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The Relationship Between Media Multitasking and Executive Function in Early Adolescents

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Abstract

The increasing prevalence of media multitasking among adolescents is concerning because it may be negatively related to goal-directed behavior. This study investigated the relationship between media multitasking and executive function in 523 early adolescents (aged 11-15; 48% girls). The three central components of executive functions (i.e., working memory, shifting, and inhibition) were measured using self-reports and standardized performance-based tasks (Digit Span, Eriksen Flankers task, Dots–Triangles task). Findings show that adolescents who media multitask more frequently reported having more problems in the three domains of executive function in their everyday lives. Media multitasking was not related to the performance on the Digit Span and Dots–Triangles task. Adolescents who media multitasked more frequently tended to be better in ignoring irrelevant distractions in the Eriksen Flankers task. Overall, results suggest that media multitasking is negatively related to executive function in everyday life.

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Nowadays, ever younger children are exposed to a variety of different media types. Most children and adolescents have their own mobile phones, and the majority of European and U.S. youth use the Internet on a daily basis (Livingstone, Haddon, Görzig, & Olafsson, 2011; Madden, Lenhart, Duggan, Cortesi, & Gasser, 2013). Due to the availability and easy accessibility of these media technologies, the way young people use media has changed dramatically. With universal accessibility to media technologies, youth increasingly squeeze more media content into the same amount of time (Carrier, Cheever, Rosen, Benitez, & Chang, 2009; Foehr, 2006; Rideout, Foehr, & Roberts, 2010). They do so by using several media types simultaneously, thereby engaging in "media multitasking." A recent study has shown that more than 25% of U.S. adolescents' media time is spent with at least two media types simultaneously (Rideout et al., 2010; Stichting ter Promotie en Optimalisatie van Televisiereclame [SPOT], 2012).

It has been argued that the increasing prevalence of media multitasking among youth is problematic because engaging frequently in media multitasking may have consequences for cognitive control processes, such as executive function (Wallis, 2006, 2010). Executive function involves several cognitive processes that are responsible for the regulation of thoughts and actions (Barkley, 1997; Miyake et al., 2000).

A recent study showed that young adults engaging frequently in media multitasking performed more poorly on several cognitive control tasks (such as filtering distractions and switching between tasks) than individuals who were not used to media multitask (Ophir, Nass, & Wagner, 2009). Despite these first findings, it is still unknown how media multitasking is related to the key executive function components of working memory, inhibition, and shifting. Importantly, previous studies have mainly focused on media multitasking in young adults, making assumptions about adolescents difficult. Therefore, the aim of the present study was to investigate how media multitasking is related to executive function in early adolescents.

Media Multitasking

At least two types of media multitasking can be distinguished (Wallis, 2010); media multitasking including two or more types of media (e.g., watching TV

and simultaneously surfing on the Internet) and media multitasking including a medium and a non-media activity (e.g., instant messaging while doing homework). Some of the most popular media activities among adolescents, such as mobile phones and instant messaging, are coined "multitasking facilitators" (Pea et al., 2012). These types of media are often used together with other types of media but are also frequently used simultaneously with other activities, such as doing homework, having dinner, and face-to-face communications (Pea et al., 2012).

Both types of media multitasking have in common that individuals frequently switch between two or more tasks; and that focus on one task (e.g., doing homework) is interrupted by switching to another task (e.g., replying to an instant message). A switch between tasks implies that an individual has to shift between different configurations of mental task sets (e.g., Monsell, 2003); in this case from one task onto another unrelated task. Switching between tasks may happen unconsciously. Brasel and Gips (2011) have shown that when exposed to the Internet and TV simultaneously, individuals switched their gaze on average 120 times in 27 minutes. This constant switching between TV and the Internet happened partly automatically, and participants highly underestimated their task-switching behavior (Brasel & Gips, 2011).

Being constantly exposed to several streams of information may have consequences for adolescents' cognitive control processes. However, to date, only one study examined the relationship between media multitasking and cognitive control processes (Ophir et al., 2009). Overall, this study suggests that young adults engaging in high levels of media multitasking differed in cognitive control abilities (such as filtering distractions and switching between tasks) from individuals who were not used to media multitask. High media multitaskers engaged in "breadth-biased" information processing strategies, that is, they had more difficulties filtering out irrelevant distractions from the environment (Ophir et al., 2009).

Whether media multitasking is also related to cognitive control abilities in *adolescents* has not yet been investigated. Investigating adolescents, however, may be of particular interest because the frequency of media multitasking strongly increases during adolescence (SPOT, 2012). Moreover, adolescents are the main users of communication technologies, such as instant messaging and text messaging. These technologies are disruptive in nature (Fox, Rosen, & Crawford, 2009; Levine, Waite, & Bowman, 2007) and are frequently used simultaneously with other types of media. It may also be that adolescents are particularly vulnerable to the effects of media multitasking because it may interfere with the development of executive functions during adolescence (Crone & Dahl, 2012; Huizinga, Dolan, & van der Molen, 2006).

Media Multitasking and Executive Function

Executive functions play a central role in an individual's, academic achievements, social skills, and personality (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Miller & Cohen, 2001; Zelazo, Muller, Frye, & Marcovitch, 2003). The development of executive functions follows a protracted trajectory, with adult levels of performance being reached between early adolescence and young-adulthood (e.g., Best & Miller, 2010; Huizinga et al., 2006). Executive function skills have been related to the development of other important skills such as social-emotional competence (Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006), theory-of-mind, academic skills, and adaptive behavior (Clark, Prior, & Kinsella, 2002).

In this study, we focus on the three key components of executive function: working memory, inhibition, and shifting (Miyake et al., 2000). Media multitasking may be related to all three components. Working memory capacity captures an individual's ability to temporarily retain information in an accessible state, suitable for carrying out any mental task (Cowan, 1998; Huizinga et al., 2006). Working memory has been related to the ability to control and focus attention (Gioia, Isquith, Kenworthy, & Barton, 2002). Adolescents who are frequent media multitaskers are used to being exposed to several incoming streams of information. It has been argued that media multitaskers may lose their skill to fully pay attention to one activity because they are used to scattering their attention to several ongoing activities (Wallis, 2010). Media multitasking may thus be negatively related to working memory capacity.

Inhibition is defined as the ability to deliberately inhibit interfering information from the environment (e.g., Ridderinkhof & van der Molen, 1995). Individuals with good inhibitory abilities are able to control interfering information and to focus on the main stimuli. Because frequent media multitaskers are used to being attentive to several streams of information, they may be more easily distracted by stimuli that are not directly related to their main activity. Ophir et al. (2009) provide initial support for this assumption. They showed that heavy media multitaskers were more easily distracted by external and internal interferences. This indicates that heavy media multitaskers may be used to being attentive to stimuli that are not directly linked to their main activity.

Shifting refers to the ability to effectively shift back and forth from one task to another (e.g., Monsell, 2003). To successfully shift between tasks, individuals have to fully disengage from the previous task and focus on the subsequent task. Individuals characterized by good shifting abilities are able to flexibly solve everyday problems and to switch attention easily from one

task to another. Task switching is central to media multitasking. During media multitasking, individuals have to switch fast between different tasks or information streams. It may, therefore, be assumed that media multitaskers may learn to effectively switch between tasks to fully profit from the media multitasking experience. Surprisingly, Ophir et al. (2009) found that heavy media multitaskers performed worse in a task-switching paradigm. According to Ophir et al., this indicates that they have difficulties disengaging from previous tasks and to fully focus on new tasks. Apparently, heavy media multitaskers are distracted by the multiple streams of information they are exposed to and not able to effectively switch back and forth between these tasks.

In line with the above reasoning and one recent study with college students (Ophir et al., 2009), we predict that frequent media multitasking is negatively related to the three central components of executive function: working memory, inhibition, and shifting (Huizinga et al., 2006; Miyake et al., 2000). Adolescents who engage frequently in media multitasking may have more problems to focus their attention, to inhibit irrelevant distractions from the environment, and to shift efficiently between tasks.

Assessing Executive Function

Executive functions are typically measured with two different methods. From a neuropsychological perspective, the different components of executive functions are measured with standardized performance-based tasks. These tasks measure executive function at a fine-grained functional level (e.g., Huizinga & Smits, 2011). In contrast, to measure executive function competence in *everyday* life, rating scales are typically used. One of the most widely used measures of executive function in daily life is the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2002; Guy, Isquith, & Gioia, 2004). The BRIEF uses parents, teachers, or a child's self-report to capture the different subcomponents of executive function in daily life.

Although there is much evidence that self-reported measures as well as performance-based tests of executive function are valid—both have been shown to correlate with specific brain functions (e.g., Amso & Casey, 2006; Casey, Tottenham, Liston, & Durston, 2005) and with real-life functioning (Huizinga & Smits, 2011)—it has been shown that they do not correlate well with each other (e.g., Anderson et al., 2002; Bodnar, Prahme, Cutting, Denckla, & Mahone, 2007). It has been argued that both types of measures assess different cognitive levels of executive function (Toplak, West, & Stanovich, 2013). Performance-based measures tap information processing abilities in the brain while self-reports assess executive function on a reflective level that takes rational control and reflective processing

into consideration (Toplak et al., 2013). To fully capture executive function competence, it is, therefore, necessary to use performance-based neuropsychological tasks, as well as rating scales to tap both the functional level as well as everyday functioning of executive function. Both measures tap unique aspects of executive function that both contribute to executive function problems (Toplak et al., 2013).

The Current Study

The aim of the present study was to investigate the relationship between media multitasking and executive function in early adolescents. We predict that media multitasking is negatively related to executive function. We assessed adolescents' self-reports of the three subdomains of executive function with the respective subscales of the Dutch adaptation of the BRIEF (Huizinga & Smits, 2011). To measure the neuropsychological aspects of executive functions, participants conducted three standardized performance-based tasks. The Digit Span (Wechsler, 2003) was used to measure working memory capacity; the Eriksen Flankers task (Ridderinkhof & van der Molen, 1995) was used to measure the ability to resist interfering information from the environment; and the Dots–Triangles task (Huizinga et al., 2006) to measure shifting.

Because previous studies have shown that high *media use* has detrimental effects on cognitive function and the capability to focus attention (e.g., Kronenberger et al., 2005; Kumari & Ahuja, 2010; Swing, Gentile, Anderson, & Walsh, 2010), the present study aimed at investigating the effect of media multitasking on executive function above the effect of media use per se. To draw a comprehensive picture of the effects of media multitasking, we assessed the total amount of daily media use of the most prevalent media types among adolescents. Moreover, we assessed the amount of media multitasking for each media type. This approach allowed us to compare the effects of media use of the most common media activities and media multitasking with these media types on executive function in adolescents.

Next to the frequency of media use, we also included age and biological sex as control variables as these variables may be related both to media multitasking and to executive function. Older adolescents are more likely to engage in media multitasking and executive functions develop over the course of adolescence. It has also been shown that biological sex is related to media multitasking, with girls engaging more frequently in media multitasking (Jeong & Fishbein, 2007) and that girls have better executive function skills than boys (Huizinga & Smits, 2011).

Method

Sample and Procedure

Data for this study were collected at six schools in the Netherlands. The Dutch school system distinguishes between three levels of education. Participants in this study came from all three levels and schools were equally distributed between suburban and urban schools. In total, 523 adolescents aged 11 to 15 ($\overline{X}_{age}$ = 13.09, *SD* = 0.85, 48.2% girls) participated in this study. Participants filled in an online survey in class, which took approximately 45 minutes. Moreover, participants conducted a series of cognitive experimental tasks in individual sessions of up to two participants. These cognitive tasks were conducted on a laptop and took approximately 45 minutes per participant. The Netherlands is a very technology-savvy country comparable with many Western countries, including the United States. Ninety-nine percent of Dutch teenagers aged 12 to 15 use the Internet and 86% use the Internet from mobile devices (Centraal Bureau voor de Statistiek [CBS], 2013). Recent studies on media multitasking have shown that the media time adolescents spent with media multitasking is highly comparable between the United States and the Netherlands (United States: 25%, the Netherlands: 27%, see Rideout et al., 2010; SPOT, 2012).

Measures

Media use and media multitasking. Media multitasking was measured with an adapted version of the measure used by Pea et al. (2012) and Ophir et al. (2009). Nine media activities were assessed: (a) watching TV, (b) reading, (c) listening to music, (d) talking on the phone, (e) sending messages via phone or computer[1] (e.g., text messages, Ping, WhatsApp, Instant messaging), (f) using social networking sites (e.g., Facebook, Twitter), (g) watching movies on the computer, (h) other computer activities (e.g., surfing on the web, Photoshop), and (i) playing video games. For these nine media categories, participants indicated for how long they use each media type on an average day. Response categories ranged from 1 (*not at all*) to 6 (*3 hours or more*) in half hour intervals. Moreover, participants were asked how often they engage in each activity simultaneously with each of the other eight activities. For example, participants were asked, "While watching *TV*, how often do you use *social networking sites* at the same time?" and "While watching *TV*, how often do you *listen to music* at the same time?" Participants indicated this on a four-point scale ranging from 1 (*never*) to 4 (*very often*).

For each media activity, an average score for media multitasking with the eight other media activities was formed. The resulting nine subscores indicated how often a specific medium was used together with other media activities. For example, high scores on the TV media multitasking index indicate that a person engages often in other media activities while watching TV. Low scores indicate that adolescents mostly focus on the TV and do not engage in other media activities simultaneously. This score, therefore, provides an indication of how much of the TV time is used with other media activities simultaneously.

These nine media multitasking subcategories correlated highly with each other indicating that most adolescents media multitasked with many media types and that it was not restricted to specific media activities (all correlations at least, $r > .50$, $p < .01$). Therefore, the average of these nine subscores was calculated to build a main media multitasking index (MMM), Cronbach's alpha = .93. This media multitasking index indicates the relative amount of media multitasking across different media categories. The means and standard deviations of the nine subscores as well as of the main media multitasking index are displayed in Table 1.

To not only assess media multitasking between or within media but also between media and non-media activities, five non-media activities were assessed: (a) doing homework, (b) eating, (c) being in class, (d) using transportation, and (e) engaging in face-to-face conversation. Also for these five categories, participants indicated how often they typically engage in these activities simultaneously with each of the nine media activities. Summed media multitasking scores for each activity were calculated as well as the overall score for media multitasking including non-media activities (MMA; see Table 1 for means and standard deviations; Cronbach's $\alpha = .82$).

Executive Function

Self-reports. The Dutch version of the BRIEF (Huizinga & Smits, 2011) was used to measure adolescents' self-reports of executive function. The BRIEF consists of 68 items and eight subscales. For this study, the subscales for working memory, inhibition, and shifting were used. Response categories were 1 (*never*), 2 (*sometimes*), and 3 (*often*). The subscale for working memory consists of 10 items. An example item is "I forget what I am doing in the middle of things," $\bar{X} = 1.57$, $SD = 0.36$, Cronbach's alpha = .83. The inhibition subscale consists of 12 items (example item: "I have problems waiting my turn"), $\bar{X} = 1.53$, $SD = 0.35$, Cronbach's alpha = .84. The subscale for shifting consists of eight items. An example item is "I have trouble changing

Table 1. Means and Standard Deviations for the Media Multitasking Sub- and Overall Scores.

	$\bar{X}$	*SD*
Media multitasking subscales		
TV	1.94	0.58
Sending messages[a]	1.90	0.73
Music	1.90	0.63
Social network sites	1.77	0.69
Other computer activities	1.67	0.63
Reading	1.61	0.70
Online videos	1.58	0.61
Phoning	1.52	0.62
Video gaming	1.48	0.60
Overall media multitasking score within media (MMM)	1.71	0.52
Media multitasking with non-media activities subscales		
Homework	1.51	0.54
Face-to-face communication	1.45	0.59
Eating	1.43	0.56
Transportation	1.41	0.44
In class	1.17	0.33
Overall media multitasking score with media and other activities (MMA)	1.39	0.38

Note. The multitasking scores can have values ranging from 1 to 4. MMM refers to media multitasking including multiple media activities (e.g., watching TV and playing video games). MMA refers to the combination of media activities with a non-media activity (e.g., doing homework and watching TV).
[a]Sending messages refers to sending text messages as well as sending messages via the computer (e.g., instant messaging).

from one activity to another," $\bar{X}$ = 1.48, *SD* = 0.35, Cronbach's alpha = .72. Higher values on the subscores indicate more executive function problems.

Performance-based tasks. All three experimental tasks are standardized tasks that have been frequently used to measure the respective subdomains of executive functions (Huizinga et al., 2006; Wechsler, 2003).

Working memory: Digit Span task. The Digit Span task (Wechsler, 2003) was used to measure working memory. Series of random digits with increas-

ing length (i.e., two digits, three digits, four digits, etc.) were presented on the screen. Every series length was repeated twice (including different numbers). In the "forward condition," participants had to repeat these digits in the same order by using the keyboard; in the "backward condition," participants had to repeat the digits in reversed order. A score of one point was assigned when a series was repeated correctly. The test was terminated after two incorrect repetitions of one series length. The scores for the forward and backward sequences were summed to receive the total score. Higher scores, therefore, indicate better working memory capacities.

Inhibition: Eriksen Flankers task. An adapted version of the Eriksen Flankers task (Ridderinkhof & van der Molen, 1995) was used to measure inhibition. In this task, respondents had to react to a target arrow that was presented in the middle of four additional (distractor) arrows. Respondents had to indicate in which direction (right or left) the target arrow was pointing by pressing a left or right response button. In the congruent condition, the four flanker arrows pointed in the same direction as the target arrow ($\rightarrow \rightarrow \rightarrow \rightarrow \rightarrow$). In the incongruent condition, the flanker arrows pointed in the opposite direction ($\rightarrow\rightarrow \leftarrow \rightarrow \rightarrow$). When a response button was pressed, the arrows disappeared. Participants had 2,500 milliseconds to respond. After a time period of 900 to 1,000 milliseconds a new set of arrows appeared. The task consisted of 50 practice and 50 experimental trials (presented pseudorandomly). The main indicator was the ratio between congruent and incongruent scores (incongruent/congruent). A higher ratio score (incongruent/congruent) indicates more problems with inhibiting irrelevant information.

Shifting: Dots–Triangles task. In the Dots–Triangles task (Huizinga et al., 2006) varying numbers of either red dots or green triangles are presented in a 4 × 4 grid on the screen. During Block 1 of the task ("dots"-trials), participants have to indicate whether there are more dots on the left or right side of the screen (three to eight dots are presented on each half of the grid). During Block 2 ("triangles"-trials), participants have to decide whether there are more triangles on the top or bottom part of the grid (three to eight triangles are presented on the bottom and the top part). In Block 3, a series of four dots and four triangles trials are alternated. Blocks 1 and 2 consist of 30 practice trials and 50 experimental trials each. Block 3 consists of 90 practice and 150 experimental trials. Each stimulus remained on the screen until a response was given. Participants had 3,500 milliseconds to respond. The time interval between response and next stimulus was varied pseudorandomly between 900 and 1,000 milliseconds. As an indicator of shifting ability, the ratio score was calculated between the median response time on switch trials versus rep-

etition trials in the third block. This indicator is a measure for switch costs. The larger the ratio (switch trials/repetition trials), the more problems participants had to switch between task sets.

Control variables. Biological sex, age, and frequency of media use were used as control variables. Frequency of media use was measured as the overall score of the nine media activities, $\overline{X} = 2.73$, $SD = 0.78$ (ranging from 1 to 6).

Results

Table 1 presents the means and standard deviations for the media multitasking subcategories, the overall score for media multitasking involving only media activities, and the overall score for media multitasking including non-media activities. As can be seen from this table, media multitasking while watching TV was most prominent, followed by multitasking while sending messages (via Internet or mobile phone) and multitasking while listening to music. Overall, media multitasking across different media types was more prominent than media multitasking including non-media activities (such as doing homework). Engaging in media multitasking was not related to age in this sample. Girls were somewhat more likely to engage in media multitasking including other activities ($\overline{X} = 1.43$, $SD = 0.40$) in comparison with boys ($\overline{X} = 1.36$, $SD = 0.36$), $t(521) = -2.02$, $p = .04$. There were no sex differences in the frequency of media multitasking including two media activities (MMM). The two media multitasking indices were strongly related, $r = .71$, $p < .001$.

Performance indicators for the cognitive tasks as well as means and standard deviations of the self-reports of executive function are shown in Table 2. All correlations between the two media multitasking indices, the performance-based and self-report measures of executive functions, media use, age, and biological sex are presented in Table 3. The self-reported measures of executive functions were not significantly related to the respective executive function tasks (see Table 3).

Relationship Between Media Multitasking and Working Memory

To investigate whether media multitasking predicted self-reported working memory capacity, we conducted two multiple linear regressions. All regressions were controlled for age, biological sex, and media use. The dependent variable was the score on the BRIEF subscale for working memory. The two

Table 2. Performance Indicators of Executive Functions.

	$\overline{X}$	*SD*
BRIEF		
Working memory	1.56	0.36
Inhibition	1.53	0.35
Shifting	1.48	0.35
Digit Span task		
Forward	7.81	2.08
Backward	6.37	2.59
Total	14.18	3.78
Eriksen Flankers task		
Congruent	435.77	62.16
Incongruent	489.98	68.28
Ratio	1.13	0.06
Dots–Triangles task		
Repetition	772.66	242.91
Alternation	994.54	337.91
Ratio	1.29	0.18

Note. Values for the BRIEF range between 1 and 3. Higher values indicate more executive function problems. Values for the Digit Span task report the mean number of digits correctly remembered. Higher values indicate better working memory capacity. Values for the Eriksen Flankers and Dots–Triangles task are presented in milliseconds (except for the ratio scores). Higher values indicate more inhibition and shifting problems. BRIEF = Behavior Rating Inventory of Executive Function.

media multitasking overall scores (MMM and MMA) were separately entered as independent variables. As can be seen from Table 4, both types of media multitasking significantly predicted working memory as measured with self-reports. Adolescents, who engaged in media multitasking more frequently, reported having more problems in their everyday lives to focus and control their attention.

To investigate whether media multitasking predicted performance on the experimental task for working memory (Digit Span), two linear regressions were conducted with the total score on the Digit Span as dependent variable. The coefficients of these regressions are displayed in Table 4. In all regressions, biological sex, age, and media use were included as control variables. MMM did not significantly predict performance on the Digit Span task. However, MMA approached significance, with $p = .07$, indicating a trend toward the finding that adolescents engaging more often in media

Table 3. Correlations Between All Independent and Dependent Variables.

	MMM	MMA	Media use	Age	Gender	BRIEF: Working memory	BRIEF: Inhibition	BRIEF: Shifting	Digit Span task	Eriksen Flankers task
MMM	1									
MMA	.71***	1								
Media use	.65***	.49***	1							
Age	.06	.11*	.09*	1						
Gender	.05	.09*	0.01	−.09*	1					
BRIEF: Working memory	.20***	.21***	0.07	.07	.06	1				
BRIEF: Inhibition	.24***	.24***	.19***	.07	−.03	.75***	1			
BRIEF: Shifting	.12**	.15***	.07	.08	.03	.65***	.55***	1		
Digit Span task	−.09	−.09*	−.06	.04	.07	.05	.04	.03	1	
Eriksen Flankers task	−.12**	−.09*	−.09*	.02	−.08	.01	−.002	−.01	−.04	1
Dots–Triangles task	−.01	−.05	−.004	−.09*	.01	−.02	−.04	−.02	.06	−.03

Note. Higher values on the BRIEF subscales indicate more executive function problems. Higher values on the Digit Span task indicate better working memory capacity. Higher values on the Eriksen Flankers and the Dots–Triangles task indicate more executive function problems. MMM = media multitasking within media types. MMA = media multitasking across media and non-media activities; BRIEF = Behavior Rating Inventory of Executive Function.

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 4. Regression Analyses for Working Memory.

	BRIEF—Working memory subscale			Digit Span		
	B	*SE* (*B*)	β	*B*	*SE* (*B*)	β
Age	0.03	0.01	−0.07	0.26	0.20	0.06
Sex	0.04	0.03	0.06	0.64†	0.33	0.08
Media use	−0.05†	0.03	−0.10	−0.05	0.28	−0.01
MMM	0.18***	0.04	0.25	−0.62	0.42	−0.09
Constant	0.93***	0.25		11.06***	2.67	
R^2		.05			.02	
Adjusted R^2		.04			.01	
Age	0.02	0.02	0.06	0.29	0.20	0.06
Sex	0.04	0.03	0.05	0.67*	0.33	0.09
Media use	−0.02	0.02	−0.04	−0.11	0.24	−0.02
MMA	0.21***	0.05	0.22	−0.89†	0.50	−0.09
Constant	0.95***	0.25		11.00***	2.67	
R^2		.05			.02	
Adjusted R^2		.05			.01	

Note. Higher values on the BRIEF subscale "working memory" indicate more working memory problems. Higher values on the Digit Span task indicate better working memory capacity. BRIEF = Behavior Rating Inventory of Executive Function; MMM = media multitasking within media types. MMA = media multitasking across media and non-media activities.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

multitasking including media and non-media activities performed somewhat worse on the Digit Span task.

Relationship Between Media Multitasking and Inhibition

The results of the linear regressions for the relationship between media multitasking and inhibition are presented in Table 5. As expected, both types of media multitasking significantly predicted self-reported inhibition. This indicated that adolescents engaging more frequently in media multitasking were more likely to report everyday problems in inhibiting impulses and inappropriate behavior.

For the performance on the Eriksen Flankers task, the media multitasking index including only media activities (MMM) also approached significance, $p = .06$. However, this relationship was different than expected. There was a trend toward the finding that the more adolescents engaged in media

Table 5. Regression Analyses for Inhibition.

	BRIEF—Inhibition subscale			Eriksen Flankers		
	B	*SE* (*B*)	β	*B*	*SE* (*B*)	β
Age	0.02	0.02	0.05	0.002	0.003	0.02
Sex	−0.03	0.03	−0.04	−0.01	0.01	−0.07
Media use	0.02	0.03	0.04	−0.002	0.01	−0.02
MMM	0.14***	0.04	0.21	−0.01†	0.01	−0.11
Constant	1.01***	0.24		1.15***	0.04	
R^2		.06			.02	
Adjusted R^2		.06			.01	
Age	0.02	0.02	0.04	0.002	0.003	0.02
Sex	−0.03	0.03	−0.05	−0.01	0.01	−0.07
Media use	0.04†	0.02	0.08	−0.01	0.004	−0.07
MMA	0.018***	0.05	0.20	−0.01	0.008	−0.05
Constant	1.03***	0.24		1.14***	0.01	
R^2		.07			.02	
Adjusted R^2		.06			.01	

Note. Higher values on the BRIEF subscale "inhibition" indicate more inhibition problems. Higher values on the Eriksen Flankers task indicate more inhibition problems. BRIEF = Behavior Rating Inventory of Executive Function; MMM = media multitasking within media types. MMA = media multitasking across media and non-media activities.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

multitasking, the less they were distracted by irrelevant information. Media multitasking across media and other activities was not significantly related to performance on the Eriksen Flankers task.

Relationship Between Media Multitasking and Shifting

Both media multitasking types also significantly predicted self-reported shifting. Table 6 reports the findings of the linear regressions, controlled for biological sex, age, and media use. These findings show that adolescents who engage more frequently in media multitasking reported more problems in their everyday lives to shift between several tasks.

However, none of the two media multitasking indices significantly predicted performance on the Dots–Triangles task (see Table 6). This indicates that media multitasking is not related to the ability to, at a more abstract level, switch between several tasks as measured with the Dots–Triangles task.

Table 6. Regression Analyses for Shifting.

	BRIEF—Shifting subscale			Dots–Triangles		
	B	*SE* (*B*)	β	*B*	*SE* (*B*)	β
Age	0.03†	0.02	0.08	−0.02*	0.01	−0.09
Sex	0.02	0.03	0.03	0.000	0.02	0.001
Media use	−0.01	0.03	−0.03	0.003	0.01	0.01
MMM	0.09*	0.04	0.13	−0.004	0.02	−0.01
Constant	0.92***	0.25		1.55***	0.13	
R^2		.02			.01	
Adjusted R^2		.01			.001	
Age	0.03	0.02	0.06	−0.02*	0.10	−0.09
Sex	0.02	0.03	0.02	0.002	0.02	0.01
Media use	−0.01	0.02	−0.01	0.01	0.01	0.03
MMA	0.14**	0.05	0.15	−0.03	0.02	−0.06
Constant	0.93***	0.25		1.55***	0.13	
R^2		.03			.01	
Adjusted R^2		.02			.003	

Note. Higher values on the BRIEF subscale "shifting" indicate more shifting problems. Higher values on the Dots–Triangles task indicate more shifting problems. BRIEF = Behavior Rating Inventory of Executive Function; MMM = media multitasking within media types. MMA = media multitasking across media and non-media activities.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Extreme Group Analysis

In the regression analyses above, media multitasking was used as a continuous variable. It may, however, be that, although no effects were found with the continuous variable on the experimental tasks, adolescents who show very high levels of media multitasking still differ on these tasks from adolescents who almost never engage in media multitasking. The comparison between these two types of media multitaskers is also in line with the procedure used by Ophir et al. (2009). We, therefore, compared those 10% of the adolescents with the lowest scores on the MMM ($n = 53$, $\overline{X}_{\text{multitasking}} = 1.10$, $SD = 0.06$) with those 10% reporting the highest levels of media multitasking ($n = 51$, $\overline{X}_{\text{multitasking}} = 2.87$, $SD = 0.44$). Repeated-measures ANCOVA were conducted with the performance indicators on the experimental tasks as within-subject factor, the media multitasking extreme groups as between-subject factor, and age, biological sex, and media use as covariates. For the Digit Span and the Dots–Triangles task, no significant main or interaction effects for the extreme groups were found. In the repeated-measures

ANCOVA for the Eriksen Flankers task (with congruent and incongruent trials as repeated-measures factor), the interaction effect between extreme groups and within-subject factor approached significance, $F(1,99) = 3.11$, $\eta_p^2 = .03$, $p = .08$. Although the two groups did not differ in reaction times in the congruent trials, heavy media multitaskers tended to respond faster in the incongruent trials (low multitaskers: $\overline{X} = 504.05$, $SD = 74.38$; heavy multitaskers: $\overline{X} = 482.78$, $SD = 71.10$).

We also conducted a repeated-measures ANCOVA with the self-reports on the three subscales of the BRIEF as within-subject factor, the extreme groups as between-subject factor and age, biological sex, and media use as covariates. In line with the results of the regression analyses, a significant main effect for the extreme groups was found, $F(1,99) = 7.49$, $\eta_p^2 = .07$, $p < .01$. Heavy media multitaskers reported significantly more behavioral problems than light media multitaskers.

Discussion

The last years have seen a revolutionary change in how people, most notably youth and young adults, use media. Using several media types at the same time has become a popular form of media consumption for many adolescents. Because media multitasking is an increasingly occurring form of media use, it is important to understand its role in adolescent development. The present study, therefore, investigated the relationship between media multitasking and executive function in early adolescents.

As expected, frequent media multitasking was related to negative behavioral aspects of executive function as assessed with self-reports of everyday functioning. Adolescents who multitask more frequently reported a variety of behavioral problems in their everyday lives. These adolescents seem to have more problems staying focused, inhibiting inappropriate behavior, and to switch effectively between tasks. The incapacity to concentrate for longer periods of time, to adapt to new situations and to suppress inappropriate behavior may lead to problems in school and to social problems. These findings are in line with previous studies showing that media multitasking or the use of disruptive media is related to distractibility for school-related tasks (Fox et al., 2009; Junco & Cotten, 2011; Levine et al., 2007). These findings also fit well to the findings of Pea et al. (2012) who showed that among 8- to 12-year-old girls, media multitasking was negatively related to social well-being, such as feeling normal and having social success.

The relationship between media multitasking and self-reported executive function holds for both types of media multitasking: media multitasking including two types of media and media multitasking including media and

other activities. Several explanations may account for the relationship between media multitasking and self-reported executive functions. First, the constant overstimulation provided by media multitasking may lead to an overexcited mind state. Adolescents who engage in media multitasking frequently may get used to this overstimulation and lose their willingness to bear less stimulating situations (Wallis, 2010).

A second explanation is that media multitasking may substitute other activities, such as face-to-face communication (Pea et al., 2012), learning, and reading, that play a functional role in adolescent development. This displacement hypothesis of media use has been previously posed about youth' media consumption (Kraut et al., 1998; Mutz, Roberts, & van Vuuren, 1993). However, the displacement hypotheses may have a new meaning in light of media multitasking, as media multitasking may not completely substitute non-media activities but complement these activities with additional media activities. This may change these previously non-media situations and interfere with their original functions (e.g., text messaging during family dinner). If media multitasking substitutes or changes social and contemplative activities that play a crucial role in healthy adolescent development (such as face-to-face conversations, or physical activity, see Guiney, & Machado, 2013), it may interfere with the development of important social and cognitive skills during adolescence, such as executive functions.

A third explanation for the relationship between media multitasking and executive function is that deficits in executive functions may promote media multitasking. Although most previous research assumed that media multitasking influences executive functions and cognitive abilities, the relationship may also be reverse. Deficits in executive functioning are related to impulsive, poorly planned behavior (Barkley, 1997; Kronenberger et al., 2005). Adolescents who have problems regulating their behavior in their everyday life may be more attracted to media multitasking situations (Pea et al., 2012). These adolescents may be less likely to inhibit the impulse to turn to gratifying media situations in less stimulating environments (e.g., checking their social networking sites while doing homework).

However, even if deficits in executive functions are the cause rather than the consequence of media multitasking, it is possible that media multitasking may enhance these deficits in executive functioning. Adolescents who have problems concentrating and focusing on one task may even be less willing to do so if they are used to stimulating media multitasking situations. In this case, media multitasking may reinforce already existing behavioral problems. Due to the cross-sectional design of the present study, the causality of the relationship between media multitasking and executive function cannot be determined. Future studies including longitudinal assessments of media

multitasking are needed to fully understand the relationship between media multitasking and executive function.

Interestingly, in this study, we found no distinct effect of media use per se above the effect of media multitasking. Previous studies have shown that, for example, the frequency of Facebook use or instant messaging has an influence on academic performance and academic distractibility (Kirschner & Karpinski, 2010; Levine et al., 2007). However, in our study, the effects of the frequency of media use had no influence above the effects of media multitasking. Therefore, it seems that media multitasking is a stronger predictor of executive function problems than media use per se.

Despite the rather strong relationship between media multitasking and self-reported measures of executive functions, media multitasking was not related to the performance on performance-based tasks that measure working memory and shifting. It thus seems that adolescents who media multitask frequently do not differ in their working memory or shifting capacities on a functional level from those adolescents who do not engage in media multitasking. The discrepancy between the findings for the self-reported and performance-based measures of executive function is not surprising considering that many studies find weak or no correlations between these two types of measures of executive function (Anderson et al., 2002; Guy et al., 2004; for a review, see Toplak et al., 2013). Self-reports tap more complex, behavioral, everyday aspects of executive function, while the performance-based neuropsychological tasks are meant to tap the underlying neural correlates of executive function. Both measures thus assess executive functions on a very different level. It has been argued that the performance-based and self-report measures provide unique information on executive functions and, therefore, contribute individually to the explanation of executive function problems (Toplak et al., 2013). In contrast to many real-life situations, cognitive tasks are administered in quiet environments without distractions. It may happen that adolescents who show behavioral problems in everyday life perform normally on cognitive tasks in a laboratory setting (Anderson et al., 2002; Vriezen & Pigott, 2002).

Interestingly, media multitasking tended to be related to the performance-based assessment of inhibition using the Eriksen Flankers task. Adolescents who engaged more frequently in media multitasking tended to be better in ignoring irrelevant distractions. There are two possible explanations for this finding. First, adolescents who frequently media multitask may have acquired the ability to willingly ignore distractions. Because heavy media multitaskers are used to distractions, they may have learned to ignore them if they want to. This ability may develop as a compensation for a lack in other areas. Another possible explanation is that adolescents who are able to ignore distractions

are more likely to engage in media multitasking. These adolescents may be able to engage in a second activity without being distracted from their main activity (e.g., they may not be distracted from reading while listening to music). In contrast, adolescents who are sensitive to interferences may be less willing to engage in media multitasking because they may feel overwhelmed and distracted. However, these findings need to be interpreted with caution as the relationship between media multitasking and the performance on the Eriksen Flankers task was only marginally significant.

The finding that media multitasking was marginally significantly related to less distractibility in the Flankers task is in contrast to the findings by Ophir et al. (2009). They report that frequent media multitaskers were more easily distracted by internal and external interferences. They conclude that heavy media multitaskers show "breadth-biased" cognitive processing. The differences in our findings and Ophir et al.'s findings may be due to the different age groups that have been investigated in these studies. It may be that younger adolescents who are better in ignoring interruptions tend to multitask more but that the effect on cognitive processes only appears later during adolescence or young-adulthood. Differences in findings may also be due to different measures of inhibition (Eriksen Flankers vs. Continuous Performance Test [AX-CPT] task) and to a slightly different measure of media multitasking. Further studies are needed to investigate whether and how media multitasking is related to these cognitive control processes in adolescents.

Limitations

The fact that we found mostly relationships between self-reported measures of media multitasking and self-reported measures of executive functions may also be due to method variance between these measures in contrast to the performance-based measures of executive function. Another potential alternative explanation for the findings may be that participants in this study hold a self-schema about their ability to focus attention and were, therefore, more likely to report higher levels of media multitasking and executive function problems. However, although both were based on self-reports, media multitasking and self-reported measures of executive function were measured very differently. Media multitasking was measured with very specific questions, such as how often someone engaged in text messaging while watching TV. Relating these items to cognitive control problems requires a rather complex understanding of the relationship between media multitasking and attention problems. We, therefore, believe that problems of method variance and self-schema may not fully explain these findings.

Due to the cross-sectional design of the study, it is neither possible to draw conclusions about the causality of the relationship between media multitasking and executive function nor about possible underlying mechanisms of this relationship. Future studies are needed to fully understand the underlying mechanisms of the relationship.

Conclusion

In sum, the present study shows that media multitasking in adolescents is negatively related to executive function in everyday life. Adolescents who engage in media multitasking more frequently report more problems to control their thoughts and behavior in everyday life. Although media multitasking is negatively related to executive function in everyday life, there was also some indication—although only marginally significant—that media multitasking may be positively related to specific components of cognitive functioning (see also Lui & Wong, 2012). Further research is needed to investigate the causal relationship between media multitasking and executive functioning as well as to investigate in more detail potential neuropsychological correlates of media multitasking.

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Note

1. We decided to combine instant messaging via computer and text messaging because the distinction between both becomes increasingly blurred. This is due to new technological developments, such as tablets and smartphones, and applications that cannot be categorized as either text messaging or instant messaging (e.g., iMessage and WhatsApp).

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