amount of screen time related positively to attention problems varied from >1h/day (Lingineni et al., 2012) to > 2h/day (Özmert et al., 2002) of watching television in young children. In adolescence, the value for which negative effects on attention are reported increases to >3h/day (Johnson et al., 2007).

In contrast to watching television, which represents a passive way of using (digital) media, computers, tablets, and smartphones allow children to increasingly interact with the devices and applications. Video games are one of the applications most commonly used by children. They have even been reported to generally improve attention skills (Green & Bavelier, 2012). More specifically, findings from children/teenager of different ages show improvements in alerting and orienting (Dye et al., 2009), selective visual attention (Dye & Bavelier, 2010) as well as sustained attention (Trisolini et al., 2018) related to playing action video games. However, evidence from clinical studies shows a positive relation between pathological gaming behavior and attention problems (Muzwagi et al., 2021). Similar findings have been reported in clinical studies on problematic smartphone use (Bozkurt et al., 2013). However, in both there is also evidence showing no relation between video-gaming and attention problems (Nikkelen et al., 2015; Zimmerman & Christakis, 2007).

In children/adolescents, smartphones are most frequently used for communication applications (phone calls, social networking apps, messenger apps) and Internet browsing, in addition to listening to music and watching videos (Statista, 2022). Counterintuitive, findings show a relation between heavy use of social networking site/Internet browsing and improvements in attention performance in children and adolescents (Alobaid et al., 2018). However, there is, to our best knowledge, no further evidence on the effects of smartphone usage on attention processes in children/adolescents. However, evidence from adult samples show an increased level of distraction/inattention in the mere presence of a smartphone, but longitudinal studies are also missing (Liebherr et al., 2020).

Digital devices are constantly evolving, and so are their applications. As a result, demands and possible effects on attention processes are also permanently changing, which calls for a regularly update of our understandings in the present field of interest. Especially in children, findings on the effects of using digital media on subcomponents of attention are limited. Here, the present study aims to contribute by providing findings on the relation between using different digital media applications (Television, Laptop/Computer, Tablet, Smartphone) and subcomponents of attention in primary school-aged children. We focus on the most relevant attention subcomponents of everyday life: selective attention, divided attention, and switching attention (McDowd & Shaw, 2000).

2. Methods

2.1. Participants

In total, 77 children (age (in years): *M*=8.04, *SD*=1.35; range: 6–10; 35 girls; 1st grade-4th grade) participated in the present study. All were reported by parents to have normal or corrected to normal hearing and vision, and to have no history of psychological and/or neurological disorders or any acute disease. Both, children and parents were informed about the study, with parents providing consent and children assent for participation. Children were further informed that they could end the study at any time. The study was performed in accordance with the ethical standards laid down in the Declaration of Helsinki and approved by the local ethics committee of the Department of Computer Science and Applied Cognitive Sciences, University Duisburg-Essen.

2.2. Materials

2.2.1. Switching between selective and divided attention

A modified version of the Switching Attentional Demands (SwAD) task was used to measure performance of selective, divided, and switching between selective and divided attention (Liebherr et al., 2019). The modification refers to the visual stimuli, presented. In the present context, we used simple symbols, instead of geometric shapes, to make the task less complex for administration to children.

The task comprises a training session that provides feedback, as well as four blocks of selective attention, four blocks of divided attention, and eight blocks of switching attention. Each block includes 26 trials with five to eight target stimuli. Stimuli include coloured dots (e.g., blue, red, green) and symbols (e.g., heart, moon, star, flower), each presented for 250ms. The respective symbol as well as coloured dot are presented simultaneously in the middle of the screen (see Figure 1). The two conditions differ solely in its instruction. In selective attention, participants should respond to either a coloured dot (e.g., blue) or a shape (e.g., flower) by pressing a button. In divided attention, both coloured dots and shapes act as target stimuli on which participants had to respond by pressing different buttons. In switching attention, four blocks of selective attention and four blocks of divided attention are applied alternating with no break in between. Interstimulus intervals are randomized between 500ms and 2300ms in which a fixation-cross is presented in the middle of the screen. Maximum time to respond on a single stimulus is set to 1800ms. Time to complete the task took approximately 20 minutes. Task-performance was quantified by reaction time, while error rate was used to identify outliers (Liebherr et al., 2019).

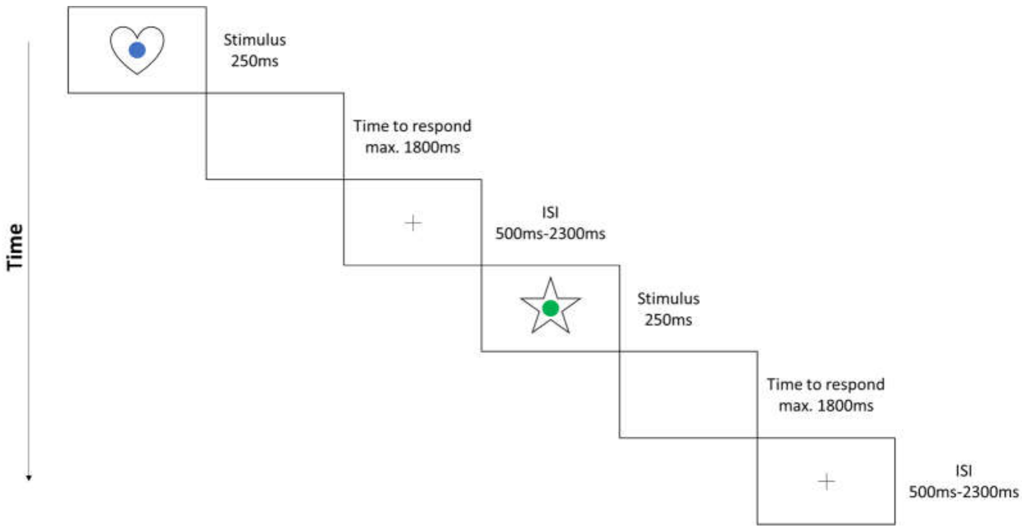

Figure 1. Schematic overview of the SwAD-task (child version) (see also Liebherr et al., 2019).

2.2.2. Digital Media use and leisure activity

Digital media use was measured using an online survey. Parents were asked if the children have an own television, smartphone, tablet, game console, or computer as well as how much they use it on average each day. Ratings were made on a scale of none, <30 min, 30 min, 1h, 2h, 3h, to > 4h separately for each media device as would be typical for a regular day. In addition, all children were asked after their testing which games they usually play on the PC/game console, which applications they use on their smartphone. Furthermore, they were asked which non-digital activities are important to them in their leisure time and whether they go to a care facility in the afternoon or not.

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2.3. Procedure

Participants were recruited through a local elementary school. The children were informed about the study and asked if they would like to participate. In the event of acceptance, the parents were informed and provided written consent. Together with the information, the parents received a link to the online survey where data regarding the age, gender, school level, and media usage of the child were obtained. In order to be able to match the data of the online survey with the data of the laboratory study and still guarantee anonymity, codes were assigned in advance. The laboratory part of the study took place in an empty room at the children's school to keep the effort for the children as low as possible. A usual classroom table and chair were positioned in a standardized position. An external monitor was used to present the tasks. The upper edge of the screen was set at the participant's eye level. In addition, a keyboard for answering the tasks was placed on a predefined position on the table in front of the participant. All instructions were read to the children to ensure that the tasks were understood. At the end of all tasks each child received a small present for participating.

2.4. Statistical analysis

The statistical analyses were computed using SPSS 26.0 for Windows (IBM SPSS Statistics, released 2019). Mean reaction times for selective and divided attention in single demand and switching conditions were calculated. Prior to mean calculations, error rates of each block that exceeded two standard deviations of a participant's mean of the respective block were identified as outliers. A repeated-measures ANOVA was used to analyze reaction times in single and switching demands conditions with the within-subject factors "type of attentional demand" (selective/divided) and "condition" (single demand/switching demand). Effect sizes were reported as eta squares for the ANOVA and Cohen's d for the t-tests. Pearson's correlations were calculated for associations between media use and attentional demands.

3. Results

3.1. Descriptive statistics

None of the children attended a care facility in the afternoon. Within their leisure time, 92% met up with friends, 91% played sports, and 78% found it important to spend time with their families. In addition, 66% did handcraft and 65% red regularly. Listening to music is mentioned by 62% as an activity in their leisure time and 27% liked to go shopping.

Roughly half of the children owned a game console (57%), a smartphone (43%) and/or a tablet (48%). Significantly less owned a Computer/Laptop (16%) and/or a TV (19%). However, all children watched TV regularly, with 66.2% of participants watching one hour or less per day. About half of all children did not use a smartphone (50.6%), tablet (49.4%), or game console (40.3%). Most children (76.6%) did not use a computer regularly. Media use of all children participating in the study was reported as restricted by their parents Mean media usage time in hours per day as well as minimum and maximum values are reported in Table 1.

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Table 1. Descriptive statistics of media use in hours per day.

	Min	*Max*	*M*	*SD*
TV	1	4	1.47	0.74
Smartphone	0	4	0.73	0.88
Tablet	0	3	0.70	0.83
Game console	0	5	1.04	1.14
Computer	0	3	0.29	0.58
Overall media use	1	12	4.22	2.41

Notes. N = *77;* Min = *minimum,* Max = *maximum,* M = *mean,* SD = *standard deviation. Overall media usage represents the sum of usage times of individual applications.*

In addition, smartphone usage behavior shows that the children use the device mainly for gaming and watching YouTube videos. Only a small percentage uses it for texting, social media, and calling. In video-gaming, knowledge games are the most popular, followed by role playing games, sports games, and platform games (see also Figure 2).

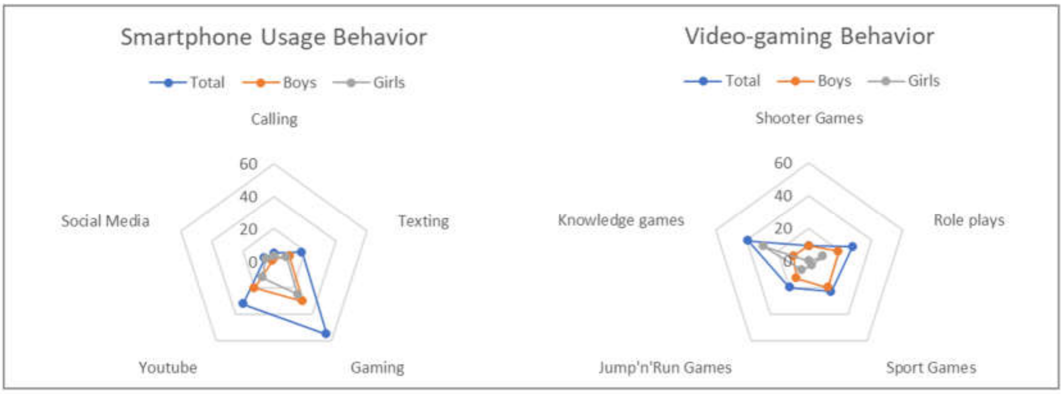

Figure 2. Usage behavior for single applications in gaming and smartphone use, for the total sample and divided by gender.

3.2. Attentional demands in children

Due to dropouts in specific tasks, analyses are based on data from 61 children. For SwAD performance, there was a main effect of switching, $F(1, 60) = 42.81$, $MSE = 5579.20$, $p < .001$, $\eta^2 = .416$, and type of attentional demand, $F(1, 60) = 448.82$, $MSE = 7966.96$, $p < .001$, $\eta^2 = .882$. In addition, there was also a significant interaction between type of attentional demand and switching, $F(1, 60) = 11.41$, $MSE = 6660.07$, $p = .001$, $\eta^2 = .160$. Figure 3 shows the interaction effects. In selective attention, reaction times were faster in the single demand compared to switching, $M_{dif} = -97.87$, $t(60) = -8.03$, $p < .001$, $d = 0.75$, CI_d [0.23, 1.27]. Reaction times for divided attention were only slightly faster in the single demand condition compared to the switching condition, however, this effect did not reach significance, $M_{dif} = -27.27$, $t(60) = -1.75$, $p = .091$, $d = 0.55$, CI_d [-0.33, 0.68].

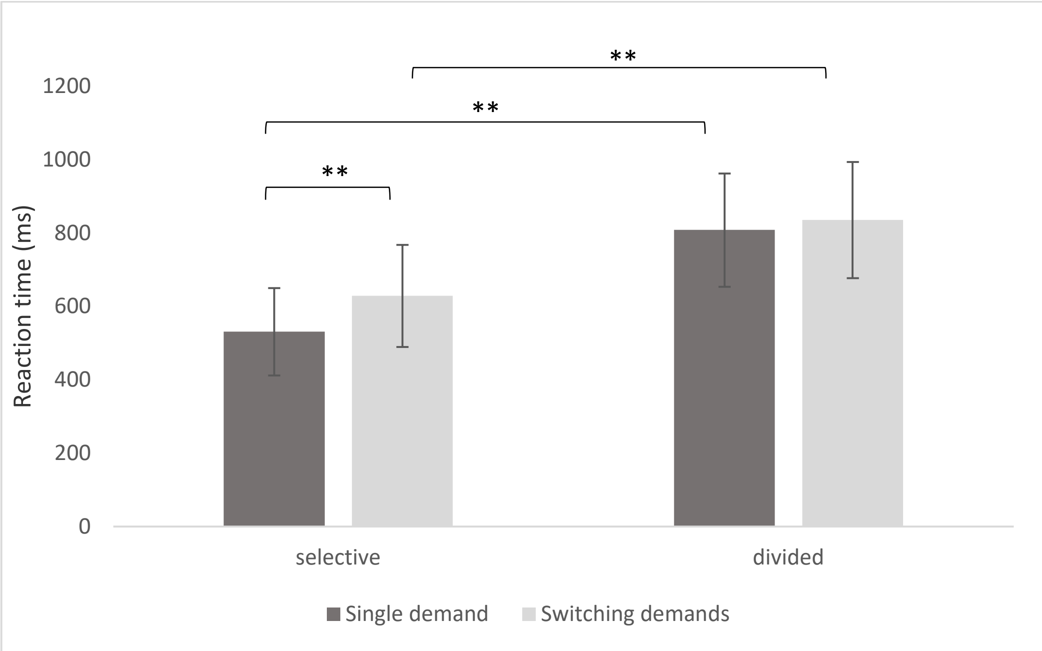

Figure 3. Means and standard deviations for SwAD performance.

3.3. Associations between media use and attentional demands

There were no significant correlations between media use and attentional demands as measured with the SwAD Task (see Table 2). Due to low variances in the use of specific media, no correlations were calculated between attentional demands and the use of TV, smartphone, tablet, game console, and computer.

Table 2. Pearson correlations between overall media use and attentional demands.

		(1)	(2)	(3)	(4)	(5)
(1)	Overall media use	-				
(2)	Single demand: selective	.120	-			
(3)	Single demand: divided	.017	.593**	-		
(4)	Switching demands: selective	.131	.740**	.761**	-	
(5)	Switching demands: divided	.068	.603**	.685**	.713**	-

Notes. *N* = 61; ***p* < .001.

4. Discussion

The use of digital media is becoming increasingly prevalent amongst children, with its use extended to younger and younger ages (McNeill et al., 2019; Twenge & Campbell, 2018). However, an understanding of the effects of using digital media, such as smartphones, tablets, etc., on the development of cognitive functions is still limited. Therefore, the major focus of the current study was to investigate the effect of digital media use on subcomponents of attention. While previous studies show an influence of using digital media on cognitive functions (McNeill et al., 2019; Razel, 2001), we did not identify any effect on attentional subcomponents.

However, the study design and effects shown, do provide valuable information to the field. Together with previous findings – that show specific improvements in cognitive functions for certain applications (Dye et al., 2009; Fisch & Truglio, 2014; Green & Bavelier,

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2012) – we suggest a possible non-linear relationship between the amount of digital media use and cognitive functions that requires investigation (see Figure 4). The proposal is that digital media in a lower or middle intensity range, as in the present study, could have no or even positive effects on attention performance, depending on the content (i.e., domains are trained by using corresponding digital media applications whose content is closely related to them). However, as soon as the use becomes excessive or there is a tendency towards problematic or pathological use, the positive effects turn into the opposite.

Most promising evidence supporting our suggestion comes from studies on video-gaming. Here, studies describe lower hyperactivity, fewer conduct problems, and fewer internalizing and externalizing problems for low-use gaming (Przybylski, 2014; Przybylski & Mishkin, 2016).

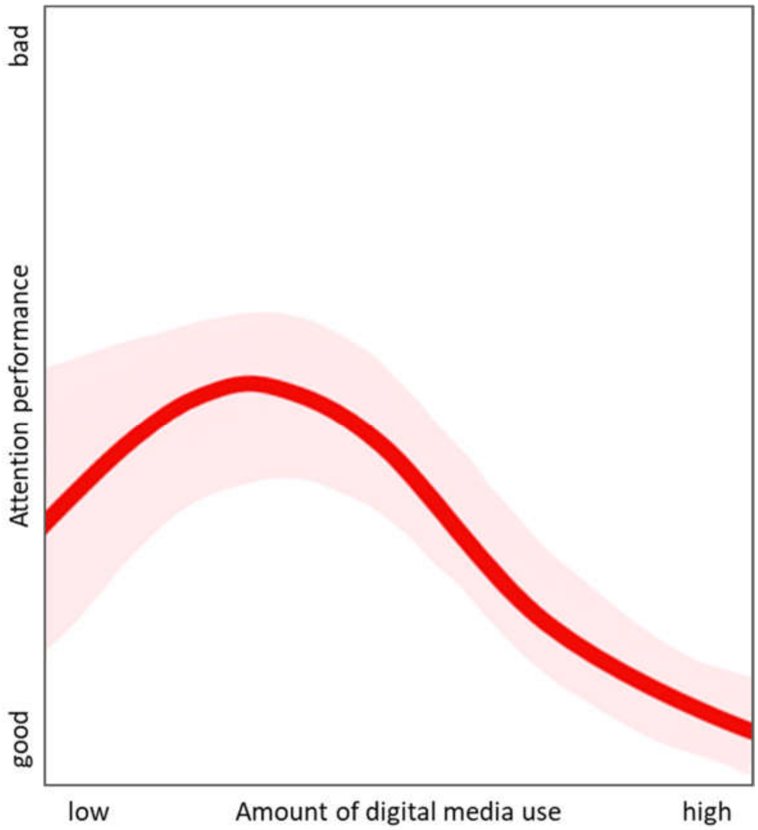

Figure 4. Suggestion of a non-linear relationship between the amount of digital media use and cognitive functions/attention performance. Assuming a variation in the effects depending on the content, as well as intra- and interpersonal factors such as the family, the social environment, as well as the individual characteristics of the children (shown in light red).

Further evidence comes from studies investigating the effect of digital media use on mental health and psychological well-being (Przybylski & Weinstein, 2017; Twenge, 2019). In this context, Twenge and colleagues advocate an exposure-response curve hypothesis that originates in the context of alcohol and marijuana (Twenge, Joiner, et al., 2018; Twenge, Martin, et al., 2018). The authors assume that well-being peaks at light use and progressively lowers as digital media use moves from light to moderate to heavy.

In the present sample, we did not assess the socio-economic background, but recruited participants solely in one school, with children from the near surrounding. The school is located in a suburb with relatively high land prices and exclusively single-family homes. It can therefore be assumed that the group examined consists of children with a relatively high socio-economic background, representing a very homogeneous group. The lack of an explicit consideration of the socio-economic background, however, represents a limitation. Therefore, future studies on media use in children and adolescents should increasingly consider aspects such as maternal education, child poverty, and parents monitoring as potential covariates.

Furthermore, given the low variance in overall media usage, and the lack of association between overall media use and attention subcomponents, we did not test the individual effects of television, smartphone, tablet, game console, and computer. Future studies should address this limitation by investigation such associations in a broader range of children with differing media usage behavior. Furthermore, future studies should aim to investigate further subcomponents of switching attention, such as switching between different modalities, spaces, attributes, and stimulus/response sets. In order to address the limitations above, we suggest the need to undertake longitudinal considerations in future studies to provide a deeper understanding of cause-and-effect relationships, as well as more accurately track developmental trajectories.

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