Media Multitasking and Cognitive Flexibility: An Investigation of a Non-linear Correlation

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Abstract

Research on media multitasking is troubled by ambiguous results, often comparing extreme groups of media multitasking behavior. This study investigated a potential non-linear correlation by using all data from the short media multitasking measure and the Modified Card Sorting Test to gain a comprehensive understanding of the relationship. Anticipating an inverse U-shaped correlation, the study employed a novel approach by using polynomial regression. A total of 149 participants were tested online via survey exchange sites. By comprehensively exploring the impact of media multitasking on cognitive flexibility, this study aimed to address various conflicting aspects of the current literature. However, no significant relationships were found, and underlying limitations were discussed to guide future research in this area.

Keywords: media-multitasking, cognitive flexibility, polynomial regression, MMM-S, Modified Card Sorting Test

Media Multitasking and Cognitive Flexibility: An Investigation of a Non-linear Correlation

With the increased use of media technology and media multitasking (MM), there is a growing interest in the influence on our cognitions and behaviors (Carrier et al., 2009). One of the first studies that researched MM as a trait was conducted by Ophir et al. (2009). In their paper, MM was defined as the simultaneous consumption of different streams of content through different forms of media. The present work examines media multitasking as defined by the Media Multitasking Index, a questionnaire devised by Ophir and colleagues in the course of their work. This questionnaire categorizes individuals into Heavy (HMM), Light (LMM), and Intermediate Media Multitasking Users (IMM) based on standard deviations from the mean of the current sample. Future studies also used oter cut-off methods based on either quantiles or percentiles (Van Der Schuur et al., 2015). Further explanations of the MMI will be provided in the methods section. A review of the effects of media multitasking on youth by Van Der Schuur et al. (2015) found that MM was primarily investigated regarding three different aspects: cognitive control abilities, academic performance, and socioemotional function. In their review, the authors formulated two opposing hypotheses regarding the effects of MM on cognitive control: the scattered attention hypothesis and the trained attention hypothesis. The arguments supporting each one can be traced back to the discussion presented by Ophir et al. (2009). According to the scattered attention hypothesis, regular media multitasking leads to not only a "breadth-bias" toward media consumption but also a breadth-bias in cognitive control, which makes them susceptible to distractors. Conversely, the trained attention hypothesis argues that the ability to switch between tasks and focus on relevant stimuli can be developed through training. Since then, there has been evidence for either the scattered attention hypotheses (Kong et al., 2023; Ophir et al., 2009; Uncapher & Wagner, 2018; Van Der Schuur et al., 2015; Yap & Lim, 2013) or the trained attention hypothesis (Alzahabi & Becker, 2013; Ophir et al., 2009; Van Der Schuur et al., 2015). However, not all studies

have found significant relationships; for instance, Edwards and Shin (2017) and Seddon et al. (2018) reported no significant effects of media multitasking on cognitive control.

Media Multitasking and Cognitive Control

Cognitive control is separated into three different aspects: cognitive flexibility, working memory, and inhibitory control (Davidson et al., 2006). Working memory is the ability to temporarily hold and manipulate information necessary for cognitive tasks, allowing individuals to process and use relevant information (Baddeley & Hitch, 1994). Cognitive flexibility is the competence to adapt and switch between different cognitive processes or tasks. Inhibitory control is the ability to suppress or override automatic responses, impulses, or distractions, allowing individuals to focus on relevant information and make intentional, goal-directed decisions (Diamond, 2013). Every aspect has its unique relationship with MM (Uncapher & Wagner, 2018). A recent meta-analysis by Kong et al. (2023), which examined the effect of MM on cognitive control while considering the different subsets as moderators, found a significant negative impact. The authors also found a significant moderating effect of type for working memory and inhibitory control, while being non-significant for cognitive flexibility. Other reviews, however, did not come to the same decisive conclusions (Kobayashi et al., 2020; Uncapher & Wagner, 2018). While the research regarding cognitive flexibility argues for a non-significant relationship, there are considerations that these findings may result from comparing extreme groups. For example, some research found that IMMs performed better than HMMs on tests of focused attention, suggesting a possible inverse U-shaped correlation between MM and components of cognitive control (Cardoso-Leite et al., 2016; Shin et al., 2020). Shin et al. (2020) demonstrated that IMMs outperformed both HMMs and LLMs on a more challenging variant of the n-back task, as opposed to the easier versions. Additionally, HMMs did not score significantly differently from LMMs, which aligns with the inverse U-shape hypothesis. To better understand the subtle differences influencing the effects of

MM on cognitive flexibility, it is important to examine the full spectrum of MM behavior. Thus, this study explores the shape of the relationship between media multitasking and cognitive flexibility without excluding data based on MM index scores. This study postulates a non-linear correlation between MM and cognitive flexibility, and further, it postulates that the non-linear relationship follows an inverse u-shape.

Methods

We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study.

Participants

Participants were primarily recruited through two survey-exchange platforms: surveycircle.com and surveyswap.io. On these platforms, participants complete surveys to earn credit points, which they can then use to gather participants for their own studies. Additionally, some participants were recruited via convenience sampling through WhatsApp and by colleagues who asked their study participants to also participate in this study. The majority of participants were recruited through the survey-exchange platforms. A total of 149 participants aged 18 - 67(M = 26.34, SD = 6.55, 93 females) were included in the study. Initially, 161 participants were recruited, but 12 were excluded due to being outliers based on the 1.5 * IQR criterion of the dependent variable the percentage of the perseverative errors of the modified card sorting test (see Material section). These outliers suggested non-conformity with the instructions, such as misunderstandings or non-compliance. The sample predominantly consisted of individuals presumed to be students, given the recruitment methods (student WhatsApp groups, colleagues' experiments involving psychology students, and survey-exchange platforms typically used by other students). To determine the appropriate sample size for a polynomial regression, a power analysis was conducted using the 'pwr' package in R (R Core Team, 2024). Given the expectation of a small effect size ($f^2 = 0.02$), a significance level (α) of 0.05, and a

desired power of 0.80, the power analysis indicated that a minimum of 484 participants would be required for a multiple regression analysis with two predictors. Due to lack of resources, this number was not met.

Measures

The primary exposure variable in this study is the index score from the MMM-S, a condensed version of the Media Multitasking Questionnaire. The MMM-S (Short Measure of Media Multitasking), developed by Baumgartner et al. (2017), is a streamlined adaptation of the original Media Multitasking Index (MMI) by Ophir et al. (2009). It is designed for efficiency and relevance, particularly among adolescents, by focusing on the most prevalent media multitasking activities, such as the use of social media and instant messaging. The MMM-S combines sending messages via phone or computer, acknowledging the convergence of text messaging and instant messaging (e.g., WhatsApp). Through this item selection it reduced the number of items from the original 132 to 9. Participants indicate the frequency with which they engage in multitasking between a primary activity and a secondary activity (e.g "While watching TV, how often do you engage in the following activities... - ... listening to music/sending messages via phone or computer/using social networking sites) on a four-point scale: 1 (never), 2 (sometimes), 3 (often), and 4 (very often). An overall media multitasking index (MMM-S) is derived by averaging all multitasking items, representing the overall extent of media multitasking across different categories. To measure cognitive flexibility the modified card sorting test based on Nelson (1976) was used. The test was programmed in OpenSesame following the instructions of their website (osdoc.cogsci.nl, n.d.). In this test, participants are required to assign a card to one of four piles based on an unknown matching rule. The rule could be based on one of three categories: shape, number, or color. The cards on top of the piles distinct, regarding those categories, ensuring that only one pile could be correct for each trial. After five successful assignments the unknown rule changes, which is also unknown to

the participant. In total there were 64 trials to complete. The primary dependent variable is the percentage of perseverative errors during the modified card sorting test. Perseverative errors were identified by comparing participants' responses. If a participant made an error that would have been correct according to the last correctly identified matching rule, it was counted as a perseverative error. The percentage of perseverative errors was then calculated. There were no predefined criteria for categorizing or interpreting the dependent variable. However, data was filtered based on the 1.5 * IQR rule to exclude outliers, which was deemed the most effective method for ensuring data quality. Since the final scores showed a non-normal distribution and a left skewness (number), the data were reflected and boxcox-transformed (new numbers) to meet the assumptions required for statistical analyses.

Material

Procedure

Data analysis

We used R (Version 4.4.1; R Core Team, 2024) and the R-packages *dplyr* (Version 1.1.4; **R-dplyr?**), *e1071* (Version 1.7.14; **R-e1071?**), *ggplot2* (Version 3.5.1; **R-ggplot2?**), *kableExtra* (Version 1.4.0; **R-kableExtra?**), *knitr* (Version 1.48; **R-knitr?**), *MASS* (Version 7.3.61; **R-MASS?**), *papaja* (Version 0.1.2.9000; Aust & Barth, 2023), *shiny* (Version 1.9.0; **R-shiny?**), and *tinylabels* (Version 0.2.4; Barth, 2023) for all our analyses.

Results

Discussion

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Appendix

[tbp]

Table A1

Distribution of Participants Across Groups

Group	Standard.Deviation.Method	Quantile.Method
LMMs	30.00	50.00
IMMs	98.00	54.00
HMMs	21.00	45.00