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Media Multitasking and Performance of Executive Function Among Secondary-School Students in Indonesia

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Abstract: This study aims to examine the contribution of media multitasking in predicting the performance of executive function which covers inhibitory control, cognitive flexibility, and working memory among secondary-school students. This study used a quantitative approach with a cross-sectional study design. Research participants were secondary-school students aged 13 – 18 years who attended school in Jakarta, Bogor, Depok, Tangerang, and Bekasi areas (N = 192). Data were collected using convenience sampling. Media multitasking was measured through a media use questionnaire. EF components were calculated using a performance-based approach by employing the Go/No-Go Task for inhibitory control, the Dots-Triangle Task for cognitive flexibility, and the N-2-Back Task for working memory. All data were analyzed statistically by descriptive, assumption testing, and hierarchical regression analysis. The result shows that media multitasking only contributes significantly to predicting performance inhibitory control after controlling gender and age. However, media multitasking is not significantly associated with the performance of cognitive flexibility and working memory. This study found that the use of digital media is related to the ability of students to inhibit irrelevant stimuli in learning.

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Introduction

Media multitasking (MM) is a phenomenon that become popular in conjunction with broader distribution of information technology, increasing levels of internet penetration as well as ownership of devices, especially portable devices, and access to the internet (Kononova et al., 2013; Srivastava et al., 2016). Activities involving two or more types of media or activities involving the use of media and non-media, where the various activities are carried out simultaneously are the definition of MM (Lang & Chrzan, 2015; van der Schuur et al., 2015). High exposure to information and communication technology has encouraged individuals from various age groups to multitask with media spending an average of 4 hours a week (Segijn et al., 2017).

Media multitasking (MM) requires a high level of cognitive effort as well as overlapping cognitive resources (Sun & Zhong, 2020). While doing MM, individuals are required to process two or more streams of information, in which insufficient cognitive resources happened, which can result in decreased performance on the tasks (Ralph et al., 2020; Wang et al., 2015; Wiradhany et al., 2021). The cognitive processes in MM, in regards to process and responding streams of information, require the role of executive function. Executive function (EF) is a high-level cognitive process that enables the achievement of goal-directed behavior through strategic planning and cognitive flexibility (Magen, 2017). Executive function (EF) is a neurocognitive skill that supports conscious control of thoughts, actions, and emotions which can generally be measured through skills of working memory, inhibitory control, and cognitive flexibility (Diamond, 2013; Zelazo & Carlson, 2020).

During MM, individuals are exposed to a variety of information flows. So that component of working memory plays a role in storing information and manipulating information. Exposure to various streams of information also requires individuals to focus their attention on relevant information and ignore information that is not relevant to the task at hand. This is related to the role of inhibitory control in controlling attention and behavioral responses to existing stimuli. Cognitive flexibility helps individuals to be able to move from processing one information to another, as well as disengage from one task before moving completely to new tasks with different task rules or requirements (Seddon et al., 2018). Individuals with poor EF performance will have higher difficulties in coping with mixed tasks due to an inability to control attention and inhibitory behavior (Zamanzadeh & Rice, 2021).

Research conducted by Ophir et al. (2009), a pioneer in examining the relationship between the performance of executive function and MM, finds that individuals who perform MM more frequently have greater difficulty in filtering out internal or external stimuli that are not relevant to the main task, have attentional control that was influenced by external stimuli and are less effective in switching between tasks. However, subsequent studies on MM and EF abilities have not all shown results consistent with the findings of Ophir et al. (2009). Alzahabi & Becker (2013) find that individuals with high levels of MM have better skills in performing task switching, where the individuals have the opportunity to practice their skills in switching tasks. Findings from Elbe et al. (2019) also prove that a high level of MM is correlated with low switch cost. Meanwhile, research by Murphy & Creux (2021) shows that a higher level of MM is significantly associated with greater capacity of working memory. Several other studies did not even find a correlation between MM and individual performance on cognitive control, either working memory, inhibitory control, and cognitive flexibility (Edward & Shin, 2017; Minear et al., 2013; Murphy et al., 2017).

Secondary-school students, who are in the adolescent developmental stage, are the group with high exposure to media and have a high prevalence of MM (Cain et al., 2016; Rideout et al., 2010; van der Schuur et al., 2015). Development of EF among secondary-school students is sensitive to the influence of environmental factors, such as socioeconomic status and parenting, social and affective influences, and media exposure through internet use (Blair, 2016; Boelema et al., 2014; Crone & Dahl, 2012; Mills, 2016; Theodoraki, et al). EF has been proven to contribute to student's academic achievement, particularly in the areas of mathematics and literacy. EF skills are useful for students in learning environments where students are required to continuously maintain attention, follow rules, and focus on various cognitive tasks (Ahmed et al., 2019; Lan et al., 2011; Samuels et al., 2016). Students who report higher levels of MM are known to perform lower in academic achievement, specifically in mathematics and literacy, and have poorer EF performance (Cain et al., 2016; Martin-Perpina et al., 2019). However, another study conducted by Baumgartner et al. (2014) found that MM in junior high school students could only significantly predict the performance of inhibitory control where students who frequently do MM show better skills in ignoring irrelevant distractions. Meanwhile, other studies show MM has a significant relationship only to the performance of cognitive flexibility (Luo et al., 2021; Rogobete et al., 2021).

Hence, the purpose of this study is to examine the contribution of MM in predicting performance of executive function which contains inhibitory control, cognitive flexibility, and working memory among secondary school students after controlling their gender and age. This study stands out due to its coverage of all secondary students as participants coming from middle school and high school levels. Apart from that, this study offers novelty by considering the age and gender of students as covariate variables in examining the relationship between MM and the performance of executive function. Previous research has found that there are differences in the performance of EF components between men and women according to developmental age (Grissom & Reyes, 2019). EF performance improves along with increasing age from childhood to young adulthood (Filippi et al., 2020). Each component of EF develops at its own pace throughout childhood and adolescence until it reaches maturity levels in adulthood (Diamond, 2013; Ferguson et al., 2021).

Research Method

This study used a quantitative approach with a cross-sectional study design. To answer the research objectives, the researcher attempted to test and identify the relationships between the variables and measure the strength of these relationships (Gravetter & Forzano, 2012). Furthermore, the researcher also attempted to test whether the predictor variables in this study could predict other variables by controlling covariate variables while examining the contribution of these predictor variables (Field, 2009). Using convenience sampling, the participants, aged 13 – 18 years, were recruited from middle school and high school in the Jabodetabek area. Participants were asked to complete computerized executive function tasks Go-No-Go Task, Dots-Triangle Task, and N-2-Back Task sequentially. After that, participants filled out a media use questionnaire to measure MM which was carried out online. This research procedure has been approved by the Research Ethics Committee of the Faculty of Psychology, University of Indonesia with certificate number 171/FPsi.Ethics Committee/PDP.04.00/2022.

To measure the performance of an executive function, this study employed the N-2-Back Task for assessing working memory, the Go/No-Go Task for assessing inhibitory control, and the Dots-Triangle Task for assessing cognitive flexibility, adapted from Xu et al. (2013). On *the Go-no-go task*, the accuracy rate of participants in responding to both the Go and No-Go stimulus was considered as the outcome variable. Higher accuracy in the Go/No-Go Task reflected better performance in inhibitory control.

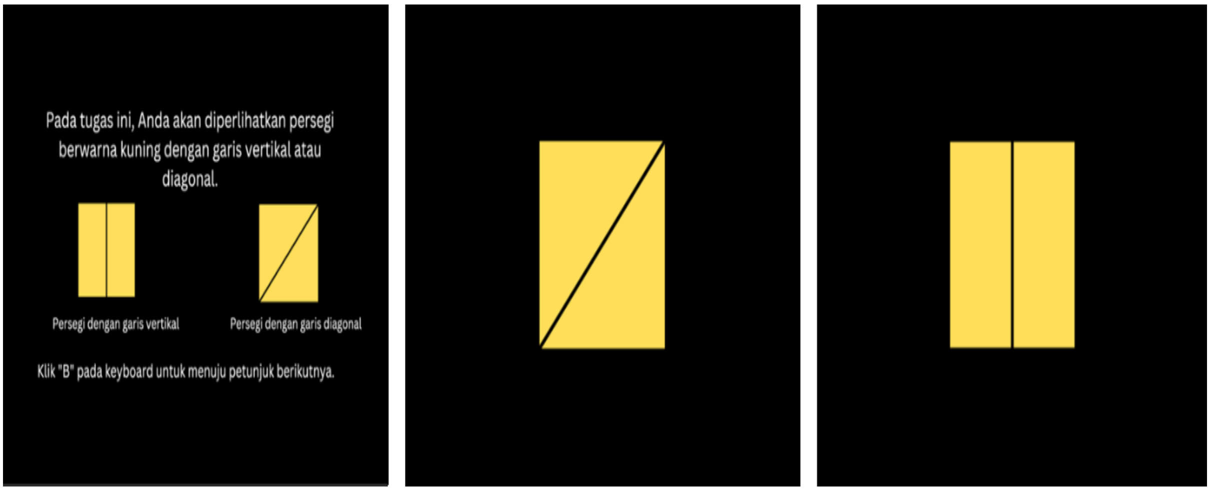

Figure 1. Stimuli for Go/No-Go Task

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For the Dots-Triangle Task, the outcome variable was measured by the difference in reaction time in responding to dots-triangle trials with dots trials only and triangle trials only. A greater difference in response time indicated lower performance of cognitive flexibility.

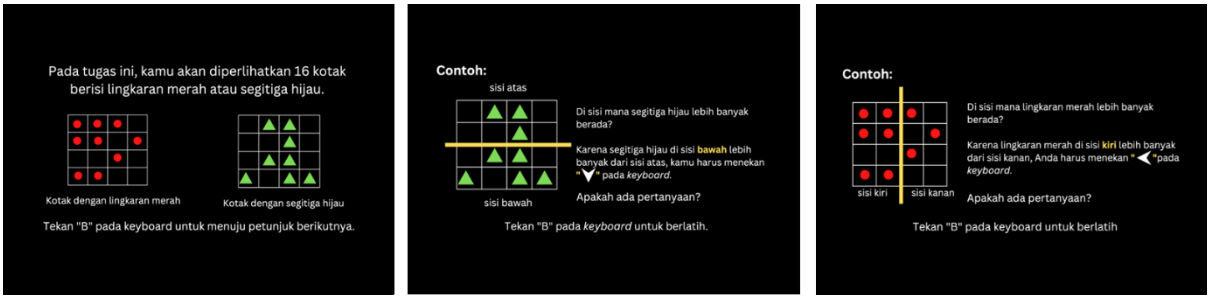

Figure 2. Stimuli for Dots-Triangle Task

On N-2-Back Task, the correct response from participants was measured as an outcome variable in which a higher accuracy rate reflected the greater performance of working memory.

Figure 3. Stimuli for N-2-Back Task

Adolescent MM behavior was assessed using the *Media Use Questionnaire* adapted from Hahm (2021) and Madore et al. (2018). Participants were asked to report how many hours they spent each week using nine main activities involving media: reading activities (including e-books), doing homework other than reading, watching videos online or offline/watching TV, listening to music/radio/audiobooks, play video games, surfing on web (via cell phone, tablet, e-book reader, TV, PC), sending texts/accessing social media/instant messaging (IM), talking on the phone or video chatting, and other activities that use a computer (such as editing videos, photos or coding). For each primary media accessed, participants were also asked how often they engaged with other media as a secondary task with answer options of "Never" to "Most of The Time". The nine MM subcategories have a high correlation with each other ($r > 0.5$, $p < 0.01$). This indicates that adolescents do multitasking with various types of media, not limited to certain media activities (Baumgartner et al., 2014). Then, the average of these nine sub-scores was weighted by the total time-consuming main media to get the MM Index (MMI), Cronbach's alpha = 0.949. MM Index (MMI) was calculated by adding up the secondary media that was also accessed when accessing the main media which was weighted by the percentage of time spent accessing each main media (Ophir et al., 2009). MMI was an indicator of participants' level of MM when they did media multitasking.

Data were collected from October 2023 to January 2024. The researcher analyzed the data using hierarchical multiple regression to examine the contribution of MM on the performance of inhibitory control, cognitive flexibility, and working memory among secondary school students after controlling their age and gender variables. In the first order, the researcher loaded demographic variables such as gender and age. Then, media

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multitasking as a predictor variable was input in second order. Analysis was performed by SPSS 29 for Windows.

Results and Discussion

The total participants in this study was 192 secondary school students consisting of 98 female students (51.1%) and 94 male students (48.9%). The MM activity subscale in Table 1 has shown that the activity of listening to music/radio/*audiobook* was the most frequently performed activity to be done multitask (M = 5,252, SD = 1,550). Performance of inhibitory control measured with accuracy Go/No-Go showed that the average value of participants' accuracy in responding to the stimulus Go and stimulus No-Go was 90.839 with a standard deviation of 1.022. The difference reaction time on Dots-Triangle trials, which was a performance indicator of cognitive flexibility, had an average score of 16,811.590 ms with a standard deviation of 2,540.294. Meanwhile for performance of working memory, measured with accuracy N-2-Back, showed that the average participant accuracy rate was 75.298 with a standard deviation of 1.286.

Table 1. Mean and Standard Deviation for Media Multitasking Sub Scale

	Mean	SD
MM Sub Scale		
Membaca (termasuk *e-book*)	4,318	1,941
Pekerjaan Rumah Selain Membaca	4,280	1,845
Menonton video/TV	4,264	1,853
Mendengarkan musik/radio/*audiobook*	5,252	1,550
Bermain *Video Games*	4,037	2,004
Browsing (melalui ponsel, PC, tablet)	4,542	1,710
Texting/berinteraksi di media sosial/*instant messaging*	5,050	1,667
Berbicara di telepon/*video chatting*	4,097	2,128
Aktivitas lainnya menggunakan komputer	3,866	2,117
MM *Index* (MMI)	4,696	1,533

Several examinations to test assumptions have been performed before running hierarchical regression analysis: normality test, linearity test, multicollinearity test, independence test, and homoscedasticity test (Field, 2009*)*. Results on the first normality test showed that dependent variables, which were the performance of inhibitory control, cognitive flexibility, and working memory, did not have a normal distribution. Hence, the researcher performed a box-cox transformation to transform non-normal dependent variables into normal shapes (Kurtner et al., 2004). After the box-cox transformation, the normality test was re-run using Kolmogorov-Smirnov and Saphiro-Wilk and showed a significant value of p > 0,05 for all dependent variables in Table 2. It concluded that the normality assumption has been achieved and data were normally distributed.

Table 2. Normality Test for Inhibitory Control, Cognitive Flexibility, Working Memory

Variable	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Go/No-Go Accuracy – Inhibitory Control	0,060	192	0,088	0,989	192	0,158
Difference Response Time Dots Triangle – Cognitive Flexibility	0,006	192	0,200	0,998	192	0,999
N-2-Back Accuracy Rate – Working Memory	0,050	192	0,200	0,994	192	0,634

We continued to test the linearity assumption to ensure that MM as a predictor variable had a significant linear relationship with inhibitory control, cognitive flexibility, and working memory. The linearity test in Table 3 shows that the significance value of deviation

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from linearity was > 0,05 for the relationship between MM and all EF components. Hence, our regression model has complied with the linearity assumption.

Table 3. Linearity Test for Inhibitory Control, Cognitive Flexibility, and Working Memory with Media Multitasking

Variable	Sig.	Description
MM and *Inhibitory Control*	0,741	Linear relationship existed
MM and *Cognitive Flexibility*	0,745	Linear relationship existed
MM and *Working Memory*	0,611	Linear relationship existed

The researcher then did a multicollinearity test to ensure that predictor variables were not correlated to each other. In Table 4, all variables had a value of tolerance statistics > 0,02 with a VIF score of less than 10. So, this model has met the assumption of collinearity.

Table 4. Multicollinearity Test

Variable	Collinearity Statistics	
	Tolerance	VIF
Inhibitory Control		
Gender	0,980	1,021
Age	0,989	1,011
MM	0,986	1,014
Cognitive Flexibility		
Gender	0,980	1,021
Age	0,989	1,011
MM	0,986	1,014
Working Memory		
Gender	0,980	1,021
Age	0,989	1,011
MM	0,986	1,014

The independence test was performed by using the Durbin-Watson Test. The result in Table 5 shows that the value of Durbin-Watson for regression models was close to 2,00. However, the independence assumption was violated if the value of Durbin-Watson was below 1 or above 3. Hence, our regression model has satisfied the assumption of independence.

Table 5. Durbin-Watson Test

Variable	Durbin-Watson
Inhibitory Control – Predictor Variables (Gender, Age and MM)	2,033
Cognitive Flexibility - Predictor Variables (Gender, Age, and MM)	1,760
Working Memory - Predictor Variables (Gender, Age, and MM)	2,076

The homoscedasticity assumption is referred to as residuals value with constant variance which is equally distributed at each level of predictor variables. Violating this assumption could indicate that the regression model was in a heteroscedasticity condition. In Table 6, the heteroscedasticity test for the predictor variable had a significance value of p >0,05 indicating no heteroscedasticity in this model. Thus, the homoscedasticity assumption was met.

Table 6. Heteroscedasticity Test

Variable	Sig.	Description
Inhibitory Control		
Gender, Age, and MM	0,586	No heteroscedasticity
Cognitive Flexibility		
Gender, Age, and MM	0,854	No heteroscedasticity
Working Memory		
Gender, Age, and MM	0,187	No heteroscedasticity

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The result of hierarchical regression in Table 7 for the inhibitory control component by assessing Go/No-Go accuracy shows in model 1 that the value of R^2 and change in R^2 (ΔR) was 0,06 and statistically not significant. However, in model 2 value of R^2 was 0,049, and the change in R^2 (ΔR) was 0,033 as statistically significant ($F(3,188) = 3{,}204$, $p<.05$). Adding media multitasking in the regression model significantly increased 3.3% of variance counted for performance in Go/No-Go accuracy without influence of covariate variables. An increase in MM approximately degraded the performance of Go/No-Go accuracy ($\beta = -0{,}182$, $t(192) = -2{,}539$, $p<.05$) and surpassed the effect of covariate variables.

For cognitive flexibility, neither model 1 nor model 2 significantly predicted the difference in response time in doing the trials after controlling covariate variables and inserting MM. Performance of working memory, assessed by N-2-Back accuracy, also displayed similar results. Both model 1 and model 2 of the regression models could not significantly predict N-2-Back accuracy after entering gender and age as well as MM. Based on hierarchical regression, we concluded that MM significantly could predict only the performance of inhibitory control after controlling gender and age.

The result of this study on inhibitory control and MM supports the findings of Murphy & Creux (2021). After controlling age, intelligence (IQ), and impulsivity, MM significantly predicts the performance of inhibitory control (Murphy & Creux, 2021). MM as a significant predictor variable on Go/No-Go accuracy is also observable when the participants have high and low cognitive load. Individuals who perform MM more frequently are found to have more difficulties in inhibiting irrelevant stimuli or information. Although a high MM level is correlated to faster response time in responding to Go/No-Go stimuli, it is seen as impulsivity rather than efficiency (Murphy & Creux, 2021; Ralph et al., 2015).

Inhibitory control is highly related to the individual ability to control attention, behavior, and emotion to ignore internal impulses or external stimuli and to focus on relevant information or stimuli (Diamond, 2013; Matthews et al., 2005). In the academic setting, where the learning system is repetitive and aims for specific competencies, this skill is required from students (Pascual et al., 2019). In a classroom learning environment, inhibitory control enables students to follow the instructions while eliminating distractions. Hence, this ability keeps students engaged in relevant learning processes which this condition is important for academic success (Van der Stel & Veenman, 2014). Besides, inhibitory control has valuable role on social skill development as well as preventing students from externalizing problems (Di Norcia et al., 2015).

Table 7. Hierarchical Regression Analysis to Predict Inhibitory Control, Cognitive Flexibility, and Working Memory

	Inhibitory Control					*Cognitive Flexibility*					*Working Memory*				
	β	**R**	**R2**	**ΔR**	**t**	**β**	**R**	**R2**	**ΔR**	**t**	**β**	**R**	**R2**	**ΔR**	**t**
Model 1		0,127	0,016	0,016			0,146	0,021	0,021			0,110	0,012	0,012	
Gender	-0,127				-1,749	0,038				0,531	-0,077				-1,057
Age	-0,023				-0,313	0,144				1,993*	-0,086				-1,188
Model 2		0,221	0,049*	0,033*			0,177	0,032	0,010			0,146	0,021	0,009	
Gender	-0,146				-2,031*	0,049				0,679	-0,087				-1,195
Age	-0,015				-0,205	0,140				1,934	-0,082				-1,131
Media Multitasking	-0,182				-2,539*	0,102				1,416	-0,097				-1,341

*note: *p<.05, **p<.01. N=192*

This research also confirms the findings of Baumgartner et al. (2014) and Rogobete et al. (2021) who find no significant relationship between MM and cognitive flexibility among early adolescents. After controlling age, gender, and media use, MM could not significantly predict the performance of cognitive flexibility. Switch cost, which was considered an indicator of this ability, reflects an increased demand for executive function capacity as a result of cognitive resources requested in reorganizing the system of a task, which is caused by distractions from the second task (Schmitter-Edgecombe & Langill, 2006). Task switching mechanism consists of two processes contributing to switch cost, namely advance preparation and passive decay. Advance preparation poses to retrieve and restore relevant cognitive resources. Passive decay happens when the previous demand from the earlier task is still activated and potentially damages the performance of the current task (Alzahabi et al., 2017). Moreover, the findings of Alzahabi et al. (2017) find that media multitasking is only significantly associated with the advanced preparation process. Hence, the assessment of switch cost which is more sensitive toward the passive decay process would fail in testing the association of MM and cognitive flexibility.

This study finds media multitasking does not significantly predict the performance of working memory assessed by N-2-Back accuracy. This result supports the findings of Baumgartner et al. (2014), Luo et al. (2021), and Rogobete et al. (2021). Baumgartner et al. (2014) and Rogobete et al. (2021) detect no significant relationship between MM and working memory capacity particularly in short-term memory. Luo et al. (2021) also show that MM is not significantly associated with complex working memory tasks on monitoring, updating as well as manipulating stored information in mind. Measurement of working memory in this study is conducted by using the N-Back Task paradigm which emphasizes on ability to maintain relevant information and delete or replace irrelevant information in memory. Individuals with higher media multitasking are expected to have difficulties in working memory aspect specifically in managing distractions when manipulating information in memory, which could not be identified by the N-Back Task paradigm (Edwards & Shin, 2017).

Conclusion

The conclusion from this study states that MM as a predictor variable only significantly contributes to predicting inhibitory control after controlling gender and age. It indicates that students with higher MM would have lower performance of inhibitory control. Impaired inhibitory control might cause difficulties in learning particularly when students need to inhibit irrelevant distractions or stimuli. However, MM is not significantly related to the performance of cognitive flexibility and working memory.

Recommendation

Based on the result of this study, there are several recommendations to follow: (1) Future research needs to use another approach for measuring variables such as conducting observation for MM and employing more than one task paradigm for assessing executive function; (2) Teacher and parent should limit digital media usage of students mainly for learning to minimize distractions or irrelevant stimuli; (3) Students should reduce their behavior to access digital media while multitasking with other activities involving other media or non-media activities.

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