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Everyday functioning-related cognitive correlates of media multitasking: a mini meta-analysis

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ABSTRACT

A recent meta-analysis has shown that media multitasking behavior, or consuming multiple streams of media simultaneously, might not be associated with less efficient cognitive processing, as measured with objective tests. Nevertheless, a growing number of studies have reported that media multitasking is correlated with cognitive functioning in everyday situations, as measured in self-reports. Here, in a series of mini meta-analyses, we show that the self-reported correlates of media multitasking can be categorized in at least four major themes. Heavy media multitasking was associated with increasing problems with attention regulation (e.g., increased mind-wandering and distractibility), behavior regulation (e.g., emotion regulation and self-monitor), inhibition/impulsiveness (e.g., higher level of impulsiveness and lower level of inhibition), and memory. However, the pooled effect sizes were small (z =.16 to z = .22), indicating that a large proportion of variance of media multitasking behavior is still unaccounted for. Additionally, we witnessed a high level of heterogeneity in the attention regulation theme, which might indicate the presence of the risk of study bias.

In recent years, the number of studies investigating the correlates of habitual media multitasking behavior, i.e., consuming multiple streams of media-related information simultaneously, have increased. These studies investigate correlates of media multitaskers using both performance-based and self-reported measures, and have presented an interesting contradiction. On the one hand, the group of studies using performance-based measures, that is, highly controlled psychophysics experiments with clear instructions (e.g., to perform as quickly and as accurately as possible) and clear beginning and end, has shown mixed results. Specifically, some studies showed that Heavy Media Multitaskers (HMMs), compared to Light Media Multitaskers (LMMs) displayed worse performance in different objective, performance-based measures of cognition (Cain, Leonard,

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Gabrieli, & Finn, 2016; Ophir, Nass, & Wagner, 2009; Ralph & Smilek, 2016), while others reported that HMMs performed better than LMMs (Alzahabi & Becker, 2013; Baumgartner, Weeda, van der Heijden, & Huizinga, 2014). Yet, others reported mixed findings and/or null results (Cardoso-Leite et al., 2015; Gorman & Green, 2016; Minear, Brasher, McCurdy, Lewis, & Younggren, 2013; Murphy, McLauchlan, & Lee, 2017; Ralph, Thomson, Seli, Carriere, & Smilek, 2015; Wiradhany & Nieuwenstein, 2017). With this mixed evidence, it is not surprising that a recent review (van der Schuur, Baumgartner, Sumter, & Valkenburg, 2015) and a meta-analysis (Wiradhany & Nieuwenstein, 2017) have shown that pooled together, the association between media multitasking and performances on performance-based measures of cognition is weak. Furthermore, the meta-analysis has shown that upon applying meta-analytic correction, the pooled association between media multitasking and performances on performance-based measures of cognition turned out to be null.

On the other hand, there have been a growing number of studies showing associations between frequent media multitasking and problems reported on rating scales of cognition. Specifically, frequent media multitasking has been associated with more self-reported attention lapses and mind-wandering (Ralph, Thomson, Cheyne, & Smilek, 2013), higher levels of impulsiveness (Cain et al., 2016; Magen, 2017; Minear et al., 2013; Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013; Schutten, Stokes, & Arnell, 2017; Uncapher, Thieu, & Wagner, 2016), a higher number of problems with executive functions (Baumgartner et al., 2014; Magen, 2017), and more (severe) symptoms of Attention Deficit/Hyperactivity Disorders or ADHD (Magen, 2017; Uncapher et al., 2016). Together, these findings suggest that media multitasking is not associated with performances on objective measures of cognition, but nevertheless, is associated with different aspects of everyday cognitive functioning.

In cognition research, it is common to use both performance-based and self-reported methods for assessment as these two types of assessment often complement one another (e.g., Chan, Shum, Toulopoulou, & Chen, 2008). At the same time, findings from both types of measurement might disagree with one another for several reasons. To start, the two measures arguably estimate one's ability to function on different levels. Performance-based measures estimate one's optimal performance: These measures have explicit instructions and are administered under highly standardized conditions. Accordingly, the results of these measures would reflect the efficiency of cognitive processing of an individual (Stanovich, 2009; Toplak, West, & Stanovich, 2013). In contrast, self-reported measures of the same construct estimate one's typical performance: These measures probe a wide range of everyday behaviors which are related with the construct which is being estimated. Accordingly, the results of these measures would reflect the ability of an individual to execute a task in conditions in which no explicit instructions or goals are given (Stanovich, 2009; Toplak et al., 2013).

Critically, it is possible for an individual to score low in one type of measure but high in the other type and vice versa. In this light, the International Classification of Functioning, Disability, and Health (ICF), which is developed by the World Health Organization (World Health Organization, 2001), draws a distinction between functions (i.e., the structural integrity of the body to allow for optimal use) and activities (i.e., the life areas, tasks, and actions associated with an individual). One can have an impairment on the activity level, but might perform well on the functional level. For instance, individuals with dysexecutive symptoms might report frequent problems in everyday situations, yet they perform relatively well in an executive function test (Burgess et al., 2006). Similarly, impairments on a functional level do not always necessarily result in impairments on the activity level due to compensation and adaptation. For instance, individuals with mild Alzheimer's disease might perform poorly in an objective test, yet they are able to perform their daily activities using support from their environments (Farias, Harrell, Neumann, & Houtz, 2003). Accordingly, people who frequently media multitask might not perform worse in performance-based measures of cognition, yet report everyday problems associated with cognition due to the fact that laboratory measures might capture some, but not all aspects of cognition or that they measure cognition on a different level compared to self-reported measures.

Correlates of media multitasking

Due to the ubiquity of media devices in recent years (Lenhart, 2015; Marius & Anggoro, 2014), the frequency and duration of media multitasking behavior, consuming multiple streams of media information simultaneously, have increased dramatically (Carrier, Cheever, Rosen, Benitez, & Chang, 2009; Rideout, Foehr, & Roberts, 2010; Roberts & Foehr, 2008). This behavior is mainly characterized by rapid switches of attention between different media streams. An observational study of concurrent television and computer usage showed that, on average, participants switched their attention 120 times within 27.5 min (Brasel & Gips, 2011). Similarly, another observational study reported that contemporary office workers spent on average 3 min on a task before switching to another (González & Mark, 2004). Switching does not only happen between media devices, but also between different media activities. For instance, Judd (2013) reported from computer session logs that college students switched between different tasks in a computer about 70% of the time and spent on average 2.3 min on one task before switching to another.

With the high frequency of switching between different media streams, it is likely for media multitasking behavior to disrupt other ongoing cognitive and behavioral processes. With regard to cognitive processes, media multitasking might disrupt one's current train of thoughts, which may result in worse task performance. In a study in which participants were asked to study an article about influenza, participants recalled less information about the article in conditions in which they were either forced to check their Facebook account or allowed to check their Facebook account while studying the article (Kononova, Joo, & Yuan, 2016). Other studies have shown that media-induced interruptions might have no significant impact on task performance (Fox, Rosen, & Crawford, 2009; Mark, Gudith, & Klocke, 2008), but nevertheless, people who experienced constant interruptions during work reported more stress and frustration at the end of the day (Mark et al., 2008). With regard to behavioral processes, media multitasking behavior might disrupt other everyday behavior patterns. For instance, adolescents who reported higher level of media multitasking also reported having fewer hours of sleep per night (Calamaro, Mason, & Ratcliffe, 2009). Similarly, in a longitudinal study, adolescents with a higher level of media multitasking reported more sleeping problems at the time of the data collection, 3 months, and 6 months later (van der Schuur, Baumgartner, Sumter, & Valkenburg, 2018).

The current study

Media multitasking behavior might interfere with different ongoing processes in everyday situations. This behavior might not be correlated with performances on objective measures of cognition (van der Schuur et al., 2015; Wiradhany & Nieuwenstein, 2017), but nevertheless, it might have profound impact on everyday cognitive functioning, as indicated by self-reported measures of cognition. This article aims to examine and summarize the current body of literature on media multitasking in order to create an overview of the different domains of everyday cognitive functioning which might be correlated with media multitasking behavior. The evidence was synthesized in a series of mini meta-analyses. Additionally, we also examined the risk of bias across the findings and performed a moderator analysis if risk of bias occurred.

Methods

Study selection

All studies which investigated correlates of self-reported measures of media multitasking and cognition were considered for inclusion. Studies were identified in the PsycInfo, ERIC, MEDLINE, SocINDEX, and CMMC databases, as well as the Directory of Open Access Journals (DOAJ) database. A combination of the following keywords was entered in the search terms: *media multitask** AND (*problem** OR *executive** OR *impuls** OR *attention**)[1]. Together, the search yielded 130 results from the first set of databases and 68 results from the DOAJ database.

As Figure 1 shows, of the 198 studies identified, 40 were duplicates and therefore removed. Of the 158 studies, only 43 pertained to the term "media multitasking" (i.e., not only pertained to "media" or "multitasking" exclusively) and were therefore considered for further screening. Of 43 studies screened, we removed studies which did not meet the criteria below.

First, studies must have examined the association between measures of media multitasking and self-report measures of cognition, or psychological traits or mental-health issues related to cognition. Therefore, four review articles (Aagaard, 2015; Carrier, Rosen, Cheever, & Lim, 2015; Lin, 2009; van der Schuur et al., 2015), two meta-analysis (Jeong & Hwang, 2016;

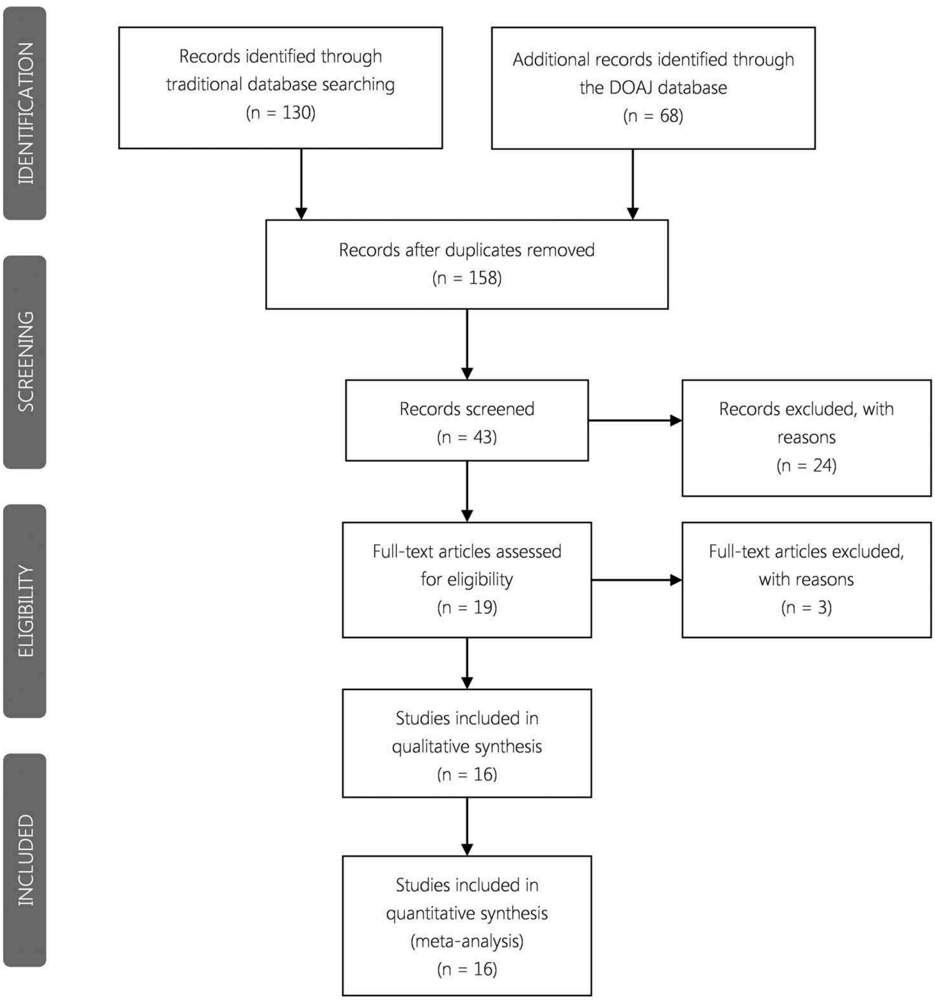

Figure 1. A flow diagram showing the selection of study process.

Wiradhany & Nieuwenstein, 2017), one measurement validity article (Baumgartner, Lemmens, Weeda, & Huizinga, 2017), 12 articles which only included laboratory task performance measures (Alzahabi & Becker, 2013; Alzahabi, Becker, & Hambrick, 2017; Cain & Mitroff, 2011; Edwards & Shin, 2017; Gorman & Green, 2016; Lui & Wong, 2012; Moisala et al., 2016; Murphy et al., 2017; Ophir et al., 2009; Ralph & Smilek, 2016; Ralph et al., 2015; Yap & Lim, 2013), two articles in which the level of media multitasking was manipulated (Kazakova, Cauberghe, Pandelaere, & De Pelsmacker, 2015; Lin, Robertson, & Lee, 2009), one article in which only a brain imaging measure was used (Loh & Kanai, 2014) and two articles in which only media multitasking behavior was observed (Loh, Tan, & Lim, 2016; Rigby, Brumby, Gould, & Cox, 2017) were excluded from further eligibility assessment.

Second, since this study pertains to general media multitasking behavior (i.e., not a specific combination of two media), only studies using a general media multitasking measure were included. Therefore, one article in which only a specific combination of media multitasking was used (Kononova, Zasorina, Diveeva, Kokoeva, & Chelokyan, 2014) and one article (Wu, 2017) which measured the perception of media multitasking ability instead of actual media multitasking frequency were removed. Thirdly, we removed two articles that measured the association between media multitasking and well-being or constructs which are related to well-being (Hatchel, Negriff, & Subrahmanyam, 2018; Pea et al., 2012). Lastly, one article was excluded since the relevant effect sizes could not be extracted from the published article (Shih, 2013)[2]. In all, a total of 13 articles containing 15 independent studies[3] were included for synthesis (Baumgartner, van der Schuur et al., 2017, 2014; Cain et al., 2016; Cardoso-Leite et al., 2015; Duff, Yoon, Wang, & Anghelcev, 2014; Hadlington & Murphy, 2018; Magen, 2017; Minear et al., 2013; Ralph et al., 2013; Sanbonmatsu et al., 2013; Schutten et al., 2017; Uncapher et al., 2016; Yang & Zhu, 2016). Table 1 shows the measures of self-reported functioning included in each study and the number of participants assessed.

Effect size selection and calculation

Effect sizes were selected from reported outcome measures which reflect distinguishable constructs. For instance, a study examining the association between media multitasking and measures of executive function would report measures of attentional shifting, working memory, and inhibition, which are separate constructs. Study findings related to these measures would be regarded as individual effect sizes. In total, 48 unique effect sizes were extracted from the studies listed in Table 1 and included in the final series of mini meta-analysis.

Effect sizes were calculated in *Fisher's z*, indicating the normalized correlation coefficients between self-reported measures of media multitasking and

Table 1. Overview of included studies in meta-analysis, including the number of participants, and the measures of self-reported functioning used in each study.

Authors (year)	N_{total}	Measure(s) of self-reported functioning	Sample description
Baumgartner et al. (2014)	523	Behavior Rating Inventory of Executive Functions (BRIEF): Working Memory, Inhibition, and Shifting subscales	48% females, M_{age} = 13.09
Baumgartner, van der Schuur et al. (2017, Study 1, wave 1)	1241	Inattentiveness scale-based on DSM-V criteria for ADHD	49% females, M_{age} = 12.61*
Baumgartner, van der Schuur et al. (2017, Study 1, wave 2)	1216	Inattentiveness scale-based on DSM-V criteria for ADHD	49% females, M_{age} = 12.61*
Baumgartner, van der Schuur et al. (2017, Study 1, wave 3)	1103	Inattentiveness scale-based on DSM-V criteria for ADHD	49% females, M_{age} = 12.61*
Baumgartner, van der Schuur et al. (2017, Study 2, wave 1)	1083	Inattentiveness scale-based on DSM-V criteria for ADHD	-
Baumgartner, van der Schuur et al. (2017, Study 2, wave 2)	939	Inattentiveness scale-based on DSM-V criteria for ADHD	-
Baumgartner, van der Schuur et al. (2017, Study 2, wave 3)	439	Inattentiveness scale-based on DSM-V criteria for ADHD	59% females, M_{age} = 14.37
Cain et al. (2016)	70	Domain-specific impulsivity in school-age children (DiSC)	49.31% females, M_{age} = 14.4
Cardoso-Leite et al. (2015)	60	Cognitive Failure Questionnaire (CFQ), Attention Deficit/Hyperactivity Disorder Self-Report Scale (ADHD-ASRS)	13.33% females, M_{age} = 20.68
Duff et al. (2014, Study, p. 1)	308	Cognitive Failures Questionnaire (CFQ), Personal Control Scale (PCS), Brief Sensation-seeking Scale (B-SSS)	58.12% females, M_{age} = 20.37
Duff et al. (2014, Study, p. 2)	501	Cognitive Failures Questionnaire (CFQ), Personal Control Scale (PCS), Brief Sensation-seeking Scale (B-SSS)	51.09% females, M_{age} = 34.43
Hadlington and Murphy (2018)	144	Risky Cybersecurity Behavior (RcSB), Cognitive Failure Questionnaire (CFQ)	77.77% females, M_{age} = 20.63
Magen (2017)	196	Behavior Rating Inventory of Executive Functions (BRIEF): all subscales, Attention Deficit/ Hyperactivity Disorder Self-Report Scale (ADHD-ASRS)	74% females, M_{age} = 23.44
Minear et al. (2013)	221	Barratt Impulsiveness Scale (BIS)	68.32% females, M_{age} = 19.8
Ralph et al. (2013)	202	Mindful Attention Awareness Scale – Lapses Only (MAAS-LO), Attention-related Cognitive Errors Scale (ARCES), Memory Failures Scale (MFS), Mind Wandering-Spontaneous (MW-S), Mind Wandering-Deliberate (MW-D), Attentional Control-Switching (AC-S), Attentional Control-Distractibility (AC-D)	72.28% females, undergraduate students
Sanbonmatsu et al. (2013)	277	Barratt Impulsiveness Scale (BIS), Sensation-seeking Scale (SSS)	56.77% females, $Median_{age}$ = 21
Schutten et al. (2017)	303	Barratt Impulsiveness Scale (BIS)	83.23% females, M age = 19.63
Uncapher et al. (2016)	139	Barratt Impulsiveness Scale (BIS), Attention Deficit/Hyperactivity Disorder Self-Report Scale (ADHD-ASRS)	58.04% females, M_{age} = 22.1
Yang and Zhu (2016)	310	Barratt Impulsiveness Scale (BIS), Brief Sensation-seeking Scale (B-SSS)	49.35% females, M_{age} = 15.3

*The sex proportion and Mean of age refers to the combined samples of Study 1 across the three study waves.

self-reported measures of cognition. A positive z indicates that frequent media multitasking is associated with more (severe) issues and a negative z indicates that frequent media multitasking is associated with less (severe) issues. In most cases, the included studies reported *Pearson's product-moment* correlations (r) as measures of effect sizes. These r's were converted into *Fisher's z* using formula 1 below (Borenstein, Hedges, Higgins, & Rothstein, 2009):

$$z = 0.5 \times ln\left(\frac{1+r}{1-r}\right) \tag{1}$$

In which r is the Pearson's product-moment correlation.

Analysis

Categorization of findings

Since different studies featured in the meta-analysis and the featured rating scales measured different domains of cognition, we grouped the respective effect sizes into different categories based on the similarity and dissimilarity between constructs. To illustrate, the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) and the self-monitoring subscales of the Behavioral Ratings of Executive Functions (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000; Gioia, Isquith, Retzlaff, & Espy, 2002) infer a relatively similar construct related to attention regulation, which is relatively dissimilar to the construct related to forming precise information in memory inferred by the Memory Failures Scale (MFS; Carriere, Cheyne, & Smilek, 2008).

To guide the categorization of our effect sizes, we first made a table of self-report measures in Table 1 along with the goal of each individual measure and some examples of its items. Considering the goal of the measure and its items, we then looked into the literature to gain insights on how to group them in a meaningful way. For instance, measures related to impulsiveness such as the Barratt Impulsiveness Scale (BIS; Patton, Stanford, & Barratt, 1995), measures related to inhibition such as the BRIEF-Inhibition (Gioia et al., 2002), and measures related to sensation seeking such as the Sensation-Seeking Scale (SSS; Zuckerman, 1996) were group together under the overarching construct of impulsiveness/inhibition (e.g., Dalley, Everitt, & Robbins, 2011). Some measures, such as the ADHD-Adult Self Report Scale (ADHD-ASRS; Kessler et al., 2005) and the Cognitive Failure Questionnaire (CFQ; Broadbent & Cooper, 1982) might have two or more distinct underlying constructs; the former has attention and impulsiveness components and the latter has attention, memory, and other components. To ensure that our resulting categories were as independent from each other as they can be, in the case of the ADHD-ASRS, we contacted the authors to request additional data regarding the correlation between media multitasking and attention deficit and between media multitasking and hyperactivity/impulsiveness separately. In the case of the CFQ, considering that studies, especially recent ones were in disagreement with regard to the underlying dimensions of CFQ (Bridger, Johnsen, & Brasher, 2013; Larson, Alderton, Neideffer, & Underhill, 2011; Wallace, Kass, & Stanny, 2002), we decided to categorize the effect sizes pertained to the general CFQ scores twice: once in the attention regulation category and once in the memory category. For all categories, the first author performed the categorizations and the second author checked the resulted categories. Disagreements between authors were resolved by consensus.

Using the categorization processes above, we identified four different themes for correlates between media multitasking and self-reports of every-day cognitive functioning, namely attention regulation, behavior regulation, impulsiveness/inhibition, and memory. The attention regulation theme pertained to the set of cognitive abilities which help to boost information processing. Traditionally, this includes the ability to react to important cues in the environment (alerting of attention), select relevant from irrelevant information (orienting of attention), and switch from one stimulus-response task rule to another (executive attention; Petersen & Posner, 2012; Posner & Petersen, 1990). More recently, our ability to suppress internally generated task-unrelated thoughts (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Smallwood & Schooler, 2006) was also considered in this array of cognitive processing-boosting ability. Accordingly, in this theme, we included measures of attention orientation/selection (e.g., ADHD-ASRS – Inattention subscale), distractibility (e.g., CFQ – distractibility subscale and CFQ – Total), switching from one task to another (e.g., BRIEF – Shifting subscale), and mind-wandering (e.g., MAAS, Mind-Wandering scale).

The impulsiveness/inhibition theme pertained to the ability to inhibit premature thoughts and actions, and difficulties with this ability can be exhibited behaviorally in one's tendency to seek additional stimulations and take risks (Dalley et al., 2011; Dalley & Robbins, 2017). Here, we included measures which were related to inhibition (BRIEF-Inhibition), behavior impulsiveness (e.g., BIS, ADHD-ASRS – Hyperactivity/impulsivity subscale), and sensation-seeking (e.g., SSS).

The memory theme pertained to the ability to retain information do mental work with information in memory (e.g., Diamond, 2013). This ability has been considered to be relatively independent to attentional regulation, yet it has been considered to play an important role in executive functioning (Diamond, 2013; Engle, 2002; Engle & Kane, 2004). In this meta-analysis, this theme included measures of working memory (e.g., BRIEF – Working memory subscale), memory failures (e.g., Memory Failures Scale), and general cognitive failures (e.g., CFQ – Total score).

Lastly, the behavior regulation theme pertained to the set of abilities which is related to the volitional control of action. According to one taxonomy of executive function (BRIEF; Gioia et al., 2002; Huizinga & Smidts, 2010), behavior regulation is an umbrella term which includes task-switching and inhibition as well. However, as discussed above, task-switching appears to be more related to attention regulation (e.g., Petersen & Posner, 2012) while inhibition, which is more internally driven, appears to be more related to impulsiveness and risk-taking (e.g., Dalley et al., 2011). Accordingly, we categorized task-switching and inhibition in the attention regulation and impulsiveness/inhibition categories, respectively. Thus, what remains in our behavior regulation theme were abilities that relate to volitional control of action which are driven by external demands and situational factors (e.g., see Tsukayama, Duckworth, & Kim, 2013). This theme included measures of self-control (e.g., Domain-specific Impulsivity in School-age Children[4]; Personal Problem-solving Inventory – Self-control subscale), emotion regulation (e.g., BRIEF – Emotion regulation subscale), and self-monitoring (e.g., BRIEF – Self monitoring subscale).

Note that while we sought out to minimize overlaps between the themes and categorize the findings as accurately as possible, the categorization remained somewhat arbitrary as different theoretical models of cognitive function would have both overlaps and distinctions of different sets of cognitive ability (e.g., see Chan et al., 2008). For each theme, a random-effect model and a pooled effect size were calculated to provide estimates of the magnitude of the correlation.

Random-effect model

Since the current meta-analysis featured different rating scales and outcome measures, we constructed a random-effect model to estimate the pooled effect size. This model assumes that the different scales had comparable, but not identical effect sizes which are distributed around some mean that reflected the true effect (Borenstein et al., 2009). In our case, we assumed that the different outcomes measured different subsets of cognitive functioning. Thus, the effects might vary from one function to another.

The random-effect model was constructed in R (R Core team, 2015) using the metafor package (Viechtbauer, 2010). To account for variance inflation of the pooled effect size due to the dependency of multiple outcome measures from one study, we calculated the robust variance estimation (RVE; Hedges, Tipton, & Johnson, 2010). RVE works by estimating the correlations between dependent outcome measures and adjusting the standard error of the pooled effect size based on these correlations (Hedges et al., 2010; Scammacca, Roberts, & Stuebing, 2013).

Heterogeneity and risk of bias

When significant between-studies heterogeneity was detected, we performed a moderator analysis and a risk of bias analysis. The moderator analysis assesses whether the between-studies heterogeneity can be explained by shared characteristics of different subgroups of studies (Hedges & Pigott, 2004).

The risk of bias analysis tested whether the heterogeneity was stemming from bias coming from the level of precision in each study. Under a presence of bias, it is common for studies with smaller sample sizes to show an overestimation of effect sizes due to sampling errors compared with studies with bigger sample sizes, a phenomenon called small-study effect (Sterne, Gavaghan, & Egger, 2000). A small-study effect might indicate the presence of publication bias, since other studies with smaller sample sizes showing underestimation of the effect ended up not being published (Ioannidis, 2005; Ioannidis, Munafò, Fusar-Poli, Nosek, & David, 2014). As a formal inspection of small-study effects, we conducted an Egger's test (Egger, Davey Smith, Schneider, & Minder, 1997), in which a simple linear regression with effect sizes as a measure of magnitude of study effect and sample sizes or standard errors as measures of study precision is constructed.

Results

Attention regulation

Random-effect model

Figure 2 shows a forest plot for a group of self-report scales which measured the association between media multitasking and constructs related to the ability to regulate attention. The scales categorized in this theme included Attentional Control (AC)-switching (e.g., "I am slow to switch from one task to another," Carriere, Seli, & Smilek, 2013), Attentional Control (AC)-distractibility (e.g., "I have difficulties concentrating when there is music in the room around me", Carriere et al., 2013), ADHD-ASRS – Inattention (e.g., "How often do you have difficulty concentrating on what people are saying to you even when they are speaking to you directly?", Kessler et al., 2005), MW – Spontaneous (e.g., "I find my thoughts wandering spontaneously", Carriere et al., 2008), MW – Deliberate (e.g., "I allow my thoughts to wander on purpose", Carriere et al., 2008), MAAS – Lapses only (e.g., "I do jobs or tasks automatically, without being aware of what I'm doing", Brown & Ryan, 2003), ARCES (e.g.,"I have gone to the fridge to get one thing (e.g., milk) and taken something else (e.g., juice)," Carriere et al., 2008), BRIEF-Shift (e.g., "I get stuck on one topic or activity," Gioia et al., 2002); CFQ – Distractibility, also with CFQ – total score (e.g., "Do you read something and find you

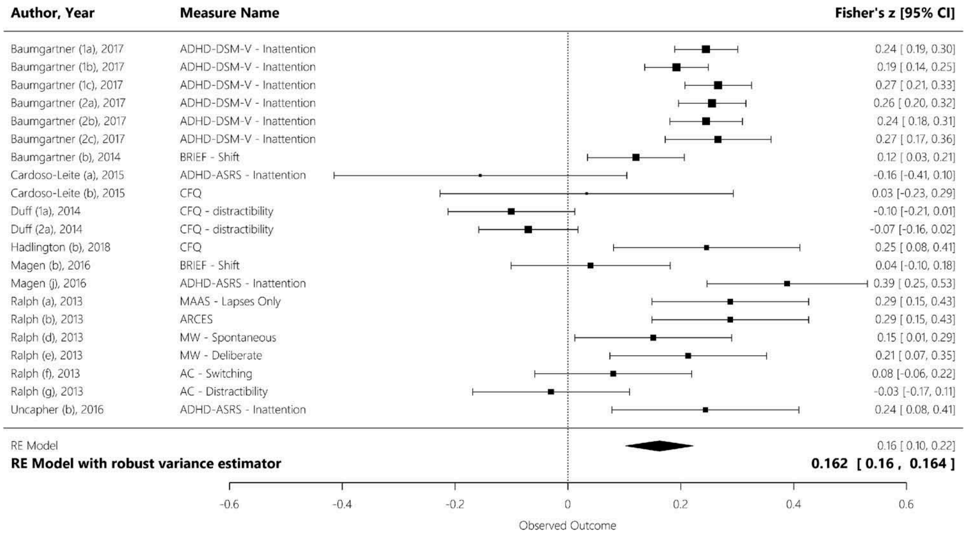

Figure 2. Forest plot of the effect sizes (Fisher's z) for studies measuring the association between media multitasking and attention regulation. Error bars indicate 95% confidence intervals of the means. AC: Attentional Control scale; ADHD-ASRS: Attention Deficit/Hyperactivity Disorder Adult Self Report Scale; ARCES: Attention-Related Cognitive Error Scale; BRIEF: Behavior Rating Inventory of Executive Function; CFQ: Cognitive Failure Questionnaire; MAAS: Mindful Awareness Attention Scale; MW: Mind-Wandering scale.

haven't been thinking about it and must read it again?," Broadbent & Cooper, 1982).

Overall, the pooled effect size of the correlates between media multitasking and self-reported problems related to attention regulation was small, yet statistically significant, $z = .162$, 95% CI [.160, .164], $p < .001$. At the same time, however, a significant heterogeneity between the effect sizes was detected, $I^2 = 86.76\%$, $Q(21) = 118.93$, $p < .001$.

Heterogeneity & risk of bias analysis

To address the heterogeneity in the model, we performed moderator analyses with two moderators. First, we added sex, as indicated by the proportion of females in the study samples as a moderator. Second, we added age, as indicated by the mean age of the study samples as a moderator. The two moderators did not contribute to the unexplained variance in the model, $F(1, 17) = 2.59$, $p = .125$; $F(1, 11) = 3.08$, $p = .107$, respectively, indicating that the heterogeneity could not be explained by differences in sex, and age.

As for the risk of bias, the Egger's test showed no relationship between effect size and study precision, $z = -1.46$, $p = .144$. This indicates that under the presence of heterogeneity, effect sizes were stable across different studies with different sample sizes.

Impulsiveness – inhibition

Random-effect model

Figure 3 shows a forest plot for a group of self-report scales which measured the association between media multitasking and constructs related to impulsiveness and/or inhibition. The scales categorized in this theme included ADHD-ASRS – hyperactivity (e.g., “How often do you fidget or squirm with your hands or your feet when you have to sit down for a long time?”, Kessler et al., 2005), BIS (e.g. “I do things without thinking”, Patton et al., 1995), BRIEF-Inhibit (e.g., “I do not think before doing,” Gioia et al., 2002), SSS, also the brief version; B-SSS (e.g., “I sometimes like to do things that are a little frightening”, Zuckerman, 1996), and RCsB (e.g., “Sharing passwords with friends and colleagues”).

Overall, the pooled effect size of the correlates between media multitasking and self-reported problems related to impulsiveness and/or inhibition was small, yet statistically significant, z = .219, 95% CI [.218, .219], p < .001. The between-studies heterogeneity was low, I^2 < .001%, $Q(14)$ = 9.82, p = .775, indicating that the effect was consistent across different studies.

Memory

Random-effect model

Figure 4 shows a forest plot for a group of self-report scales which measured the association between media multitasking and constructs related to memory. The scales categorized in this theme included BRIEF-Working Memory

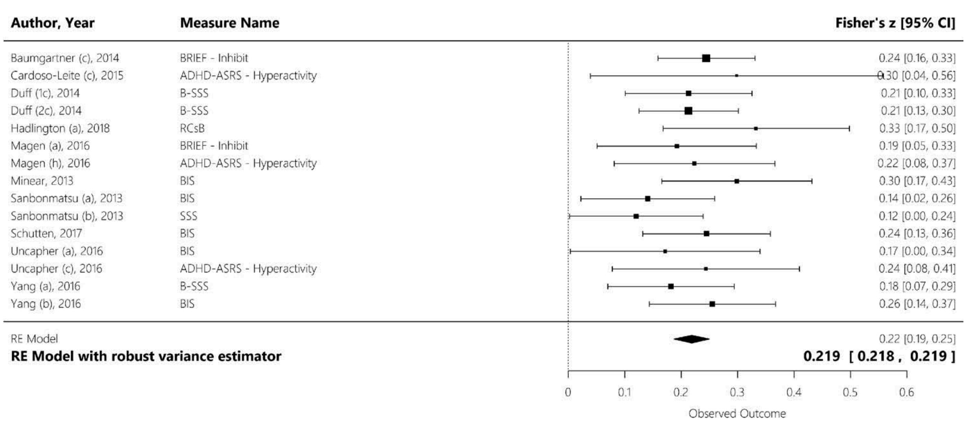

Figure 3. Forest plot of the effect sizes (Fisher’s z) for studies measuring the association between media multitasking and impulsiveness and/or inhibition. Error bars indicate 95% confidence intervals of the means. ADHD-ASRS: Attention Deficit/Hyperactivity Disorder – Adult Self Report Scales; B-SSS: Brief Sensation-Seeking Scale; BIS: Barratt Impulsiveness Scale; BRIEF: Behavior Rating Inventory of Executive Function; RCsB: Risky Cybersecurity Behavior scale; SSS: Sensation-seeking Scale.

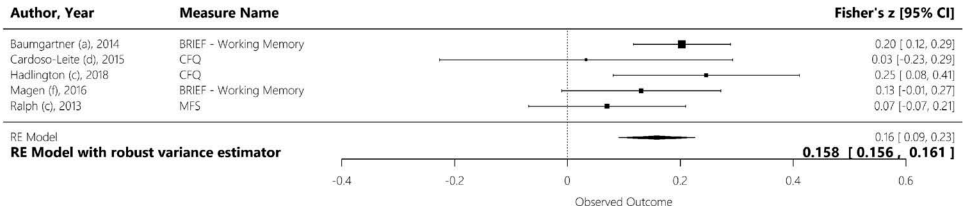

Figure 4. Forest plot of the effect sizes (Fisher's z) for studies measuring the association between media multitasking and memory. Error bars indicate 95% confidence intervals of the means. BRIEF: Behavior Rating Inventory of Executive Function; CFQ: Cognitive Failures Questionnaire; MFS: Memory Failures Scale.

(e.g., "I have trouble remembering things, even for a few minutes," Gioia et al., 2002), CFQ (e.g., "Do you find you forget people's names?", Broadbent & Cooper, 1982), and MFS (e.g., "I forget what I went to the supermarket to buy", Carriere et al., 2008).

Overall, the pooled effect size of the correlates between media multitasking and self-reported problems related to memory was small, yet statistically significant, z = .158, 95% CI [.156, .161], p < .001. The between-studies heterogeneity was low, I^2 = 16.49%, $Q(4)$ = 4.67, p = .323, indicating that the effect was consistent across different studies.

Behavior regulation

Random-effect model

Figure 5 shows a forest plot for a group of self-report scales which measured the association between media multitasking and constructs related to the ability to regulate behavior. The scales categorized in this theme included Emotional Control (e.g. "Has outburst for little reason", Gioia et al., 2002), BRIEF-Initiate (e.g., "I need to be told to begin a task even when willing"),

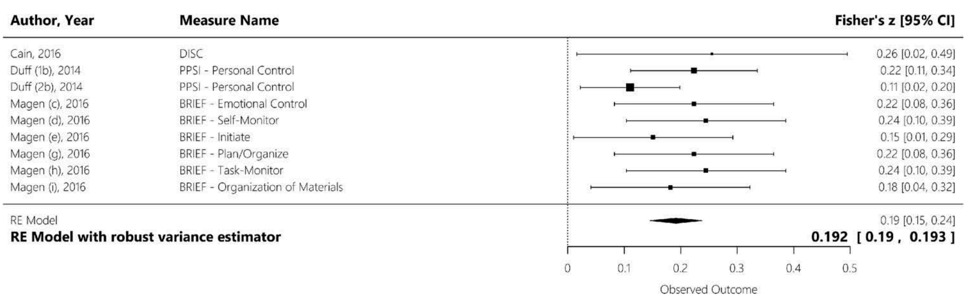

Figure 5. Forest plot of the effect sizes (Fisher's z) for studies measuring the association between media multitasking and behavior regulation. Error bars indicate 95% confidence intervals of the means. BRIEF: Behavior Rating Inventory of Executive Function; DISC: Domain-specific Impulsivity in School-age Children; PPSI: Personal Problem-solving Inventory.

BRIEF-Organization of Materials (e.g., “I cannot find things in room or school desk”), Plan/Organize, (e.g., “I become overwhelmed by large assignments”), BRIEF-Self-monitor (e.g. “I am unaware of how my behavior affects or bothers others”), BRIEF-Task-Monitor (e.g., “I make careless errors”), DiSC (e.g., “I interrupted other people” Tsukayama et al., 2013), and PPSI-Personal control (e.g., “Sometimes I do not stop and take time to deal with my problems, but just kind of muddle ahead” Heppner & Petersen, 1982).

Overall, the pooled effect size of the correlates between media multitasking and self-reported problems related to behavior regulation was small, yet statistically significant, z = .192, 95% *CI* [.190, .193], $p < .001$. The between-studies heterogeneity was low, $I^2 = 6.67\%$, $Q(8) = 5.69$, $p = .683$, indicating that the effect was consistent across different studies.

General discussion

In this meta-analysis, we examined the correlates of media multitasking behavior with different domains of everyday cognitive functioning in a series of mini meta-analysis. The effect sizes were categorized into different themes reflecting different domains of everyday cognitive functioning, based on the similarities and dissimilarities between the reflected constructs. Overall, the effect sizes can be categorized into four distinct themes. Pooled together, frequent media multitasking had weak, but significant associations with a decrease of attention regulation (z = .16), lower levels of inhibition/higher levels of impulsiveness (z = .22), an increase of memory problems (z = .16), and a decreased behavior regulation (z = .19).

Regarding the association between media multitasking and attention regulation, we found that heavy media multitasking was associated with higher frequency of mind-wandering, higher distractibility, and more problems with task switching. With regard to mind-wandering, this finding was somewhat consistent with other findings in the literature which used objective measures. In an experiment in which participants were asked to memorize materials from a video-recorded lecture, Loh et al. (2016) found that heavy media multitaskers retained less information from the lecture, and this effect could be explained by the increased tendency to mind-wander in this group. However, at least one study showed a null correlation between media multitasking and mind-wandering: heavy media multitaskers performed worse in a metronome-response task, but they did not show a tendency to have increased mind-wandering during the experiment (Ralph et al., 2015). With regard to distractibility, other studies which used objective measures showed that, for instance, heavy media multitaskers were less able to filter out irrelevant information from their immediate environment (Cain & Mitroff, 2011; Ophir et al., 2009). However, a recent meta-analysis (Wiradhany & Nieuwenstein, 2017) has shown that other studies have failed to replicate this finding. Lastly, with regard to task-switching, other studies using objective tests showed mixed evidence for the correlation between media multitasking and task switching. Some studies found a negative correlation between media multitasking and task performance (Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017, Exp., p. 1), others found positive correlations (Alzahabi & Becker, 2013), yet others found null results (see Wiradhany & Nieuwenstein, 2017, for a meta-analysis). Thus, it can be said that while frequent media multitasking is associated with more problems with attentional control in everyday situations, media multitasking might not directly influence one's ability to regulate attention, as measured by objective tests, per se.

Heavier media multitasking was associated with increased impulsiveness/decreased inhibition; heavier media multitaskers were associated with higher scores in impulsiveness traits and they reported more (severe) symptoms of hyperactivity/impulsivity. Heavier media multitasking was also associated with higher scores in other traits which are related to impulsiveness, such as sensation-seeking and risk-taking (Dalley et al., 2011; Whiteside & Lynam, 2001). This finding was consistent with findings using objective measures. For instance, heavy media multitaskers were more likely to choose smaller, immediate rewards instead of later, larger ones and they endorsed intuitive, but incorrect answers of the Cognitive Reflection Test (Schutten et al., 2017). Additionally, another study indicated that HMMs scored lower in a fluid intelligence test due to them giving up earlier in the test (Minear et al., 2013). Individuals with higher levels of sensation-seeking trait are characterized by a higher stimulation threshold for optimal behavioral performance (Hoyle, Stephenson, Palmgreen, Lorch, & Donohew, 2002; Zuckerman, 2007) and a higher likelihood to act prematurely without foresight, which at times lead to risk-taking behaviors (Dalley et al., 2011; Hoyle et al., 2002; Zuckerman, 2007). Indeed, consuming multiple streams of information has been shown to promote a higher level of engagement (Bardhi, Rohm, & Sultan, 2010; Wang & Tchernev, 2009) and to provide gratifications (Hwang, Kim, & Jeong, 2014) which together provide stimulations for those who seek them. Accordingly, people with higher levels of sensation-seeking and risk-taking might media multitask to seek for additional stimulations.

Heavier media multitasking was associated with increased problems related to memory. In this regard, one study using an objective measure, namely a change-detection task has shown that HMMs had difficulties retaining specific information in working memory, regardless of the presence of distractors, and importantly, they performed more poorly in a later long-term memory test for both relevant and irrelevant objects compared to LMMs (Uncapher et al., 2016; but see Wiradhany, van Vugt, & Nieuwenstein, 2019 for null results). Other studies have shown that HMMs, compared to LMMs performed worse in a complex working memory test (Sanbonmatsu et al., 2013) and an N-back test (Cain et al., 2016; Ophir et al., 2009; Ralph & Smilek, 2016; but see Cardoso-Leite et al., 2015; Wiradhany & Nieuwenstein, 2017 for null results).

Lastly, regarding the association between media multitasking and behavior regulation, we found that heavier media multitaskers had more difficulties to adjust their thoughts, emotions, and actions to the situational demands. This finding is in line with its counterpart in objective tasks, where studies have found that HMMs performed worse in tasks in which they have to respond to different cue-probe contingencies, such as the AXE-CPT task (Ophir et al., 2009; Wiradhany & Nieuwenstein, 2017; but see Cardoso-Leite et al., 2015 for null results). However, there were mixed findings with regard to performance of HMMs in a change-detection task in which distractor filtering was involved, with one study showed that HMMs performed worse (Ophir et al., 2009), while other, recent ones showed null findings (Cardoso-Leite et al., 2015; Uncapher et al., 2016; Wiradhany & Nieuwenstein, 2017; Wiradhany et al., 2019).

Collectively, we witnessed a discrepancy between the findings in this meta-analysis and the findings in a previous meta-analysis (Wiradhany & Nieuwenstein, 2017). In this meta-analysis, we found overall weak, but stable-pooled correlations between media multitasking and self-reports of cognitive functioning in everyday situations whereas in the previous meta-analysis, we found an overall weak-pooled correlation, but the correlation became null upon corrections. This discrepancy, as we previously mentioned, might exist for several reasons. First, performance-based measures might capture some, but not all aspects of everyday cognitive functioning. Consider the tests for one's ability to regulate attention, for instance. One group of researcher may assess attention regulation using the perspective of mind-wandering to investigate the waxing and waning of attention (e.g., Christoff et al., 2016). Yet, others assess attention regulation using the perspective of divided attention (e.g., Moisala et al., 2016). The two perspectives might cover some, but not all aspects of attention regulation, and in everyday situations one might need to suppress both mind-wandering and distraction to regulate attention properly. Second, performance-based measures are often designed to assess one's ability at a pathological level (Chan et al., 2008). For instance, as a diagnostic tool to inquire whether one's ability to regulate attention is clearly impaired. Therefore, one interpretation of the weak correlations across all themes would be that media multitasking behavior is associated with the increased number of everyday problems related to cognition, but this does not mean that media multitasking is associated with the presence of an impairment in cognitive abilities. The weak correlations between media multitasking and everyday cognitive functioning as shown in self-reports suggest that performance-based measures might not be adequately sensitive to detect everyday cognitive problems in media multitaskers.

Notes on causality

Media multitasking behavior might precede, occur as a consequence, or have a reciprocal relationship with everyday cognitive functioning. Currently, this meta-analysis does not allow for disentangling the causal relationship between the two. Preceding problems with cognition, media multitasking behavior may promote a specific mode of processing information in the environment (Lin, 2009. Specifically, heavy media multitaskers might develop a breadth-biased focus of attention, due to constant exposures to media-saturated environments. That is, they prefer to skim a large quantity of information rather than deeply processing a small amount of information. Consequently, adopting this mode of information processing might lead media multitaskers to apply cognitive control processes such as thought-monitoring and attention regulation less strictly. This might have profound consequences. In an fMRI study; Moisala et al. (2016) found that in addition to worse task performance in which participants had to attend to sentences in one modality (e.g. auditory) while they had to ignore distractor sentences presented in another modality (e.g. visual), HMMs, compared to LMMs also have higher activations in the right superior and medial frontal gyri, and the medial frontal gyrus. Increased activations in these areas have been linked to, among others, increased top-down attentional control. Therefore, heavy media multitaskers might require more effort in filtering distracting information than light media multitaskers. Alternatively, it could also be the case that media multitasking behavior leads to overreliance of exogenous control of attention (i.e. from incoming notifications from media; Ralph et al., 2013). Consequently, heavy media multitaskers train their endogenous control less often and thus, experience more problems related to cognitive control.

Media multitasking behavior might also occur as a consequence of existing problems with cognition. People with ADHD and people with problems with behavior regulation and metacognition are more easily distracted and therefore have a higher propensity to media multitask. Similarly, people with high levels of sensation-seeking are more inclined to media multitask for stimulation-seeking purposes. Relatedly, indicating that excessive media multitasking behavior might be a result from a preexisting condition, studies have also shown that individuals with smaller grey matter volumes in the Anterior Cingulate Cortex (ACC) – a brain region which has been shown to be more active during error and conflict detections (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004) – reported higher levels of media multitasking (Loh & Kanai, 2014). Similarly, the increased activations of the brain areas associated with top-down control in heavy media multitaskers (Moisala et al., 2016) might also indicate that these areas function less efficiently in heavy media multitaskers, compared to light media multitaskers.

Lastly, media multitasking behavior might have a reciprocal relationship with problems with cognition and vice versa. On this reciprocity, several longitudinal studies have attempted to examine whether media multitasking behavior and everyday-related problems are reinforcing each other over a longer time period. The results of these studies showed that media multitasking did not appear to have a reciprocal relationship with the occurrence attentional problems (Baumgartner, van der Schuur, Lemmens, & Te Poel, 2017) 3 and 6 months later. Nevertheless, these studies showed that the associations between media multitasking and attentional problems were stable over time. That is, the correlation remained significant during the first, second, and third periods of data collection. Together, this might indicate that individuals have a stable level of media multitasking behavior over time and similarly, the occurrence of some everyday-related problems is also stable over time.

Limitation and future directions

The findings in our set of mini-meta-analyses are limited in several ways. First, while the effects found in different groups of findings were somewhat reliable across different studies, critically, the overall pooled effects were weak, with z ranging from .16 to .22. Thus, most of the variance underlying the media multitasking behavior is still unaccounted for. Additionally, while we refer to the literature, our categorization of effect sizes remained somewhat subjective. This subjectivity might introduce bias and or contribute to our level of within-theme heterogeneity. We witnessed a high level of heterogeneity in the attention regulation theme, and this high heterogeneity could not be explained by our moderators. Arguably, this high level of heterogeneity might be driven by the effect sizes related to CFQ, which dimensionality is still being argued for in recent studies (e.g., Bridger et al., 2013). It might be that the null and negative correlations in the CFQ-related effect sizes were driven by the other dimensions of CFQ.

Third, the current meta-analysis focuses on studies pertained to everyday cognitive functioning. However, media multitasking studies have gone beyond the cognition-related themes, as some studies have investigated the correlates between media multitasking and depression (Becker, Alzahabi, & Hopwood, 2013), anxiety (Becker et al., 2013; Hatchel et al., 2018), creativity and imagination (Duff et al., 2014), and well-being (Pea et al., 2012; Shih, 2013; Xu, Wang, & David, 2016). With regards to depression and anxiety, heavy media multitasking was correlated with more (severe) depressive and anxiety symptoms (Becker et al., 2013; Hatchel et al., 2018). This finding was somewhat consistent with a recent nation-wide study which also showed that individuals who use multiple social media platforms in daily life had higher odds of having increased levels of depression and anxiety (Primack et al., 2017). Furthermore, media multitasking was negatively correlated with imagination, but it was positively correlated with creativity (Duff et al., 2014). Lastly, the correlations between media multitasking and well-being were somewhat mixed. In a large-scale study which involved 3461 8-12-year-old girls, Pea et al. (2012) found that media multitasking was positively correlated with social success, but it was negatively correlated with normalcy feelings, positive feelings, and social stress. Shih (2013) found that media multitasking was not correlated with well-being as assessed using two versions of self-report questionnaires which focused on well-being. While part of these findings was discouraging, suggesting that media multitasking behavior might have potential ramifications on other aspects of everyday functioning beyond cognition, the other part, namely the positive correlations with social success and creativity suggests that media multitasking behavior might be beneficial as well. It could be interesting for future studies to further examine the adaptive values of everyday media multitasking behavior, especially given that several longitudinal studies have indicated that media multitasking behavior is stable over time (Baumgartner, van der Schuur et al., 2017; van der Schuur et al., 2018).

Fourth and lastly, since all findings we synthesized in the meta-analysis were correlational, it is still an open question whether media multitasking behavior leads to, is an effect, or have a reciprocal relationship with the occurrence of cognitive problems in everyday situations. Futures studies might be interested in disentangling this association in a more controlled manner.

Conclusion

In a series of mini meta-analyses, we categorized the correlates between media multitasking and everyday cognitive functioning, as assessed using self-reports, in four different themes. Heavier media multitasking was associated with increased of levels of self-reported problems with attention regulation, behavior regulation, impulsiveness/inhibition, and memory. Together, media multitasking appears to be correlated with increasing problems everyday cognitive functioning. However, the overall small effects were small, a high level of heterogeneity was detected in one theme, and a large proportion of variance of media multitasking behavior is still unaccounted for. Additionally, since most studies reported correlations, the causality direction is still unclear.

Notes

1. To ensure that all possible relevant results have been included in the meta-analysis, in addition to these keywords, we performed a search using more general keywords,

namely *media multitask** AND (*cognition OR emotion OR trait*). This search yielded no additional results. Lists of the references found using our search terms can be found in the supplementary materials of this article.
2. The author was contacted for requesting the relevant zero-order correlations not reported in the article. Unfortunately, due to unforeseen circumstances, the original dataset was no longer available. Nevertheless, we are thankful to Dr. Shui-I Shih for her cooperation.
3. Two of the studies (Baumgartner, van der Schuur, et al., 2017) were longitudinal studies with three waves each. All study waves were included (see Table 1).
4. Note that while this measure has impulsivity on its name, the scale was intended to measure how an individual may act (e.g., suppressing their impulse) in situational contexts (Tsukayama et al., 2013, p. 880). These authors also proposed a distinction between domain-specific impulsivity, which is externally driven and measured by their scale and domain-general impulsivity, which is more internally driven and measured by other impulsivity scales such as the BIS.

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