Chapter 1

General Introduction
Chapter 1

One morning, I had seven different tabs opened on my internet browser, and I found myself completely lost. Due to the recent developments of media communications technology, I can afford to have multiple powerful devices. Having one of these devices (e.g., a smartphone) allows me to interleave between multiple activities within a single device (e.g., Yeykelis, Cummings, & Reeves, 2014). Having several of these devices (e.g., a smartphone and a laptop) allows me to interleave across multiple devices (e.g., Judd, 2013). For people like me, the experience of being bombarded with multiple streams of information can be overwhelming. Others, however, may navigate such information-rich environments with ease (see Strayer & Watson, 2012; Watson & Strayer, 2010), while yet others might be inclined to multitask due to their lack of behavioral control. What drives these individual differences? To what extent does the experience in dealing with these devices affect our capabilities in processing information? To what extent are people driven to multitask (or get distracted) due to the presence of these devices? These are some of the main questions addressed in this thesis.

The so-called media multitasking behavior – accessing multiple streams of media-related information – has been shown to be increasingly prevalent over the years (Rideout, Foehr, & Roberts, 2010; Roberts & Foehr, 2008). For instance, adolescents have been estimated to spend about 30% of their media-consumption hours multitasking (Rideout et al., 2010). The frequency of switches is also rather remarkable: It has been estimated that switches between different media streams can occur within minutes (Brasel & Gips, 2011; González & Mark, 2004) to seconds (Yeykelis et al., 2014). Attached to this phenomenon is an interesting puzzle: On the one hand, the human cognitive architecture has been argued to be poorly equipped for multitasking (Salvucci & Taatgen, 2008, 2011). Yet, on the other hand, people keep doing it, sometimes in spite of their awareness of the performance costs (Bardhi, Rohm, & Sultan, 2010). Additionally, the same cognitive architecture is considered to be highly plastic. Recent reviews on the effects of contemporary technologies on human cognition suggest that this plasticity is not always for the better. The constant interactions with technologies may lead to structural changes in the brain (Loh & Kanai, 2016) which could result in better...

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1 I wrote the introduction to reflect the topic addressed in this thesis from a personal experience and to some extent, to add my responsibility to the project. Thus, the pronoun “I” was used. I used “we” in the following chapters to reflect the collaborative nature of this thesis.

2 I am really bad at multitasking. Close friends of mine would know this, often asking if I would be alright taking a coffee to go since I would have to interleave between walking and sipping coffee.
functioning in some domains but worse functioning in others (see Bavelier, Green, & Dye, 2010; Loh & Kanai, 2016, for reviews). In a similar vein, habitual media multitasking might promote worse and/or better everyday functioning to some extent.

**Understanding (Media) Multitasking**

**The Multitasking Paradox: Costs and Benefits**

Our cognitive architecture has been suggested to be poorly equipped for multitasking (Salvucci & Taatgen, 2008). This relates to the idea that multitasking generally involves at least two types of cost. The first type of cost relates to the increase of response times when we attempt to interleave multiple tasks, as opposed to performing them one at a time. In a task-switching paradigm (Kiesel et al., 2010; Monsell, 2003), this cost is observed as a slower response time in alternating between two tasks with different stimulus-response mappings, as compared to when the same task is performed repeatedly. This so-called switch cost does not disappear in conditions in which people are given the opportunity to alternate or repeat between tasks at will (Arrington & Logan, 2004; Arrington, Reiman, & Weaver, 2014), and it has been associated with a fundamental bottleneck in information processing (Kiesel et al., 2010; Monsell, 2003). For instance, one interpretation of this cognitive bottleneck is that of the “problem state,” which suggests that we can only keep one goal active at a time (e.g., Borst, Taatgen, & van Rijn, 2010).

In addition to the performance cost, multitasking appears to create psychological costs as well. In a study in which the researchers monitored both the computer-related activities and heart rates of college students for seven days, Mark, Wang, and Niiya (2014) found that students who switched more frequently between computer tabs reported higher levels of stress in a stress-related questionnaire and showed a lower heart-rate variability on average, which, contrary to intuition, corresponds to a higher level of experienced stress (Mark et al., 2014). Together, these findings indicate that multitasking may be associated with a higher level of experienced stress. In another in situ study in which the researchers monitored the activities and interactions of employees in a workplace, Mark, Iqbal, Czerwinski, and Johns (2015) found that employees who switched more frequently between different computer applications and between different internet tabs reported a lower level of productivity at the end of the working day.
Somewhat ironically, it has been reported that people continue to switch between different tasks in spite of their awareness of the switching costs (Kessler, Shencar, & Meiran, 2009) and the psychological costs (Bardhi et al., 2010; Junco & Cotten, 2011). To better understand why people continue to media multitask, we can look into a number of studies which investigated the potential benefits of media multitasking in addition to its costs. Bardhi et al. (2010) interviewed a group of undergraduate students to probe their motives for media multitasking. The results of this interview captured the paradoxical nature of multitasking. On the one hand, media multitasking was harmful: frequent multitaskers experienced a higher level of inefficiency in processing information from the media, a higher level of disorder (e.g., stemming from the number of information streams to be managed), and a higher level of dependency to various forms of media. In line with these results, Hwang, Kim, and Jeong (2014) also found that perceived efficiency predicted the general level of media multitasking. On the other hand, media multitasking was beneficial: people who frequently media multitask perceived a higher level of control over their interaction with the media devices, a higher level of efficiency due to performing multiple things at once, a higher level of engagement to the media consumption process, and a higher level of connectedness to others (e.g., since most of these activities involved forms of communication).

Another benefit of media multitasking might be the ability to modulate one’s performance in multitasking situation. Kononova, Joo, and Yuan (2016) found that one’s ability to recognize facts from a reading material in a multitasking condition was modulated by one’s preference for media multitasking. In their study, memory for an online article was compared between conditions in which participants were required to check their Facebook account (forced multitasking), or in which they could freely check their Facebook account at will (voluntary multitasking), or in a control condition in which they were only asked to read the article. Additionally, Kononova et al. also measured participants’ level of media multitasking using a polychronicity index; i.e., an index of how much they preferred to multitask (König & Waller, 2010). They found a main effect of multitasking: Participants recognize fewer facts in the two multitasking conditions compared to the control condition. However, they also found an interaction between conditions and media-multitasking preference: Participants with a higher preference for multitasking were equally accurate in recognizing information in the multitasking conditions as in the control condition. This indicates that people who prefer to
multitask may be more efficient in switching between reading an online material and checking Facebook.

Lastly, media multitasking might allow a third party to communicate their message more effectively (see Jeong & Hwang, 2016 for a meta-analysis). Voorveld (2011) found that simultaneous exposure to both online and radio advertising of a product, compared to an individual exposure of each, was associated with a more positive attitude towards the product and a higher intention to buy the product, and it was also associated with better product recognition. Similarly, Chinchachokchais, Duff, and Sar (2015) found that presenting an advertisement while participants were doing one or two additional tasks, namely reporting letters and dots that appeared on a screen, was associated with a more positive evaluation of the advertisement and a higher task-enjoyment. Somewhat ironically, however, these positive effects of media multitasking might have stemmed from users having a depleted cognitive capacity due to concurrent multitasking, thus leaving less resources available for a thorough evaluation of the advertisements (Jeong & Hwang, 2016). Therefore, there appears to be more about media multitasking than the typical performance costs reported in laboratory studies of task-switching.

Transfer of Training in (Media) Multitasking?

Reports, especially in popular media (e.g., Palfrey & Gasser, 2008; Small & Vorgan, 2008) have suggested that the constant exposures to media-saturated environment might alter people’s ability to process information. These reports focused on the youths in particular, who are supposedly exposed to many multitasking scenarios in everyday situations more often. The assumption would be that since they multitask almost constantly, they would become expert multitaskers. In other words, the cognitive skills they acquire from multitasking using media should generalize to other multitasking scenarios as well. There are several problems with this notion. First, there is only limited evidence that multitasking training in one context results in better multitasking ability in another (Lee et al., 2012; Liefelt, Stroback, Frensch, & Schubert, 2011; Stroback, Frensch, Soutschek, & Schubert, 2012). Second and perhaps more importantly, this so-called transfer of training notion would predict that everyday multitasking using media would lead to better or more efficient information processing. As we will witness in the following chapters, this is not always the case.
Chapter 1

**Consequences of Media Multitasking**

The transfer of training account would predict better multitasking, yet, multiple studies reported (negative) consequences of media multitasking. To address this contradiction, I think that an important distinction needs to be made. In general, studies that have demonstrated the negative consequences of media multitasking can be distinguished into two types. The first type pertains to studies in which participants were asked to access media devices while doing a primary task such as driving or studying. The results of these studies on multitasking in inappropriate contexts were rather tautological (i.e., being distracted is distracting), since the decrease in performance can simply be attributed to the additional tasks which have to be performed simultaneously (Aagaard, 2015). Indeed, interacting with mobile phones while driving, as opposed to not interacting with mobile phones while driving, has been associated with various impairments in driving performance (Horrey & Wickens, 2006; Strayer, Drews, & Johnston, 2003), and media multitasking while studying, as opposed to not media multitasking while studying, has been associated with worse recollection of study content (Fox, Rosen, & Crawford, 2009; Hembrooke & Gay, 2003).

The second type of media multitasking studies, which I mainly addressed in this thesis, pertain to studies which attempted to find the neural, cognitive, and behavioral correlates of media multitasking behavior. In other words, these studies tried to evaluate to what extent the differences in the intensity or frequency of media multitasking were correlated with how we think, act, and feel. Studies investigating these questions have used a cross-sectional design (see Uncapher et al., 2017; Uncapher & Wagner, 2018; van der Schuur, Baumgartner, Sumter, & Valkenburg, 2015 for reviews). Typically, participants with very high and low scores on the media-multitasking questionnaire were assigned to groups of heavy and light media multitaskers (HMMs and LMMs, respectively) and they were asked to perform tasks and/or to fill in a series of self-report questionnaires which pertained to different domains of cognition and behavior. The results of these studies yielded elaborate profiles of media multitaskers, suggesting that certain domains of cognition and behavior might correlate with media multitasking. Importantly, however, a comparison of the results across different studies has shown some inconsistencies in these profiles (see Uncapher et al., 2017; Uncapher & Wagner, 2018; van der Schuur, Baumgartner, Sumter, & Valkenburg, 2015 for reviews). Likewise, a number of studies have indicated that HMMs performed worse in tasks related to different domains of
cognition (Cain & Mitroff, 2011; Ophir, Nass, & Wagner, 2009; Uncapher, Thieu, & Wagner, 2016), but these findings were largely confined to small-sample studies.

**This Thesis**

The projects described in the following chapters in this thesis attempted to answer three questions: What constitutes the media multitasking behavior that is captured by the MMI, which domains of cognition and behavior correlate with media multitasking, and to what extent does the presence of media devices affect one’s ability to process information? To answer the first question, I relied on network analysis as a visualization and an analysis tool (Borgatti, Mehra, Brass, & Labianca, 2009). To answer the second, I reassessed the current findings in the literature using meta-analytic approach (Borenstein, Hedges, Higgins, & Rothstein, 2009; Liberati et al., 2009) and replication studies (Brandt et al., 2014; Goodman, Fanelli, & Ioannidis, 2016). This reassessment process provided a more critical look towards the available evidence and better estimations of some of the reported correlates. To answer the last question, I conducted an experiment to evaluate to what extent the presence of media devices, in absence of any interaction with them, influenced task performance (e.g., Thornton, Faires, Robbins, & Rollins, 2014). Wrapping up this thesis, I propose a framework for explaining when and why people may engage media multitasking, and why some people may do this more often than others.

**Chapter 2: What Constitutes the Media Multitasking Behavior?**

Some people multitask more frequently than others. To estimate one’s level of media multitasking, we can ask how many hours people spend using media and during what proportion of this time people also concurrently use another type of media. In a seminal study, Ophir, Nass, and Wagner (2009) asked these questions for all possible combinations of 12 mainstream media types in the Media Use Questionnaire (MUQ) and computed the Media Multitasking Index (MMI). This index supposedly reflects the number of media shared in a typical media-consumption hour. Thus, participants with higher MMI would share more types of media in a typical hour. This index has become the most commonly used metric for measuring media multitasking (Baumgartner, Lemmens, Weeda, & Huizinga, 2017).

The MMI captures an overall level of media multitasking behavior per individual, but
Chapter 1

to what extent the behavior varies across different media types and populations has not been explored. Understanding the underlying media combinations in MMI is important, since we do not know which combinations of media contribute significantly to the final MMI score. I investigated the underlying media combinations behind the MMI in Chapter 2, which I wrote in collaboration with Susanne Baumgartner. We sought to answer this question by reanalyzing existing MUQ responses and rendering them into networks with media types as network nodes and time-sharing between media as network edges. We found that some media combinations were more likely to occur than others and that these more prevalent combinations were stable over different populations.

Chapters 3 & 4: Minds of Media Multitaskers

In Chapter 3, which I wrote with the help of Mark Nieuwenstein, we tested the robustness of the correlates of media multitasking behavior as reported in Ophir et al. (2009) in two sets of experiments. Initially, this study provided us the first mixed findings in the project: out of 14 tests conducted, only five yielded a statistically significant effect in the direction proposed by Ophir et al.: An increased distractibility for people with higher scores on the media-use questionnaire. Importantly, only two of these five effects held in a more conservative Bayesian analysis. To get a more reliable, conservative estimate of the strength of these correlates, we then performed a meta-analysis on a total of 39 effect sizes pertaining to the association between media multitasking and distractibility. The results yielded a weak, but significant association between media multitasking and distractibility that turned nonsignificant after correction for small-study effects.

Additionally, a recent study showed a specific, yet divergent finding from one of the tasks presented in Ophir et al. (2009): The change-detection task. Specifically, Ophir et al. (2009) showed that HMMs retained less relevant information when the number of distrac-

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3 Susanne has a background in communication science and is one of the most active researchers in media multitasking in The Netherlands. In helping me writing this chapter (and in discussing the topic with me in general), she has helped me realized that multitasking is more than just a problem in processing information.

4 Mark is a cognitive scientist with particular interests in how we can process stimuli which come in rapid successions (e.g., using the Attentional Blink paradigm) and decision-making. However, it was his experience in meta-analysis which contributes the most in helping me developing and writing this chapter. He also acts as my daily supervisor in this project and is one of the first people who introduced me to experiments in cognitive science (I have a background in social psychology).
tors that was shown together with the to-be-remembered information increased. On the other hand, Uncapher et al. (2016) showed that HMMs retained less relevant information regardless of the number of distractors present in the immediate environment, thus suggesting that HMMs might be affected by internal distractions. In Chapter 4, which I wrote with Marieke van Vugt\textsuperscript{5} and Mark Nieuwenstein, we conducted a large-scale replication study to provide a more rigorous test of this internal distraction hypothesis. As a formal evaluation of internal distractions, we included experience sampling probes during the experiment, to probe the extent to which participants could remain focused during the experiment. The results showed that frequent media multitasking was not associated with mind-wandering or with a decrease in performance in the change-detection task, thus dismissing the internal-distraction hypothesis.

Chapter 5: Behaviors of Media Multitaskers

The studies presented in Chapters 3 and 4 suggest that media multitasking is not associated with increased susceptibility to internal or external sources of distraction during task performance. At the same time, a growing number of studies have reported correlates of media multitasking with seemingly unrelated types of daily functioning and mental health-related problems. In the study presented in Chapter 5, Janneke Koerts\textsuperscript{6} helped me to categorize these findings into different domains in a series of mini meta-analyses (Goh, Hall, & Rosenthal, 2016). Overall, we found that media multitasking behavior is associated with problems in behavior regulation (e.g., inhibition and increased impulsiveness), problems in metacognition (e.g., meta-awareness and planning), frequency of ADHD symptoms, and sensation seeking. To a certain extent, these findings could be interpreted as evidence that people who are easily distracted in everyday situations might be more inclined to media multitask.

Chapter 6: Media-induced Distractions

Chapters 2-5 investigated the cognitive and behavioral correlates of media multitask-

\textsuperscript{5} Marieke is a cognitive modeler with a particular interest in mind-wandering. Naturally, in this chapter she contributed her expertise in mind-wandering.

\textsuperscript{6} Janneke is a Clinical Neuropsychologist. She has an extensive knowledge on different types of self-reports of executive function (e.g., the Behavioral Ratings Index of Executive Function; BRIEF) and self-reports of mental health (particularly ADHD). The knowledge she shared has helped me in categorizing the findings in this mini meta-analysis.
ing, under the assumption that the tendency to use different media at the same time might influence our way of processing information. Yet, there is at least one other way in which media may affect information processing and task performance, namely through the mere-presence effect of media devices (e.g., Thornton et al., 2014). In Chapter 6, which I wrote in collaboration with Sebastiaan Mathôt and Mark Nieuwenstein, we tested to what extent the mere-presence of one’s (own) mobile phone might disrupt task performance in an antisaccade experiment, and whether the decrease of task performance could be explained by overt attention towards the phone (Ito & Kawahara, 2017). As partial support for the mere-presence effect and the spatial bias effect, we found that the mere-presence of one’s own mobile phone was associated with a small increase of certain types of errors in the task, and indeed, participants showed a slight bias in making eye movements toward their phone. At the same time, however, eye movements in the direction of the phone were not faster and they had a smaller amplitude than eye movements made away from the phone. This suggests that while the mobile phone seemed to attract attention, thus biasing eye movements towards its location, participants also tried to avoid looking directly to it, resulting to slower eye movements with smaller amplitudes.

General Discussion: From Mind to Behavior of Media Multitaskers

Having performed studies on the variability in media multitasking and the correlates of media multitasking with minds and behaviors, I became aware that a theoretical framework is missing for explaining some of the questions I ask at the beginning of this introduction: Why do people continue to multitask in spite of their knowledge of the cost? Which (cognitive) system is likely to demarcate heavy from light media multitaskers?

A high level of everyday multitasking as indicated by a high MMI score might reflect multiple things. It might reflect one’s ability to do multiple things simultaneously while keeping the performance costs at minimum. In a driving simulation study, Watson and Strayer, (2010) found that a small subset of their participants did not suffer from the costs commonly associated with multitasking. About 2.5% of their participants performed equally well in a sin-

7 Sebastiaan is a cognitive scientist with a particular interest in vision, especially in pupillometry. In this chapter, he helped me analyze the eye-movement data. He is also the programmer of OpenSesame: An open-source, graphical experiment builder which I used a lot in this thesis (and will continue to use in years to come).
gle-task (only driving) and in a dual-task (driving and performing an auditory working memory task) conditions. In other words, these participants did not show divided-attention costs. Later, in a separate fMRI study (Medeiros-Ward, Watson, & Strayer, 2015), it was found that these so-called “supertaskers” showed less activation in the brain regions which are proposed to play important roles in multitasking, namely the Anterior Cingulate Cortex (ACC) and the Prefrontal Cortex (PFC; Botvinick, Cohen, & Carter, 2004), indicating that supertaskers may be more efficient in recruiting crucial brain regions which help them to multitask. It could thus be the case that some people become frequent multitaskers because they are actually good at it. I will refer the first group as “good multitaskers.”

A high MMI score might also reflect to what extent people are driven to multitask. This might be related to a certain psychological trait, such as impulsiveness (Dalley, Everitt, & Robbins, 2011) or to a certain mental health condition, such as ADHD. With regard to the former, Minear, Brasher, McCurdy, Lewis, and Younggren (2013) found that indeed, people with higher MMI scores reported a higher level of impulsiveness. With regard to the latter, Magen (2017) found that people with higher MMI scores reported more (severe) symptoms of ADHD. Together, these findings suggest that individuals with behavior-regulation problems are more inclined to multitask in everyday situations (Baumgartner, van der Schuur, Lemmens, & te Poel, 2017; Baumgartner, Weeda, van der Heijden, & Huizinga, 2014; Magen, 2017) and this could occur in spite of the individual’s awareness of the multitasking costs (e.g., Bardhi et al., 2010). I will refer this second group as “distracted multitaskers.”

Good and distracted multitaskers might develop media multitasking habits for different reasons. For good multitaskers, interleaving multiple tasks might actually help them to complete the tasks more efficiently. For distracted multitaskers, interleaving multiple tasks might occur since they find it difficult to maintain their focus of attention to a single task.

It could be the case that among heavy media multitaskers, there are good and distracted multitaskers, and this decreases the magnitude of the association between media multitasking and distractibility. On the other hand, it could be the case that habitual multitasking behavior is not correlated with cognitive functioning. After all, habitual media multitasking might develop for various reasons, and those who have the habit might still be able to perform

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8 One can also have a high level of multitasking because one prefers to do so (Poposki & Oswald, 2010). However, in my view, this preference can still be attributable to either the ability to multitask or the lack of behavioral control.
well in different domains of cognition. A framework for explaining the individual differences might help the field to move forward, by shifting the research efforts from a trial-and-error search for correlates, to a more theoretically inspired prediction of how heavy and light media multitaskers might differ from each other.

In the general discussion, which I wrote in consultation with Mark Nieuwenstein and Ritske de Jong\(^9\), I propose that the locus coeruleus-norepinephrine (LC-NE) system (Aston-Jones & Cohen, 2005; Sara & Bouret, 2012) might play an important role not only in regulating switching behavior in media multitasking, but also in demarcating good from distracted multitaskers. Specifically, I propose that 1) the LC-NE system regulates whether and when people switch from an exploitation-related mode of behavior (e.g., consuming information from one media stream) to an exploration-related mode of behavior (e.g., switching from one media stream to another); 2) good multitaskers might balance exploitations and explorations; they might only get involved in multitasking in situations in which it is strategic to do so (Ralph & Smilek, 2016) whereas 3) distracted multitaskers might be biased toward explorations; they are less able to set an optimum balance between exploiting and exploring. Subsequently, I discuss the questions and predictions this proposed framework yields for future studies on media multitasking.

Together, the empirical chapters I present in the following examine the cognitive (Chapters 3 & 4) and behavioral (Chapter 5) domains which might vary as a function of media multitasking behavior, after considering which type of media combinations define the typical media multitasking behavior (Chapter 2). Additionally, I provide some evidence for the mere-presence effect of media devices (Chapter 6) and a potential account on what drives the individual differences in media multitasking behavior and why people seem to persist to multitask in spite of their understanding of the cost (General discussion).

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\(^9\) Ritske is a cognitive scientist. It is difficult to pinpoint his main interests since he has contributed in different projects of varying topics. I think his interest in my project relates to the question of individual differences: How much of the variation in everyday multitasking behavior can be attributed by differences in information processing efficiency (e.g., working memory capacity) and how much can be attributed by differences in psychological dispositions (e.g., personality traits)? He is also my main promotor.