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Media multitasking is associated with distractibility and increased prefrontal activity in adolescents and young adults

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ABSTRACT

The current generation of young people indulges in more media multitasking behavior (e.g., instant messaging while watching videos) in their everyday lives than older generations. Concerns have been raised about how this might affect their attentional functioning, as previous studies have indicated that extensive media multitasking in everyday life may be associated with decreased attentional control. In the current study, 149 adolescents and young adults (aged 13–24 years) performed speech-listening and reading tasks that required maintaining attention in the presence of distractor stimuli in the other modality or dividing attention between two concurrent tasks. Brain activity during task performance was measured using functional magnetic resonance imaging (fMRI). We studied the relationship between self-reported daily media multitasking (MMT), task performance and brain activity during task performance. The results showed that in the presence of distractor stimuli, a higher MMT score was associated with worse performance and increased brain activity in right prefrontal regions. The level of performance during divided attention did not depend on MMT. This suggests that daily media multitasking is associated with behavioral distractibility and increased recruitment of brain areas involved in attentional and inhibitory control, and that media multitasking in everyday life does not translate to performance benefits in multitasking in laboratory settings.

Introduction

With the use of smartphones and other forms of digital technologies becoming an ever more prevalent activity in young people's everyday lives, concerns have been raised about how this might affect their brain development and cognitive functioning. One of the suggested effects of constant use of digital technologies is an increased tendency to multitask, since the currently available platforms support the nearly seamless use of several simultaneous programs and applications. It has been shown that today's generation of young people grown up immersed in modern technology (i.e., "digital natives"; Prensky, 2001) indulge in more multitasking behavior than older generations (Carrier et al., 2009; Zhang et al., 2015). It is estimated that almost a third of the time young people use media they use two or more media simultaneously (Rideout et al., 2010). This technology-mediated multitasking behavior may have implications for attention-dependent functioning, as studies have shown that training can induce benefits in multitasking and task switching abilities (Cepeda et al., 2001; Minear and Shah, 2008; Lussier et al., 2012; Strobach et al., 2012), albeit transfer effects in such cognitive training studies have often been narrow and specific to the features of the trained task (Green and Bavelier, 2008). It is therefore plausible to think that intensive use of digital technologies could in a sense "train the brain" to become more skilled at multitasking, especially when the brain's attention networks are still developing (Rothbart and Posner, 2015). In recent years, several studies have been conducted on the relationship between daily media multitasking (i.e., using

Abbreviations: MMT, media multitasking; DA, digital activity; SDP, sociodigital participation; GPA, grade point average; SPL, superior parietal lobule.

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multiple media forms simultaneously) and cognitive functioning. Yap and Lim (2013) demonstrated that high levels of daily media multitasking activity were associated with a tendency for split versus focal visual attention, and concluded that prolonged simultaneous media usage might reduce the effort needed to maintain split attention. Task switching abilities have also been reported to be positively associated with media multitasking (Alzahabi and Becker, 2013).

From a less optimistic point of view, a tendency to multitask can be seen as a result of increased distractibility and poor executive control abilities (Loh and Kanai, 2015). Results from several studies support this notion by showing that excessive media multitasking is related to decrements in attentional processes (Cardoso-Leite et al., 2015). For example, Ophir et al. (2009) found that frequent media multitasking is associated with an increase in distractibility and greater task switching costs. Furthermore, according to the results of Alzahabi and Becker (2013) as well as those of Sanbonmatsu et al. (2013), media multitaskers exhibit declined performance on actual tests of multitasking. Recent studies have also shown that multitasking behavior is positively correlated with higher self-reported impulsivity (Minear et al., 2013; Yang and Zhu, 2015; Uncapher et al., 2015), suggesting that decreased executive control may lead to a tendency to multitask while using technology, or vice versa. Media multitasking has also been shown to be associated with a decrease in gray matter volume in frontal brain regions (in the anterior cingulate cortex; Loh and Kanai, 2014) belonging to the executive attention network (Bush et al., 2000). This suggests that media multitasking might have a negative impact on brain areas involved in attentional control. It is important to note, however, that an extensive follow-up study (Minear et al., 2013) failed to replicate the results of Ophir et al. (2009), and that a recent study failed to find evidence for a relationship between the amount of daily media multitasking activity and the ability to sustain attention (Ralph et al., 2015). These contradictory findings were the motivation for the current study.

The aim of the current study was to examine whether self-reported media multitasking activity is related to adolescents' and young adults' (aged 13–24 years) attentional abilities or attention-related brain activity. More specifically, our participants performed speech-listening and reading tasks which required maintaining attention in the presence of distractor stimuli or dividing attention between the two tasks. Brain activity during these tasks was recorded using event-related functional magnetic resonance imaging (fMRI). The tasks involved performing a sentence congruence judgment task in the auditory or visual modality in the presence of irrelevant inputs in the other modality (distracted attention condition), or performing both tasks in parallel (divided attention condition). A condition where sentences were presented only in one modality (undistracted attention condition) was used as a baseline condition. The relationship between the level of media multitasking, task performance and task-related brain activity was then examined, and discerned from the effects of the overall use of digital technologies. The current study therefore extends previous findings on media multitasking by using a more ecologically valid attentional task with complex linguistic stimuli, and by studying not only young adults but also adolescents in a sample much larger than in most related brain imaging studies. Based on previous studies, we expected media multitasking to be associated with increased distractibility (Ophir et al., 2009) but not with benefits in multitasking performance (Alzahabi and Becker, 2013; Sanbonmatsu et al., 2013) in the current study.

Materials and methods

Participants

The participants were selected from a sample of 2977 respondents who filled out a questionnaire including a wide variety of questions relating to the use of digital technologies in everyday life as a part of the research project titled Mind the Gap between Digital Natives and Educational Practices (2013–2016) and funded by the Academy of Finland (http://wiredminds.fi/projects/mind-the-gap/). The respondents belonged to three different age cohorts: 13- and 16-year-old pupils and 20–24-year-old university students. The questionnaire included a Sociodigital Participation (SDP) inventory (Hietajärvi et al., unpublished results) assessing various dimensions of technology-mediated practices in everyday life. Using a latent profile analysis (Vermunt and Magidson, 2002) the participants (each cohort separately) were first grouped into profiles representing their SDP practices. The identified profiles (across cohorts) were interpreted as basic participants (control), gaming-oriented participators and creative participators. Respondents ineligible for an fMRI measurement were screened out, as well as respondents with any learning difficulties or notably poor school performance with a self-reported grade point average (GPA) below 7 on a 4-to-10 point scale system. As a result, brain activity and performance of 173 participants were measured for the study, out of which 149 returned a filled media multitasking questionnaire (see below) mailed to the participants afterwards. These 149 participants were included in the present analyses. All participants were native Finnish speakers with normal hearing, normal or corrected-to-normal vision, and no self-reported history of psychiatric or neurological illnesses. An informed written consent was obtained from each participant (and from a guardian in the case of underage participants) before the experiment. The experimental protocol was approved by the Ethics Committee for Gynecology and Obstetrics, Pediatrics and Psychiatry of The Hospital District of Helsinki and Uusimaa, Finland.

Media multitasking score

The level of media multitasking was defined as the mean number of media a person simultaneously consumes while using media. We used the shorter version of the media multitasking questionnaire (Ophir et al., 2009) adapted by Pea et al. (2012) to create a media multitasking variable for each participant. The external validity of the resulting media multitasking questionnaire is yet to be firmly established, but several independent research groups have produced comparable indices for average media multitasking activity in their samples based on this questionnaire. Furthermore, since the questionnaire is designed simply to measure occurrences of certain type of behavior without making any further inferences about possible latent variables underlying that behavior, its external validity is most likely not questionable.

Six categories of media use were included in the media multitasking questionnaire: (1) watching video content (TV, YouTube, movies, etc.), including playing video games; (2) listening to music; (3) reading or doing homework; (4) e-mailing or sending messages/posting on Facebook, MySpace, etc. (not including Facebook chat); (5) texting or instant messaging (including Facebook chat); (6) talking on the phone or video chatting. For each media use category i there were six questions: "*While using* [medium i], *how much time do you spend using* [medium j]?" where j also ran across the six media use categories. To create the final Media Multitasking (MMT) score, scores for multitasking in each media category were summed per participant. The distribution of MMT scores was compared between the three age cohorts using a chi-squared test.

The MMT score used in the current study reflects the absolute time the participant reports spending media multitasking. Ophir et al. (2009) and Pea et al. (2012) calculated a Media Multitasking Index (MMI), which was a measure of time spent multitasking in relation to the time spent using media in general. This means that a participant who uses little media but has a tendency to multitask while doing so gets a high MMI, whereas a participant who spends a lot of time using technology but only a small portion of it multitasking gets a low MMI, even though the absolute time spent media multitasking would be identical for these two participants. Since the aim of the current study was to examine how media multitasking might affect cognitive functions such as attentional control or multitasking, and since it is know that the time