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Exploitation–Exploration Model of Media Multitasking

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Abstract: Media multitasking has been long considered as a distraction, as something that is inherently negative or irrational. Yet, casual observations and study findings indicate that in the current permanently online, permanently connected society, people still media multitask frequently, sometimes in spite of their knowledge of the costs. In this article, we introduce the exploitation–exploration model of media multitasking (EEMMM), which proposes that media multitasking occurs as a natural part of the waxing and waning of our task engagement: When primary task engagement (exploitation) begins to wane, alternative tasks become more attractive (exploration). In the first part of this paper, we delineate the limitations of the current perspective of media multitasking as a distraction. The second part provides an exposition for our model: What defines behavior exploitation and exploration, and why maintaining an optimal trade-off between the two is important; the everyday, media-related cues for exploiting and exploring; and the neurobiological evidence of a brain system that supports the transition from exploitation to exploration. Lastly, we show how our approach may explain why people media multitask spontaneously and in spite of their knowledge of the costs, and why not all media multitaskers are able to multitask optimally. We conclude the paper with an agenda for future media multitasking research based on the proposed framework.

Keywords: media multitasking, exploration–exploitation, adaptive gain theory, network reset

If, like the first author, you are terrible at juggling multiple tasks, you would be amazed at how people keep up with the bombardment of incoming information in this digital era. Media multitasking appears to have become the norm in our permanently online, permanently connected society (POPC; Vorderer et al., 2018), which suggests that the omnipresence of media has led to people constantly dividing their attention between everyday activities and media content/online communication. Indeed, surveys and studies in recent years have shown that not only is media consumption continually increasing (Deloitte Southeast Asia, 2017; Standard Eurobarometer 92, 2019), but also that media are frequently used while engaging in other media or non-media activities such as working, studying, or talking to someone face to face (Calderwood et al., 2014; Rideout et al., 2010; Segijn et al., 2017).

In the psychology literature, multitasking has been generally defined as the act of interleaving two or more independent tasks that might occur almost concurrently or in a serial manner (Broeker et al., 2017; Burgess, 2000; Carrier et al., 2015; Salvucci & Taatgen, 2011). In *media* multitasking, at least one of these tasks involves media use (Aagaard, 2015). In many experimental paradigms investigating media multitasking, researchers typically compare task performance in a condition in which participants had to engage only with the primary task with a condition in which participants had to interact with media *in addition to* their primary task. For instance, the researcher may ask participants to answer a phone call while driving or check social media while studying (Bowman et al., 2010; Sana et al., 2013; Strayer & Johnston, 2001). Not surprisingly, these studies showed that using media while engaging in another primary task interferes with task performance.

Together, findings from the aforementioned studies have formed a common conception in the literature that equates media multitasking with distraction (Aagaard, 2018b; Bowman et al., 2010). Unsurprisingly, then, participants who had to do an additional media-related task simultaneously with a main task performed worse. Performance decrease as a function of an additional task relates to the limitations of the human cognitive architecture; when humans need to process several streams of information, the incoming information needs to be processed in a serial instead of parallel manner, which produces interference and task performance reduction (e.g., Pashler, 1994; Salvucci & Taatgen, 2008; Wickens, 2002). This is also in line with predictions of the limited capacity model of motivated mediated message processing (e.g., Lang, 2009).

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In spite of its coherence with the theories of information processing, considering media multitasking research *exclusively* as a distraction inherits a tautological problem. If media multitasking is always conceptualized as a task that participants had to carry out in addition to some primary task, the additional task would almost always negatively affect performance on the primary task. In other words, using the typical paradigm, media multitasking researchers would almost always find that, "[media] distraction *is* distracting" (Aagaard, 2018b, p. 10, emphasis added). Subsequently, media as the de facto distraction needs to be avoided. Yet, media multitasking could occur spontaneously (Brasel & Gips, 2017), or even in spite of the user's knowledge of the actual costs (Bardhi et al., 2010). In specific cases, media multitasking may be even beneficial. For instance, listening to music has been shown to boost performance in various settings (see Rickard et al., 2005 for a review), including, but not limited to driving tasks (Ünal et al., 2013; Van der Zwaag et al., 2012) and memory tasks (Hallam et al., 2002). The media multitasking as distraction model helps us to understand the performance costs related to media multitasking. However, it does not provide insights on why media multitasking behavior persists despite the unfavorable costs, and it does not explain potential beneficial effects of media multitasking.

In contrast to the current, distraction-oriented approach on media multitasking, in this paper, we propose a novel framework for media psychologists to investigate media multitasking selection and effects, the exploitation–exploration model of media multitasking (EEMMM). We start with delineating the limitations of the current perspective of media multitasking as a distraction. The following parts provide an exposition of our model. We propose how media multitasking occurs as a natural consequence of the waxing and waning of our (primary) task engagement: When primary task engagement (exploitation) begins to wane, alternative tasks become more attractive (exploration). We will continue by explaining our assumptions for this model and show the neurobiological evidence of a brain system that supports the transition from exploitation to exploration. Lastly, we show how our approach may explain everyday phenomena that could otherwise not be explained by the media multitasking as a distraction perspective. We conclude the paper with an agenda for future media multitasking research based on the proposed framework.

Exploitation–Exploration Model of Media Multitasking

Instead of treating media multitasking narrowly as a distraction, we propose to consider media multitasking as part of our behavioral exploitation–exploration cycles. Behavioral exploitation and exploration are relatively new concepts in psychology and communication science, but there is a long line of research in behavior ecology that has shown how exploration and exploitation support adaptive behavior (Addicott et al., 2017; Berger-Tal et al., 2014). During behavioral *exploitation*, we forage known sources of reward and fully engage in a certain task, but these rewards and the amount of effort we can put in that task may become depleted. During behavioral *exploration*, we put breaks on exploitation when the reward becomes too low or the costs of continuous exploitation become too high, and seek for alternative sources. These two modes of behavior allow us to invest our effort proportionally and flexibly adapt to changes in the environment (Cohen et al., 2007; Inzlicht et al., 2014).

We alternate between exploiting known resources and exploring alternative ones in order to perform optimally in many everyday situations (Addicott et al., 2017; Aston-Jones & Cohen, 2005; Inzlicht et al., 2014). In the media-saturated, POPC world (Vorderer et al., 2018), it is likely that behavioral explorations oftentimes involve media. For instance, while studying for an exam, students may juggle between studying (exploitation) and checking social media during breaks (exploration). Studying may yield a better long-term reward (e.g., a good grade and, ultimately, a diploma), but it requires more effort and it does not provide immediate reward (e.g., the student can only learn about their grades once the exam is over). Therefore, the combination of high-effort investment and lack of immediate reward makes studying unfavorable over time. By contrast, checking social media requires very little effort and yields immediate gratifications. Thus, students may switch from studying to checking social media to counteract the aversiveness of studying (Inzlicht et al., 2014; Kool & Botvinick, 2014). Media appears to be the default distractor due to its omnipresence in the POPC world. Yet, treating media as the de facto distractor creates an unbalanced discourse since we give more weight to the costs as opposed to the benefits of media interactions. By contrast, the exploitation–exploration framework provides a more balanced view for understanding media multitasking and its effects.

Assumptions for the Framework

To implement the principles of exploitation-exploration in media multitasking research, we need to make several assumptions. Specifically, we need to assume that (1) media multitasking constitutes task switching from one activity to another as opposed to parallel actions, (2) task exploitation and exploration are triggered by exogeneous and endogenous cues, (3) individuals have different thresholds for exploiting and exploring in the presence of a similar cue, and (4) task exploration and exploitation are a biologically modulated mechanism.

Assumption 1: Task Switching Instead of Dual Tasking

There is a vast amount of evidence that the human cognitive system is unable to perform two tasks simultaneously (e.g., Schumacher et al., 2001). Thus, media multitasking always involves switching between two (media) activities. Watching TV and sending messages via social media, for instance, occur in a serial as opposed to simultaneous manner (Brasel & Gips, 2011). Here, attention is not shared across multiple tasks, but is rapidly switched from one source of information to another (Kiesel et al., 2010; Monsell, 2003). Understanding media multitasking as task switching provides the basic for the exploitation–exploration framework because a behavior can never be both exploitative and explorative (Cohen et al., 2007). Switching from one (media) activity to another in media multitasking can be considered as a switch from an exploiting to an exploring behavior. One type of media activity can only be considered as exploration or exploitation, depending on the context. For instance, both switching from writing an email to checking social media and switching from reading social media feeds to checking an email can be considered a switch from exploitation to exploration.

Assumption 2: Cues for Exploiting and Exploring

Exploration and exploitation do not occur randomly, but are instead triggered by internal (e.g., from our metacognitive or affective states) and external (i.e., from the environment) cues.

Rewards

One may switch from one task to another simply because the alternative behavior is more rewarding or that the reward of the alternative behavior is more salient. The classic uses and gratifications theory (U&G; Katz et al., 1973, 1974) postulates that users choose media in order to gain specific gratifications. Studies of motives for media use revealed different types of gratifications that are being sought: cognitive, emotional, habitual, and social (Wang & Tchernev, 2009). Cognitive gratifications include information seeking and productivity. For instance, one might multitask using media to check facts or to gain information for satisfying curiosity (Hwang et al., 2014). Emotional gratification includes the affects that are gained through media, such as fun, thrill, or being moved (Bartsch & Viehoff, 2010). Habitual gratification refers to the use of media due for routine fulfillment (Hwang et al., 2014). Lastly, social gratification refers to connectedness and closeness to others (Hwang et al., 2014; Kononova & Chiang, 2015). These gratifications resulting from media use may be perceived as highly rewarding in many situations and may drive individuals to engage in media multitasking.

In a laboratory study, Braun and Arrington (2018) showed how reward modulated the propensity to exploit or explore. Using the voluntary task-switching paradigm (Arrington & Logan, 2004), participants were asked to choose between performing two simple classification tasks (i.e., classifying colors or shapes of an object that appeared in the middle of the screen) in which they got points each time they classified correctly. Critically, in each trial, there is a 50% probability that the point they gained from the current task would be *decreased* while the point they could gain from the alternative task would be *increased,* thus, biasing participants to explore more and exploit less. The main finding was that the switch rates between the tasks increased as the points on the current task decreased and the possible points of the alternative task increased, indicating that participants used reward-related information to guide their decision to exploit and explore.

Individuals might engage in media multitasking due to the rewarding nature of media offerings. Many current media forms, such as social media promise immediate gratifications (Baumgartner & Wiradhany, 2021; Panek, 2014). For example, when watching the news or talking to a friend, quickly checking incoming social media messages might feel as a rewarding distraction. Interestingly, Wang and Tchernev (2009) found that people often started media multitasking to fulfill cognitive gratifications (e.g., information-seeking), but they ended up fulfilling their emotional gratifications instead (e.g., getting entertained). This highly rewarding nature of many media offerings might thus drive individuals to explore media options rather than exploit the primary activity they engage in. This will be particularly so if the reward that someone perceives to gain from the primary activity decreases (see, e.g., Inzlicht et al., 2014), for example, when the movie someone watches starts to become boring, or when a lecture becomes too difficult to follow. Thus, we predict that people are more likely to engage in media multitasking in situations when the perceived reward of the primary activity decreases, or if the rewarding nature of a potential media offering becomes too high (e.g., a long-expected incoming message from a friend).

Affordances

People may choose to switch from one task to another because, well, they can (Baron, 2008). According to the theory of affordances, our perceptions are guided by the perceived use of objects (i.e., what they afford; Greeno, 1994). Media technologies, especially those that relate to the Internet and social media, provide multiple affordances: novel information, social connection, and mass and rapid communication, to name a few (Bayer et al., 2020; Loh & Kanai, 2016), and thus, the presence of multimedia devices alone may increase one's propensity to explore, especially when the costs of switching are low. Indeed, one study has shown that one of the best predictors for media multitasking was media ownership, that is, the presence of a television in a bedroom increased the propensity of multitasking using television (Jeong & Fishbein, 2007). In line with this reasoning, Aagaard (2018a) argued that multimedia devices are especially powerful since they may offer multiple actions depending on the context of use. A laptop, on the one hand, may be used to pursue exploitative-related behavior, such as looking for information for problem solving. On the other hand, it may be used to pursue explorative-related behavior, such as screening for incoming instant messages. The multifunctional nature of media devices implies that whether the presence of media devices generates exploration or exploitation cues depends on the context of use.

Unused Sensory Modules

One might switch from one task to another to (automatically/unconsciously) optimize the use of our sensory modules. Threaded cognition theory, for instance, considers multitasking as our attempt to integrate multiple subtasks (Salvucci & Taatgen, 2008), where each subtask is carried out in processing "threads." These threads use resources from limited-capacity cognitive, perceptual, and motor modules. Resources are released using a greedy, but polite policy: A subtask that requires a visual resource, for instance, may use it to the fullest extent (greedy), but would release the module once the goal of the subtask is reached (polite). This model predicts that unoccupied modules are more likely to attract unused threads.

In line with the predictions of threaded cognition theory, in a survey study in which participants had to indicate the types of media they combine in multitasking, media types that require a similar visual (e.g., watching television while reading print media) and auditory (e.g., listening to radio while watching television) modality were less likely to be combined compared with activities that require less modality overlap (Baumgartner & Wiradhany, 2021; Wang et al., 2015). Interestingly, in line with the greedy–polite policy, two media activities of which one requires a behavioral response (e.g., listening to music while sending instant messages) were more likely to be performed compared with two media activities that require no behavior responses (e.g., reading print media while listening to music) or two media activities of which both require behavior responses (e.g., sending instant messages while browsing; Baumgartner & Wiradhany, 2021).

Occupying unused sensory modules can boost performance. For instance, in several driving simulation studies, it has been shown that listening to music while driving improved driving performance (Ünal et al., 2013) and helped to regulate the driver's mood (Van der Zwaag et al., 2012, 2013). However, this could also go wrong. While listening to a lecture in class, students may want to engage their motor responses, by checking their smartphones. Due to the multisensory nature of the smartphone, this simple behavior response may lead the students' attention away from the lecture to read the incoming message on the phone, for instance. In sum, behavioral exploration does not necessarily lead to media multitasking behaviors that interfere with the main activity, but the multisensory nature of media devices may lead to poor exploration choices.

Arousal Regulation

Media multitasking might help to regulate mood and arousal. In line with mood management theory (Zillmann, 1988), behavioral exploitation that leads to overstimulation might be more likely to be followed with behavioral exploration that is low in excitation and vice versa. Indeed, observational studies have shown that checking social media behavior, which is low in excitation, was longer following a task that was high in arousal compared with low arousal (Mark et al., 2015), while information-seeking in tablets, which is high in excitation, was more likely to occur following a state that was low in arousal (boredom; Leung & Zhang, 2016).

Assumption 3: Different Thresholds for Exploiting and Exploring

Given a similar set of endogenous or exogenous cues, different individuals have a different threshold to exploit and explore. Thus, media-related cues that we consider as a distraction might not be distracting to some people and vice versa. Within our framework, we consider the individual differences in media multitasking as a variation in optimizing the exploitation–exploration tradeoff. That is, some people are more able to appropriately engage in the current, ongoing task (exploitation) or switch to an alternative one (exploration) while others are less able to do so.

Optimizing or finding the appropriate balance between exploitation and exploration seems to involve two distinct, but related processes. During exploitation, one needs to determine the goal of the current behavior and disengage from the current behavior when the goal is no longer relevant. The inability to do so is referred to as "compulsivity." During exploration, one needs to collect a sufficient amount of information before deciding to engage in the alternative behavior. The inability to do so is referred to as "impulsivity" (Dalley et al., 2011; Dalley & Robbins, 2017). In line with this idea, it has been shown that frequent media multitaskers performed worse in a delayed gratification test and they tended to endorse intuitive, but incorrect answers in the Cognitive Reflection Test (Schutten et al., 2017), indicating that they might be less optimal in temporal discounting, which is one form of impulsivity (Dalley et al., 2011).

Other studies have shown that media multitasking was also correlated with other forms of impulsivity, such as attentional and motor impulsivity (Baumgartner et al., 2014; Magen, 2017; Minear et al., 2013; Sanbonmatsu et al., 2013; see Wiradhany & Koerts, 2019, for a meta-analysis). These findings indicate that frequent media multitaskers might engage in media activities without foresight and that they might be biased toward explorations. However, it is unclear to what extent media multitaskers are aware of the processes that are involved in their decisions to exploit or explore, as studies have shown that people have poor insights into their metacognition (de Bruin et al., 2017; Kruger & Dunning, 1999). At the same time, a simple metacognition exercise (i.e., asking participants to rate the quality of their own memory retrieval) could help people to better predict their actual test performance (de Bruin et al., 2017), indicating that metacognitive awareness can be improved.

Assumption 4: The Exploitation–Exploration Transition Is Biologically Modulated

Existing theories of media multitasking selection and effect oftentimes assume for the existence of psychological resources that need to be shared across different tasks (Wang et al., 2015; Wickens, 2002). Yet, cognitive resources have been argued to constitute "theoretical soup stones"; accurate behavioral predictions can be made even if the existence of resources is not assumed (Inzlicht et al., 2014; Navon, 1984). Additionally, it is unclear whether these resources correspond to existing mechanisms in the brain and the body (Inzlicht et al., 2014). In contrast to the resource-based approach, behavioral exploitation and exploration are biologically rooted. Specifically, studies from the field of cognitive neuroscience have shown that our transition from exploitation to exploration behavior is modulated by the locus coeruleus–norepinephrine (LC-NE) system in the brain (Aston-Jones & Cohen, 2005). More importantly, the same brain system has been shown to also play important roles in arousal regulation (Berridge & Waterhouse, 2003), which we discussed in Assumption 2.

The LC-NE system comprises serotonergic and noradrenergic neurons, which are sensitive to changes in stimulus-reinforcement contingencies. Releases of noradrenaline help to tune neurons that respond specifically to a target, resulting in correct task responses (Aston-Jones & Cohen, 2005; Sara, 2009). LC-NE neurons are known to be polymodal; they fire in two distinct modes: phasic and tonic (Aston-Jones & Cohen, 2005; Berridge & Waterhouse, 2003). The phasic mode is characterized by short-lasting, brief bursts of action potentials that result in accurate task performance, while the tonic mode is characterized by a more sustained, regular discharge pattern that results in less engagement to the task and the sampling of alternative behaviors (Aston-Jones & Cohen, 2005; Berridge & Waterhouse, 2003). Accordingly, Aston-Jones and Cohen (2005) proposed that the transition of the two LC modes may play a significant role in performance optimization within a task and across different tasks, in other words, keeping the balance between within-task exploitation and between-tasks exploration behaviors.

Studies have shown that shifts from behavioral exploration to exploitation coincided with phasic and tonic LC-NE firing patterns. For instance, in EEG studies, phasic LC mode modulates the amplitude of the event-related potentials (ERPs) with the (positive) peak latency around 300 ms following the presentation of stimuli, the P3, which result in better detection of oddball stimuli (see Nieuwenhuis et al., 2005, for a review). In a psychopharmacology study, an administration of the pharmacological agent modafinil was associated with an increase of LC and prefrontal cortex (PFC) activation, which in turn resulted in faster (correct) responses in participants when they prepared to switch from a response with a compatible stimulus-response mapping to another with an incompatible stimulus-response mapping (Francisco & Health, 2009). Lastly, pupil diameter, which is directly modulated by the LC-NE system (Einhauser et al., 2008; Murphy et al., 2014), changes as a function of task exploration and exploitation. In a multi-armed bandit task, phasic LC mode, which is indicated by task-evoked pupil dilations, was correlated with exploiting known rewarding arms while tonic LC mode, which is indicated by a larger pupil size during baseline, was associated with exploring unknown arms (Gilzenrat et al., 2010; Jepma & Nieuwenhuis, 2011). By evaluating inputs on the current task utility and environmental demands, the system provides an important signal for promoting optimal behavior within a task (i.e., within-task exploitations) or alternatively, facilitating shifts to a different task (i.e., between-tasks explorations). Our knowledge on the function of the LC-NE system and how it affects exploitative- and explorative-related behaviors provides arguments for media multitasking as not only a distraction, but also as an adaptive behavior.

Consolidating Media Multitasking Research?

Media multitasking has been viewed as inherently negative and irrational (Aagaard, 2018b), yet people engage in media-related distractions in spite of their understanding of the (potential) performance costs (Bardhi et al., 2010; Hwang et al., 2014; Kessler et al., 2009). Our EEMMM provides a parsimonious explanation for this phenomenon: Media multitasking might provide opportunities to balance between exploitation and exploration behaviors (Inzlicht et al., 2014). In this section, we discuss how our approach can consolidate conflicting findings in the media multitasking literature.

Multitasking in Spite of Performance Cost

People sometimes switch from one task to another despite their understanding of the (potential) performance costs (Bardhi et al., 2010; Hwang et al., 2014; Kessler et al., 2009). For example, in two voluntary task-switching experiments in which participants were asked to perform three categorization tasks, Kessler et al. (2009) found that participants switched from one task to another in spite of their awareness of the switch cost (i.e., that they responded slower following a switch as opposed to a repetition trial; Experiment 1) and in spite of their awareness of the difficulty of the task (i.e., switching from easier to more difficult categorization tasks; Experiment 2). Somewhat similarly, Bardhi et al. (2010) found that young consumers were aware that simultaneously consuming different media streams is associated with inefficient content processing, but at the same time they continued to do so because it provided a heightened sense of control and enjoyment, and it was perceived to be a more efficient way for processing information. Subsequent studies have tried providing explanations for this paradoxical relationship using the uses and gratifications theory (Katz et al., 1974): Media multitasking might start with user control and efficiency as motivations, but it continues because it provides emotional gratifications (Hwang et al., 2014; Wang & Tchernev, 2009).

The EEMMM might provide a more parsimonious, alternative explanation for this multitasking paradox: Switches between different media, or between media and non-media tasks, are the natural consequence of the waxing and waning of task engagement. We predict that when task utility is high (e.g., writing this paragraph), the phasic LC mode promotes task engagement. However, there might be a point when the task utility wanes (e.g., The first author is stuck in trying to come up with a good sentence) and the LC-NE system fires in the tonic mode, promoting task disengagement. Consequently, switches between tasks occur in spite of the knowledge over the consequences (e.g., The author is checking his emails instead of continuing writing, in spite of his knowledge that email-checking would not help him finish this article), and we argue that switching is not necessarily harmful; switching might help reset the LC-NE system and renew task engagement (Bouret & Sara, 2005).

Self-initiated switching can be beneficial. First, self-interruptions as opposed to forced interruptions in task-switching are associated with better performance (Kononova et al., 2016; Mcfarlane, 2002; but see Katidioti et al., 2014), indicating that individuals might be aware of their assessment of the current task utility and use that information to decide whether or not to switch. Kononova et al. (2016) showed that participants retained more information from an online article when they could choose to switch from article-reading to Facebook-checking at will, as opposed to when the switches were predetermined. Secondly, switches can reduce stress and arousal levels that are too high. Yeykelis et al. (2014) showed that arousal level, as measured by skin conductance, increased prior to switches from one computer tab to another and the arousal level quickly dissipated following the switches.

Unplanned Switching

Observational studies of media multitasking showed that a good proportion of switches from one media to another occurred without foresight (Brasel & Gips, 2011, 2017; Calderwood et al., 2014). Brasel and Gips (2017) reported that approximately 75–83% of switches from attending to a television show and a web browser occurred within 2 s from the prior switch and they lasted very shortly (< 30 s). Contemporary theories of media multitasking assume that media multitasking is deliberate; it occurs due to certain motives (Duff et al., 2014; Hwang et al., 2014). Thus, these theories do not account for these unplanned, spontaneous media switches.

Our exploitation–exploration model proposes that spontaneous switching might occur as part of random exploration. Behavior exploration can be directed or random. Directed exploration occurs when there is clear evidence that exploiting the current behavior no longer yields sufficient reward or that exploring alternatives does yield sufficient reward. By contrast, random exploration occurs when there is no sufficient information for exploiting or exploring. This random exploration can still be functional as it helps to ensure that the organism maintains a certain level of flexibility (Kessler et al., 2009; Wilson et al., 2017). As evidence for this distinction, Wilson et al. (2017) asked their participants to play a modified two-armed-bandit task. In this task, participants start with four forced-choice sequences that inform which arms would produce larger rewards. Following the forced-choice sequence, participants would either play one of the arms once (Horizon 1) or six (Horizon 6) more consecutive times. One of the important findings was that in the Horizon 6 condition, participants chose the arm with the smaller reward approximately 50% of the time, in spite of their awareness of the lesser reward. However, in the Horizon 1 condition, participants chose the arm with the larger reward most of the times. These findings indicate that spontaneous switching (e.g., to a multimedia device) may occur as part of random explorations and the likelihood of switching randomly is influenced by the number of possible consecutive decisions one would have to make. In environments where the level of uncertainty is high, spontaneous switching helps ensure a certain level of flexibility in individuals to reach optimal performance (Addicott et al., 2017; Kessler et al., 2009).

Profiles of Media Multitaskers

Several studies have indicated that heavy media multitaskers (HMMs; i.e., people who frequently engage in media multitasking) reported more distraction-related problems in everyday situations and they reported higher levels of distraction-related mental health issues (ADHD) and personality traits (impulsiveness, sensation-seeking) in their daily life (Baumgartner et al., 2014; Magen, 2017; Ralph et al., 2013; see Wiradhany & Koerts, 2019 for meta-analysis) compared with light media multitaskers (LMMs; i.e., people who rarely engage in media multitasking). Yet, HMMs did not always perform worse in cognitive tasks that involve cognitive processes related to multitasking. More specifically, the findings regarding the correlations between media multitasking frequency and cognitive performance have been mixed (see Uncapher et al., 2017; Uncapher & Wagner, 2018; Van der Schuur et al., 2015, for reviews and Wiradhany & Koerts, 2019; Wiradhany & Nieuwenstein, 2017 for meta-analyses).

To address the issue on inconsistent findings in light of our EEMMM framework, we propose that HMMs might consist of two distinct subsets of media multitaskers who show different multitasking profiles, that is, *optimal multitaskers* and *distracted multitaskers*. Although both subsets of media multitaskers might engage in media multitasking equally often, they can be distinguished in how optimally they exploit and explore behaviors. *Optimal multitaskers* might be able to effectively engage in a task and, therefore, are less likely to miss opportunities within the task in which a maximum gain could be obtained. At the same time, they might be quick to switch to a different task once the utility of the current task starts to decline. In other words, optimal multitaskers perform more directed explorations, and find an optimal balance between exploitation and exploration. *Distracted multitaskers*, by contrast, conduct random exploration more often than needed, for example, because of low task experience. Consequently, they might decide to promptly switch from one activity to another, even though the utility level of the current activity is still high (or conversely, even though the utility level of the alternative activity is still uncertain). Thus, distracted multitaskers – although not differing in the total amount of media multitasking from optimal multitaskers – might have less efficient strategies in switching between exploitation and exploration, and their media multitasking behavior might therefore more frequently interfere with optimal task performance.

To illustrate the existence of these subsets, in a laboratory study in which participants could choose combinations of two tasks that could or could not produce interference, Nijboer, Taatgen et al. (2013) found that about one quarter of their participants chose task combinations that produced less interference, while about one quarter chose task combinations randomly and about half did not explore task combinations. Participants who chose task combinations randomly appeared to perform (mostly) random explorations, and thus performed less efficiently.

This distinction between optimal and distracted multitaskers might provide a parsimonious explanation on why there are mixed findings with regard to the association between the frequency of engaging media multitasking (MMI) and objective measures of information processing performance (Uncapher & Wagner, 2018; Wiradhany & Nieuwenstein, 2017). It could be that media multitasking is negatively correlated with task performance for *distracted,* but not for *optimal* multitaskers. Due to sampling error, a larger proportion distracted multitaskers ended up in studies that show a negative correlation between media multitasking and performance in cognitive tasks. Our exploration–exploitation model could provide the means to distinguish optimal from distracted multitaskers among heavy media multitaskers, by monitoring whether one switches as a function of optimizing task performance in multitasking or whether someone switches randomly.

Agenda for Future Studies

The proposed EEMMM provides a parsimonious framework for understanding media multitasking behavior. To test the assumptions of our model, we provide the following agenda for future research.

Cue Utilization and Individual Differences in Exploitation and Exploration of Media Multitasking

To initially test our EEMMM, we need to better understand when and how people decide to engage in media multitasking based on available cues and information. For instance, a student who decides to check an incoming message while studying may do so because (1) they have been studying for too long and studying becomes aversive (boredom), (2) checking the incoming message is fun (reward), (3) checking the incoming message requires very little effort (affordances), or (4) a combination of any of these factors. Thus, our first suggestion for future research is to investigate which cues are used to support the decision to exploit or explore, how these cues influence task exploitation or exploration independently and in combination with one another, and the boundary conditions under which these cues are used to support exploiting or exploring. Understanding the dynamics of cue utilization will provide insights on how we can nudge people to carry out exploration behaviors more optimally in media multitasking.

Moreover, to better understand individual differences in exploiting and exploring, we need to further investigate how much individuals vary in the amount of information needed to in to an alternative task (impulsion) and the amount of information needed to disengage from the current task (compulsion). Here, we can start by investigating how much individuals monitor their current state of their performance and behavior (i.e., metacognition; Finley et al., 2014; Händel et al., 2020) in combination with paradigms that assess how individuals make decisions to exploit or explore given the available information over time (Blanchard & Gershman, 2018; Jepma & Nieuwenhuis, 2011; Nijboer, Borst, et al., 2013). Results of these studies can inform us whether optimal and distracted media multitaskers exist, and whether we can help individuals to become more effective media multitaskers.

Exploiting and Exploring in Absence of Clear Rewards and Costs

In contrast to highly controlled laboratory studies, in everyday situations, the immediate costs and benefits of behavior exploitation or exploration are often unknown. Our second agenda for future research, therefore, would be to investigate whether the same LC-NE mechanisms that govern behavioral exploitation and exploration in laboratory tasks where the costs and rewards of each behavior type are clear also apply in everyday situations. We identify two lines of research that might prove to be fruitful in answering this question: On the distinction between cognitive labor and cognitive leisure, and on the distinction between random and directed explorations.

When the immediate, moment-to-moment benefits and costs of a behavior are unclear, people try to balance between task exploitation (cognitive labor) and task exploration (cognitive leisure; Inzlicht et al., 2014; Kool & Botvinick, 2014). On the one hand, exploitation behavior is inherently costly and requires cognitive control, but yields more rewards. On the other hand, exploration behavior is less costly and provides much-needed mental rest. Exploitation tasks that are too demanding might provide greater reward, but the high cognitive control costs might lead people to gravitate toward explorations. Kool and Botvinick (2014) showed that given the freedom to choose, people indeed try to find an optimal balance between performing a cognitively demanding, but highly rewarding task and the opposite alternative, and the optimal balance between task exploitation and exploration varied across individuals. Thus, when moment-to-moment costs and benefits of exploring and exploiting are unknown, people may try to find their individual balance between the two.

Another line of research indicates that when costs and rewards of the alternative tasks are not immediately clear, people may perform random as opposed to directed (rewards/costs based) exploration (Wilson et al., 2017). In the context of media multitasking, the implication would be that switching to a media-related activity may be motivated by random as opposed to directed exploration.

Conclusion

In this article, we offer a novel approach of media multitasking behavior within an exploration–exploitation framework as opposed to conceptualizing media multitasking solely as a distraction. Our approach is supported by the known function of the polymodal neuromodulator NE, which modulates our task engagement when task utility is high and exploration of alternative tasks when task utility is low. In our everyday, media-saturated environment, we rely on cues regarding reward propensity, behavior optimization, availability of media and or information sources, and on our subjective experience to guide our decision to stay focused on our primary task or to seek for alternative ones. Our model offers a way to consolidate conflicting findings in the media multitasking literature, such as why people seem to switch randomly between tasks, why people switch to alternative tasks in spite of their knowledge of the performance cost on the primary task, and why some people multitask more frequently than others, yet a subset of these people seem to be able to multitask with minimal performance costs.

References

Aagaard, J. (2015). Media multitasking, attention, and distraction: A critical discussion. *Phenomenology and the Cognitive Sciences, 14*(4), 885–896. https://doi.org/10.1007/s11097-014-9375-x

Aagaard, J. (2018a). Magnetic and multistable: Reinterpreting the affordances of educational technology. *International Journal of Educational Technology in Higher Education, 15*(1). https://doi.org/10.1186/s41239-017-0088-4

Aagaard, J. (2018b). Multitasking as distraction: A conceptual analysis of media multitasking research. *Theory & Psychology, 29*(1), 87–99. https://doi.org/10.1177/0959354318815766

Addicott, M. A., Pearson, J. M., Sweitzer, M. M., Barack, D. L., & Platt, M. L. (2017). A primer on foraging and the explore/exploit trade-off for psychiatry research. *Neuropsychopharmacology, 42*(10), 1931–1939. https://doi.org/10.1038/npp.2017.108

Arrington, C. M., & Logan, G. D. (2004). The cost of a voluntary task switch. *Psychological Science, 15*(9), 610–615. https://doi.org/10.1111/j.0956-7976.2004.00728.x

Aston-Jones, G., & Cohen, J. D. (2005). An integrative theory of locus coeruleus-norepinephrine function: Adaptive gain and optimal performance. *Annual Review of Neuroscience, 28*(1), 403–450. https://doi.org/10.1146/annurev.neuro.28.061604.135709

Bardhi, F., Rohm, A. J., & Sultan, F. (2010). Tuning in and tuning out: Media multitasking among young consumers. *Journal of Consumer Behaviour, 9*, 316–332. https://doi.org/10.1002/cb

Baron, N. S. (2008). Adjusting the volume: Technology and multitasking in discourse control. In J. E. Katz (Ed.), *Handbook of mobile communication studies* (pp. 177–193). MIT Press.

Bartsch, A., & Viehoff, R. (2010). The use of media entertainment and emotional gratification. *Procedia – Social and Behavioral Sciences, 5*(2), 2247–2255. https://doi.org/10.1016/j.sbspro.2010.07.444

Baumgartner, S. E., Weeda, W. D., Van der Heijden, L. L., & Huizinga, M. (2014). The relationship between media multitasking and executive function in early adolescents. *The Journal of Early Adolescence, 34*(8), 1120–1144. https://doi.org/10.1177/0272431614523133

Baumgartner, S. E., & Wiradhany, W. (2021). Not all media multitasking is the same: The frequency of media multitasking depends on cognitive and affective characteristics of media combinations. *Psychology of Popular Media*. Advance online publication. https://doi.org/10.1037/ppm0000338

Bayer, J. B., Triu, P., & Ellison, N. B. (2020). Social media elements, ecologies, and effects. *Annual Review of Psychology, 71*(1), 471–497. https://doi.org/10.1146/annurev-psych-010419-050944

Berger-Tal, O., Nathan, J., Meron, E., & Saltz, D. (2014). The exploration-exploitation dilemma: A multidisciplinary framework. *PLoS One, 9*(4). https://doi.org/10.1371/journal.pone.0095693

Berridge, C. W., & Waterhouse, B. D. (2003). The locus coeruleus-noradrenergic system: Modulation of behavioral state and state-dependent cognitive processes. *Brain Research Reviews, 42*(1), 33–84. https://doi.org/10.1016/S0165-0173(03)00143-7

Blanchard, T. C., & Gershman, S. J. (2018). Pure correlates of exploration and exploitation in the human brain. *Cognitive, Affective and Behavioral Neuroscience, 18*(1), 117–126. https://doi.org/10.3758/s13415-017-0556-2

Bouret, S., & Sara, S. J. (2005). Network reset: A simplified overarching theory of locus coeruleus noradrenaline function. *Trends in Neurosciences, 28*(11), 574–582. https://doi.org/10.1016/j.tins.2005.09.002

Bowman, L. L., Levine, L. E., Waite, B. M., & Gendron, M. (2010). Can students really multitask? An experimental study of instant messaging while reading. *Computers & Education, 54*(4), 927–931. https://doi.org/10.1016/j.compedu.2009.09.024

Brasel, S. A., & Gips, J. (2011). Media multitasking behavior: concurrent television and computer usage. *Cyberpsychology, Behavior and Social Networking, 14*(9), 527–534. https://doi.org/10.1089/cyber.2010.0350

Brasel, S. A., & Gips, J. (2017). Media multitasking: How visual cues affect switching behavior. *Computers in Human Behavior, 77*, 258–265. https://doi.org/10.1016/j.chb.2017.08.042

Braun, D. A., & Arrington, C. M. (2018). Assessing the role of reward in task selection using a reward-based voluntary task switching paradigm. *Psychological Research, 82*(1), 54–64. https://doi.org/10.1007/s00426-017-0919-x

Broeker, L., Liepelt, R., Poljac, E., Künzell, S., Ewolds, H., de Oliveira, R. F., & Raab, M. (2017). Multitasking as a choice: A perspective. *Psychological Research*, 1–12. https://doi.org/10.1007/s00426-017-0938-7

Burgess, P. W. (2000). Strategy application disorder: The role of the frontal lobes in human multitasking. *Psychological Research, 63*(3–4), 279–288. https://doi.org/10.1007/s004269900006

Calderwood, C., Ackerman, P. L., & Conklin, E. M. (2014). What else do college students "do" while studying? An investigation of multitasking. *Computers and Education, 75*, 19–29. https://doi.org/10.1016/j.compedu.2014.02.004

Carrier, L. M., Rosen, L. D., Cheever, N. A., & Lim, A. F. (2015). Causes, effects, and practicalities of everyday multitasking. *Developmental Review, 35*, 64–78. https://doi.org/10.1016/j.dr.2014.12.005

Cohen, J. D., McClure, S. M., & Yu, A. J. (2007). Should I stay or should I go? How the human brain manages the trade-off between exploitation and exploration. *Philosophical Transactions of the Royal Society B: Biological Sciences, 362*(1481), 933–942. https://doi.org/10.1098/rstb.2007.2098

Dalley, J. W., Everitt, B. J., & Robbins, T. W. (2011). Impulsivity, compulsivity, and top-down cognitive control. *Neuron, 69*(4), 680–694. https://doi.org/10.1016/j.neuron.2011.01.020

Dalley, J. W., & Robbins, T. W. (2017). Fractionating impulsivity: Neuropsychiatric implications. *Nature Reviews Neuroscience, 18*(3), 158–171. https://doi.org/10.1038/nrn.2017.8

de Bruin, A. B. H., Kok, E. M., Lobbestael, J., & de Grip, A. (2017). The impact of an online tool for monitoring and regulating learning at university: Overconfidence, learning strategy, and personality. *Metacognition and Learning, 12*(1), 21–43. https://doi.org/10.1007/s11409-016-9159-5

Deloitte Southeast Asia. (2017, November 27). *Global Mobile Consumer Survey Southeast Asia Edition*. https://www2.deloitte.com

Duff, B. R.-L., Yoon, G., Wang (Glenn), Z., & Anghelcev, G. (2014). Doing it all: An Exploratory study of predictors of media multitasking. *journal of Interactive Advertising, 14*(1), 11–23. https://doi.org/10.1080/15252019.2014.884480

Einhauser, W., Stout, J., Koch, C., & Carter, O. (2008). Pupil dilation reflects perceptual selection and predicts subsequent stability in perceptual rivalry. *Proceedings of the National Academy of Sciences, 105*(5), 1704–1709. https://doi.org/10.1073/pnas.0707727105

Finley, J. R., Benjamin, A. S., & McCarley, J. S. (2014). Metacognition of multitasking: How well do we predict the costs of divided attention? *Journal of Experimental Psychology*. *Applied, 20*(2), 158–165. https://doi.org/10.1037/xap0000010

Francisco, S., & Health, T. (2009). Modafinil shifts human locus coeruleus to low-tonic, high-phasic activity during functional MRI. *Science, 322*(October 2015), 1700–1703. https://doi.org/10.1126/science.1164908

Gilzenrat, M. S., Nieuwenhuis, S., Jepma, M., & Cohen, J. D. (2010). Pupil diameter tracks changes in control state predicted by the adaptive gain theory of locus coeruleus function. *Cognitive, Affective and Behavioral Neuroscience, 10*(2), 252–269. https://doi.org/10.3758/CABN.10.2.252

Greeno, J. G. (1994). Gibson's affordances. *Psychological Review, 101*(2), 336–342. https://doi.org/10.1037/0033-295X.101.2.336

Hallam, S., Price, J., & Katsarou, G. (2002). The effects of background music on primary school pupils' task performance. *Educational Studies, 28*(2), 111–122. https://doi.org/10.1080/03055690220124551

Händel, M., de Bruin, A. B. H., & Dresel, M. (2020). Individual differences in local and global metacognitive judgments. *Metacognition and Learning, 15*(1), 51–75. https://doi.org/10.1007/s11409-020-09220-0

Hwang, Y., Kim, H., & Jeong, S. H. (2014). Why do media users multitask? Motives for general, medium-specific, and content-specific types of multitasking. *Computers in Human Behavior, 36*, 542–548. https://doi.org/10.1016/j.chb.2014.04.040

Inzlicht, M., Schmeichel, B. J., & Macrae, C. N. (2014). Why self-control seems (but may not be) limited. *Trends in Cognitive Sciences, 18*(3), 127–133. https://doi.org/10.1016/j.tics.2013.12.009

Jeong, S.-H., & Fishbein, M. (2007). Predictors of multitasking with media: Media factors and audience factors. *Media Psychology, 10*(3), 364–384. https://doi.org/10.1080/15213260701532948

Jepma, M., & Nieuwenhuis, S. (2011). Pupil Diameter predicts changes in the exploration–exploitation trade-off: Evidence for the adaptive gain theory. *Journal of Cognitive Neuroscience, 23*(7), 1587–1596. https://doi.org/10.1162/jocn.2010.21548

Katidioti, I., Borst, J. P., & Taatgen, N. A. (2014). What happens when we switch tasks: Pupil dilation in multitasking. *Journal of Experimental Psychology: Applied, 20*(4), 380–396. https://doi.org/10.1037/xap0000031

Katz, E., Blumler, J. G., & Gurevitch, M. (1973). Uses and gratifications research. *Public Opinion Quarterly, 37*(4), 509–523.

Katz, E., Blumler, J. G., & Guretvich, M. (1974). Uses of mass communication by the individual. In *The uses of mass communications: Current perspectives on gratifications research* (pp. 19–32).

Kessler, Y., Shencar, Y., & Meiran, N. (2009). Choosing to switch: Spontaneous task switching despite associated behavioral costs. *Acta Psychologica, 131*(2), 120–128. https://doi.org/10.1016/j.actpsy.2009.03.005

Kiesel, A., Steinhauser, M., Wendt, M., Falkenstein, M., Jost, K., Philipp, A. M., & Koch, I. (2010). Control and interference in task switching-a review. *Psychological Bulletin, 136*(5), 849–874. https://doi.org/10.1037/a0019842

Kononova, A., & Chiang, Y. H. (2015). Why do we multitask with media? Predictors of media multitasking among Internet users in the United States and Taiwan. *Computers in Human Behavior, 50*, 31–41. https://doi.org/10.1016/j.chb.2015.03.052

Kononova, A., Joo, E., & Yuan, S. (2016). If I choose when to switch: Heavy multitaskers remember online content better than light multitaskers when they have the freedom to multitask. *Computers in Human Behavior, 65*, 567–575. https://doi.org/10.1016/j.chb.2016.09.011

Kool, W., & Botvinick, M. (2014). A labor/leisure tradeoff in cognitive control. *Journal of Experimental Psychology: General, 143*(1), 131–141. https://doi.org/10.1037/a0031048

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology, 77*(6), 1121–1134. https://doi.org/10.1109/MMM.2011.2173980

Lang, A. (2009). The limited capacity model of motivated mediated message processing. In R. L. Nabi & M. B. Olivers (Eds.), *The SAGE handbook of media processes and effects* (pp. 193–204).

Leung, L., & Zhang, R. (2016). Predicting tablet use: A study of gratifications-sought, leisure boredom, and multitasking. *Telematics and Informatics, 33*(2), 331–341. https://doi.org/10.1016/j.tele.2015.08.013

Loh, K. K., & Kanai, R. (2016). How has the Internet reshaped human cognition? *The Neuroscientist, 5*, 506–520. https://doi.org/10.1177/1073858415595005

Magen, H. (2017). The relations between executive functions, media multitasking and polychronicity. *Computers in Human Behavior, 67*, 1–9. https://doi.org/10.1016/j.chb.2016.10.011

Mark, G., Iqbal, S., Czerwinski, M., & Johns, P. (2015). Focused, aroused, but so distractible: A temporal perspective on multitasking and communications. *CSCW '15 Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, 903–916. https://doi.org/10.1145/2675133.2675221

Mcfarlane, D. C. (2002). Comparison of four primary methods for coordinating the interruption of people in human–computer interaction. *Lockheed Martin Advanced Technology Laboratories, 17*, 63–139.

Minear, M., Brasher, F., McCurdy, M., Lewis, J., & Younggren, A. (2013). Working memory, fluid intelligence, and impulsiveness in heavy media multitaskers. *Psychonomic Bulletin & Review, 20*, 1274–1281. https://doi.org/10.3758/s13423-013-0456-6

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences, 7*(3), 134–140. https://doi.org/10.1016/S1364-6613(03)00028-7

Murphy, P. R., O'Connell, R. G., O'Sullivan, M., Robertson, I. H., & Balsters, J. H. (2014). Pupil diameter covaries with BOLD activity in human locus coeruleus. *Human Brain Mapping, 35*(8), 4140–4154. https://doi.org/10.1002/hbm.22466

Navon, D. (1984). Resources – a theoretical soup stone? *Psychological Review, 91*(2), 216–234. https://doi.org/10.1037/0033-295X.91.2.216

Nieuwenhuis, S., Aston-Jones, G., & Cohen, J. D. (2005). Decision making, the P3, and the locus coeruleus-norepinephrine system. *Psychological Bulletin, 131*(4), 510–532. https://doi.org/10.1037/0033-2909.131.4.510

Nijboer, M., Borst, J. P., Van Rijn, H., & Taatgen, N. A. (2013). Predicting interference in concurrent multitasking. *Proceedings of the 12th International Conference of Cognitive Modeling*,.

Nijboer, M., Taatgen, N. A., Brands, A., Borst, J. P., & Van Rijn, H. (2013). Decision making in concurrent multitasking: Do people adapt to task interference? *PLoS One, 8*(11), Article e79583. https://doi.org/10.1371/journal.pone.0079583

Panek, E. (2014). Left to their own devices. *Communication Research, 41*(4), 561–577. https://doi.org/10.1177/0093650213499657

Pashler, H. (1994). Dual-task interference in simple tasks: Data and theory. *Psychological Bulletin, 116*(2), 220–244. https://doi.org/10.1037/0033-2909.116.2.220

Ralph, B. C. W., Thomson, D. R., Cheyne, J. A., & Smilek, D. (2013). Media multitasking and failures of attention in everyday life. *Psychological Research, 78*(5), 661–669. https://doi.org/10.1007/s00426-013-0523-7

Rickard, N. S., Toukhsati, S. R., & Field, S. E. (2005). The effect of music on cognitive performance: Insight from neurobiological and animal studies. *Behavioral and Cognitive Neuroscience Reviews, 4*(4), 235–261. https://doi.org/10.1177/1534582305285869

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). Generation M2: Media in the lives of 8 to 18 year-olds. In *The Henry J. Kaiser Family Foundation*. https://doi.org/P0-446179799-1366925520306

Salvucci, D. D., & Taatgen, N. A. (2008). Threaded cognition: an integrated theory of concurrent multitasking. *Psychological Review, 115*(1), 101–130. https://doi.org/10.1037/0033-295X.115.1.101

Salvucci, D. D., & Taatgen, N. A. (2011). Toward a unified view of cognitive control. *Topics in Cognitive Science, 3*(2), 227–230. https://doi.org/10.1111/j.1756-8765.2011.01134.x

Sana, F., Weston, T., & Cepeda, N. J. (2013). Laptop multitasking hinders classroom learning for both users and nearby peers. *Computers and Education, 62*, 24–31. https://doi.org/10.1016/j.compedu.2012.10.003

Sanbonmatsu, D. M., Strayer, D. L., Medeiros-Ward, N., & Watson, J. M. (2013). Who multi-tasks and why? Multi-tasking ability, perceived multi-tasking ability, impulsivity, and sensation seeking. *PLoS One, 8*(1), Article e54402. https://doi.org/10.1371/journal.pone.0054402

Sara, S. J. (2009). The locus coeruleus and noradrenergic modulation of cognition. *Nature Reviews Neuroscience, 10*(3), 211–223. https://doi.org/10.1038/nrn2573

Schumacher, E. H., Seymour, T. L., Glass, J. M., Fencsik, D. E., Lauber, E. J., Kieras, D. E., & Meyer, D. E. (2001). Virtually perfect time sharing in dual-task performance: Uncorking the central cognitive bottleneck. *Psychological Science, 12*(2), 101–108. http://www.ncbi.nlm.nih.gov/pubmed/11340917

Schutten, D., Stokes, K. A., & Arnell, K. M. (2017). I want to media multitask and I want to do it now: Individual differences in media multitasking predict delay of gratification and system-1 thinking. *Cognitive Research: Principles and Implications, 2*(1), Article 8. https://doi.org/10.1186/s41235-016-0048-x

Segijn, C. M., Voorveld, H. A. M., Vandeberg, L., Pennekamp, S. F., & Smit, E. G. (2017). Insight into everyday media use with multiple screens. *International Journal of Advertising, 36*(5), 779–797. https://doi.org/10.1080/02650487.2017.1348042

Standard Eurobarometer 92. (2019). *Media use in the European Union*. (Issue November). https://ec.europa.eu/commfrontoffice/publicopinion/index.cfm/ResultDoc/download/DocumentKy/82786

Strayer, D. L., & Johnston, W. A. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science, 12*(6), 462–466. https://doi.org/10.1111/1467-9280.00386

Ünal, A. B., De Waard, D., Epstude, K., & Steg, L. (2013). Driving with music: Effects on arousal and performance. *Transportation Research Part F: Traffic Psychology and Behaviour, 21*, 52–65. https://doi.org/10.1016/j.trf.2013.09.004

Uncapher, M. R., Lin, L., Rosen, L. D., Kirkorian, H. L., Baron, N. S., Bailey, K., Cantor, J., Strayer, D. L., Anderson, D. R., Parsons, T., & Wagner, A. D. (2017). Media multitasking and cognitive, psychological, neural, and learning differences. *Pediatrics, 140* (November). https://doi.org/10.1542/peds.2016-1758D

Uncapher, M. R., & Wagner, A. D. (2018). The minds and brains of media multitaskers: Current findings and future directions. *Proceedings of the National Academy of Sciences, 115*(40), 9889–9896. https://doi.org/10.1073/pnas.1611612115

Van der Schuur, W. A., Baumgartner, S. E., Sumter, S. R., & Valkenburg, P. M. (2015). The consequences of media multitasking for youth: A review. *Computers in Human Behavior, 53*, 204–215. https://doi.org/10.1016/j.chb.2015.06.035

Van der Zwaag, M. D., Dijksterhuis, C., de Waard, D., Mulder, B. L. J. M., Westerink, J. H. D. M., & Brookhuis, K. A. (2012). The influence of music on mood and performance while driving. *Ergonomics, 55*(1), 12–22. https://doi.org/10.1080/00140139.2011.638403

Van der Zwaag, M. D., Janssen, J. H., Nass, C., Westerink, J. H. D. M., Chowdhury, S., & de Waard, D. (2013). Using music to change mood while driving. *Ergonomics, 56*(10), 1504–1514. https://doi.org/10.1080/00140139.2013.825013

Vorderer, P., Hefner, D., Reinecke, L., & Klimmt, C. (2018). Permanently online, permanently connected: A new paradigm in communication research?? In P. Vorderer, D. Hefner, L. Reinecke, & C. Klimmt (Eds.), *Permanently online, permanently connected: Living and communicating in a POPC World*. Routledge.

Wang, Z., Irwin, M., Cooper, C., & Srivastava, J. (2015). Multidimensions of media multitasking and adaptive media selection. *Human Communication Research, 41*(1), 102–127. https://doi.org/10.1111/hcre.12042

Wang, Z., & Tchernev, J. M. (2009). The "myth" of media multitasking: Reciprocal dynamics of media multitasking, personal needs, and gratifications. *Journal of Communication, 62*(3), 493–513. https://doi.org/10.1111/j.1460-2466.2012.01641.x

Wickens, C. D. C. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science, 3*(2), 159–177. https://doi.org/10.1080/14639220210123806

Wilson, R. C., Geana, A., White, J. M., Ludvig, E. A., & Cohen, J. D. (2014). Humans use directed and random exploration to solve the explore–exploit dilemma. *Journal of Experimental Psychology: General, 143*(6), 2074–2081.

Wiradhany, W., & Koerts, J. (2019). Everyday functioning-related cognitive correlates of media multitasking: A mini meta-analysis. *Media Psychology*,1–28. https://doi.org/10.1080/15213269.2019.1685393

Wiradhany, W., & Nieuwenstein, M. R. (2017). Cognitive control in media multitaskers: Two replication studies and a meta-Analysis. *Attention, Perception, & Psychophysics, 79*(8), 2620–2641. https://doi.org/10.3758/s13414-017-1408-4

Yeykelis, L., Cummings, J. J., & Reeves, B. (2014). Multitasking on a single device: Arousal and the frequency, anticipation, and prediction of switching between media content on a computer. *Journal of Communication, 64*(1), 167–192. https://doi.org/10.1111/jcom.12070

Zillmann, D. (1988). Mood management through communication choices. *American Scientist, 31*(3), 327–340.

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