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The effects of smartphone addiction on learning: A meta-analysis

Oluwafemi J. Sunday [a,b,*], Olusola O. Adesope [a], Patricia L. Maarhuis [b]

[a] Department of Educational Psychology, Washington State University, USA
[b] Cougar Health Services, Washington State University, USA

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ABSTRACT

Research on smartphone use among college students is extensive. Although numerous studies have examined the relationships between mobile phone use and academic achievements, many such studies have yielded mixed findings. Hence, the overarching goal of this meta-analysis was to comprehensively synthesize existing research to investigate the effects of smartphone addiction on learning. The authors included 44 studies (45 effects) in the analysis yielding a sample size of $N = 147{,}943$ college students from 16 countries. The results show that smartphone addiction negatively impacts students' learning and overall academic performance ($Q\,(43) = 711.87$, $p < .001$, $r = -0.12$). Further, findings suggest that the greater the use of a phone while studying, the greater the negative impact on learning and academic achievement. Additionally, the results suggest that skills and cognitive abilities needed for students' academic success and learning are negatively impacted. Implications of these findings are discussed, and recommendations for future research are delineated.

Introduction

Due to the prevalence of smartphones in our society, excessive use and even addiction have become significant global issues. Although numerous studies have examined the relationships between mobile phone use and educational outcomes, many such studies have yielded mixed findings. Most of these studies have explored the effects of problematic smartphone use and academic performance using students' self-reported course grades. Hence, this study focuses on student learning because course grades do not always measure the learning outcomes. Thus, one of the goals of this meta-analysis is to examine whether smartphone use in the classroom affects students' learning.

Research on smartphone use has focused on the negative and positive outcomes of mobile phones. Researchers have investigated negative outcomes of smartphone resulting from overuse of mobile phones, including poor sleep quality (Brunborg, Mentzoni, Model, Myrseth, ; Demirci, Akgönül, & Akpinar, 2015; Yang, Fu, Liao, & Li, 2020), everyday inattention (Marty-Dugas, Ralph, Oakman, & Smilek, 2018), attention deficit and academic procrastination (Im & Jang, 2017; Yang, Asbury, & Griffiths, 2018), deterioration of personal relationships (Seo, Park, Kim, & Park, 2016), and negative academic performance (Baert et al., 2020; Grant; Lust, & Chamberlain, 2019; Kate, Wu, Coryn, 2018; Kim, Min, Ahn, An, & Lee, 2019; Lin, Liu, Fan, Tuunainen, & Deng, 2021; Samaha & Hawi, 2016).

Positive outcomes of mobile phone use include reinforcement of social interactions and optimization of communication between individuals and systems (Geser, 2004). Mobile phone use has enhanced health promotion programs and patient care using smartphones to communicate health messages to adjust lifestyle behaviors and monitor patient health data (Blake, 2008; Fjeldsoe, Marshall, & Miller, 2009).

Despite the problematic smartphone use, some research has examined the educational benefits of using smartphones for mobile learning (Traxler, 2009), personalized instruction (Steel, 2012), self-regulated learning (Sha, Looi, Chen, & Zhang, 2012), classroom engagement (Wang, Shen, Novak, & Pan, 2009), and second language learning (Thornton & Houser, 2005). Findings from these studies highlighted educational benefits of smartphone use, such as reducing the digital gap, completing homework, collaboration among peers, quick accessibility of information, and vocabulary enhancement. These benefits culminated into reliance on smartphone use to solve educational-related tasks. These affordances have encouraged continuous dependence on smartphones among college students.

The global surge in use has led to an ever-increasing dependency on smartphones because of their embedded functionalities and portability factor. Some people, especially the younger generation, prefer a smartphone over a laptop and personal computers because of the various functionalities embedded in smartphones, such as entertainment, watching sports, online games, online banking, sending emails, chatting, agenda tracking, online shopping, social media, and ability to complete

* Corresponding author. College of Education, Washington State University Pullman, WA 99164-2114, USA.
E-mail address: sundfem@yahoo.com (O.J. Sunday).

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homework (Cha & Seo, 2018; Nayak, 2018). This has resulted in consistent use of smartphones among young adults over time, and thus, most young adults find it difficult to control the use (Bianchi & Phillips, 2005). Given the prevalence of smartphone addiction among college students, it is crucial to explore the relationships between smartphone addiction and students' learning.

Many studies have investigated educational outcomes of smartphone addiction, and there have been inconsistencies in research findings. Hence, this study contributes to the literature on smartphone addiction in two ways: (1) examine the landscape of literature on the negative impact of smartphone addiction on students' learning and overall academic performance; (2) reconcile the mixed findings in the literature regarding the effects of smartphone addiction on students' academic performance.

Conceptualization of smartphone addiction

Due to the proliferation of smartphone use, researchers have attempted to operationalize smartphone addiction in terms of smartphone overuse (Lee, 2017), excessive smartphone use (Chen, Liang, Mai, Zhong, & Qu, 2016), compulsive mobile phone usage (Kim & Byrne, 2011), mobile phone addiction (Eduardo et al., 2012), heavy smartphone use (Lee, 2014), problematic mobile phone usage (Billieux, Van der Linden, d'Acremont, Ceschi, & Zermatten, 2007; Rozgonjuk, Saal, & That, 2018), and mobile phone dependence (Wang, Wang, Li, Dong & Chi, 2013). Thus, the conceptualization of smartphone addiction has generated intense debates among researchers.

Given this, many scholars have attempted to define smartphone addiction in the context of behavioral addiction. Sussman and Sussman (2011) explored the definition of addiction under five elements: (a) engagement in the behavior to achieve appetitive effects, (b) preoccupation, (c) temporary satiation, (d) loss of control, and (e) negative consequences. They justified this definition by stating that anyone can experience each element in part(s), combined with one or more of others or a case where an individual possesses the five characteristics of addiction. Shambare, Rugimbana, and Zhowa (2012) examined six types of behavior: habitual, mandatory, voluntary, dependent, compulsive, and addictive. However, their study found support for only three: dependency, habitual, and addictive behavior. The findings explain a condition where smartphone use has fulfilled a deep need (dependency, habitual, and addictive behavior) to the extent that the individual has difficulty conducting basic activities of daily life without the concurrent use of a smartphone. For example, some people find it difficult to sleep through the night without checking social media sites multiple times.

Similarly, Griffiths (2005) operationally defined behavioral addictions as any behavior that consists of the six core components of addiction – salience, mood modification, tolerance, withdrawal symptoms, conflict, and relapse. Griffiths stated that any behavior that fulfills any of these six criteria is categorized as an addiction. Also, the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) listed eleven criteria for Substance-Related and Addictive Disorders, including withdrawal, tolerance, hazardous use, repeated attempts to control or quit, physical or psychological problems related to use, given up activities, and craving (American Psychiatric Association (APA), 2013). As stated in the DSM- 5 criteria, an individual must meet two or more of these criteria within 12 months to be diagnosed with a substance use disorder.

In addition, Griffiths (1999, 2000) relates technological addictions as a type of behavioral addiction and defines the term as "non-chemical (behavioral) addictions that involve human-machine interaction." The present study is based on the definition Griffiths proposed by categorizing this form of addiction as a subset of behavioral addiction and relating it to human-machine interaction. By doing so, we can place a distinction between chemical addiction and non-chemical addiction. Chemical addiction (substance use) involves digestion of a chemical or liquid substance, and non-chemical (behavioral) addiction arises when a person cannot resist a behavior despite experiencing a psychological need in the short term, leading to a harmful consequence in the long run.

To date, this conceptualization of smartphone addiction as a behavioral addiction is supported only by an exploratory study that heavily relies on self-report instruments (Billieux, J., Maurage, P., Lopez-Fernandez, O., Kuss, D. J., & Griffiths, M. D, 2015). The present research took account of this divergence in the conceptualization of smartphone addiction. In addition, the present meta-analysis seeks to comprehensively synthesize existing research on smartphone addiction and its effects on learning.

Due to the complexity in conceptualizing smartphone addiction, a secondary objective of this meta-analysis is to propose an integrative model in conceptualizing smartphone addiction. This meta-analysis defines smartphone addiction within the contextual framework of behavioral addiction by integrating the criteria of behavioral addiction using Griffiths (2005), Shambare et al. (2012), and the DSM-5 criteria of substance-related and addictive disorder (American Psychiatric Association, 2013). In this meta-analysis, therefore, we conceptualize smartphone addiction as a condition where the use of smartphone has fulfilled a deep need (dependency, habitual, and addictive behavior) to the extent that the individual has difficulty conducting basic activities of daily life without the concurrent use of a smartphone, and as such caused neglect of other aspects of one's life. Thus, this conceptualizatio influenced the inclusion of studies in the meta-analysis.

Given the conceptualization of smartphone addiction, an individual who experiences any of the six components of addiction, including salience, mood modification, tolerance, withdrawal symptoms, conflict, and craving, has developed a behavioral addiction to smartphone use. Hence, the conceptualization of behavioral addiction to smartphone use forms the basis of the selection criterion for this meta-analysis. Any studies that did not meet these criteria were excluded from the study.

Review of the research of smartphone addiction on learning

Smartphone addiction is defined as excessive use of smartphones in a difficult to control. Its influence affects other basic activities of daily life, leading to negative consequences (Park & Lee, 2012). Most of the literature that examines the relationship between problematic smartphone use and academic performance reports varying levels of negative consequences (Durak, 2018; Jacobsen & Forste, 2011; Kuznekoff & Titsworth, 2013; Li, Lepp, & Barkley, 2015; Longnecker, 2017; Mendoza, Pody, Lee, Kim, & McDonough, 2018; Olufadi, 2015; Rozgonjuk et al., 2018). Previous research suggests that excessive smartphone use in the classrooms can inhibit academic performance (Lepp, Barkley, and Karpinski (2014) found the negative effects of excessive smartphone use on students' academic performance through decreased GPA scores.

Roberts, Yaya, and Manolis (2014) found that cell phone addiction can negatively influence academic performance as students' attention in class is disrupted because of cell phone use, and such disruption affects their studies outside of class. Excessive mobile phone use has been associated with distraction in the classroom (Bugeja, 2007; Campbell, 2006; Dietz & Henrich, 2014; Froese et al., 2012; Harman & Seto, 2011; Wei & Wang, 2010). These studies reveal that in-class texting produces significant negative effects on students' academic performance.

Many studies have discussed smartphone addiction in terms of students' multitasking in the classroom and the effects of this multitasking on students' academic performance (Ellis, Daniels, & Jauregui, 2011; Jacobsen & Forste, 2011; Junco & Cotton, 2011). Findings on the consequences of multitasking with the smartphone on academic performance showed a negative relationship between students' problematic mobile phone use and academic performance. Junco and Cotton (2011, 2012) investigated the relationship between multitasking on phones and student academic performance among college students to account for the effects of multitasking on academic performance. This study showed that sending text messages and checking social media websites like Facebook while performing an academic task or doing homework interfered with completing their schoolwork and negatively impacted the participants' overall GPA.

However, few studies have found any effects of smartphone addiction on students' academic performance (Dos, 2014; Lau, 2017). The positive effects of smartphone addiction on students' academic performance may be associated with the shift in social practices that normalize excessive smartphone use. In addition, Tessier (2013) found that smartphone use as an education tool could enhance learning. When students are allowed to use their cell phones as a learning aid in class, it could increase academic performance and benefit educational settings.

In sum, smartphone addiction has generated mixed findings among researchers. Hence, the primary goal of this meta-analysis is to reconcile the inconsistencies in the literature regarding the size and direction of the effects of smartphone addiction on students' academic performance.

Purpose of the meta-analysis

Research on smartphone addiction has generated mixed findings. Hence, this study aims to reconcile inconsistencies in the literature by conducting a comprehensive meta-analysis on the effects of smartphone addiction on learning. Therefore, this meta-analysis sought answers to the following research questions:

1. How do past research on smartphone addiction and academic performance demonstrate the relationships between smartphone addiction and students' learning?
2. What factors moderate the relationship between smartphone addiction and academic performance as demonstrated by past research?
3. How do the relationships of smartphone addiction and students' learning vary with characteristics of research design and methodological features of past research?

Method

The approach for conducting this meta-analysis is consistent with a well-established review protocol guiding the procedures for collecting and synthesizing research (Cooper, Hedges, & Valentine, 2009).

Inclusion/exclusion criteria

Following a preliminary examination of empirical studies and reviews, we developed selection criteria to examine the impact of smartphone addiction on students' academic performance. To be included in this meta-analysis, studies must meet the following criteria:

1. Examine smartphone addiction or mobile phone use about learning and academic performance. The study must fall within the scope of a smartphone, cell phone, or mobile phone use.
2. Student academic performance was measured by constructs of learning performance such as GPA, test scores, SAT scores, GRE/GMAT scores, overall class scores. In addition, any cognitive tasks that measure learning outcomes are used as proxies.
3. Studies must satisfy the conditions stated for the conceptualization of smartphone addiction within the framework or model of this meta-analysis, such as but not limited to problematic use, behavioral addiction, compulsive use (texting or smartphone use), excessive use, and multitasking in class.
4. Studies must report sufficient and appropriate data to calculate effect sizes.
5. Studies must be publicly available either online or in library archives.

Studies that reported insufficient data for effect size calculations were excluded. Studies that measured computer, internet addiction, or laptop use were also excluded.

Data sources and search strategies

We used the query *smartphone* addict* OR *mobile phone* addiction* OR *mobile phone *use* AND *academic performance** OR *GPA** OR *learning** as keywords to conduct a comprehensive and systematic search on the following electronic databases: PsycINFO, Education Full Text, ERIC, PsycARTICLES, PubMed, Pro-Quest, Google Scholar, and web of science. Also, a manual search of the reference lists of earlier reviews of the literature on smartphone addiction was subsequently conducted (Dietz & Henrich, 2014; Junco & Cotton, 2012; Lepp, Barkley, & Karpinski, 2015; Samaha & Hawi, 2016).

Outcomes of the search strategy

A total of 320 articles were obtained from the search procedure and entered into an extensive coding form. This meta-analysis adopted two screening phases to guide the inclusion/exclusion criteria. In the first phase of the screening, both the first and second authors independently screened the relevant sources, reviewed the title and keywords of these articles for possible inclusion, and strictly ensured the inclusion criteria were applied. We removed 39 duplicate articles from the study. Besides, studies that did not meet the selection criteria were excluded, resulting in 51 articles after the first phase. The full text of the articles was obtained and read by two researchers.

In the second phase, we developed a coding sheet and independently read the full text of each of the 51 articles after the inclusion to further determine suitability based on the inclusion criteria. Only 44 articles met the second inclusion criteria, and data from these articles were extracted and saved to Zotero. The coding variables consisted of 11 categorical moderators: (a) study name, (b) source, (c) region, (d) sampling group, (e), purpose of use, (f) GPA predictor, (g) smartphone construct, (h) test format, (i) research design, (j) test instrument, and (k) grade level. The moderator variables were derived a priori and incorporated characteristics of studies into our coding forms. This process was informed by our research questions and readings from extant literature on smartphone addictions.

In cases where a variable was not explicit, authors had extensive discussions to resolve all discrepancies and jointly agree on the coding. Fig. 1 shows the flowchart of how studies were filtered throughout the searching process for eligible studies to be included in this meta-analysis.

Data analysis procedure

This study followed the standard guidelines for conducting a meta-analysis (Adesope, Lavin, Thomson, & Ungerleider, 2010; Cooper & Hedges, 1994; Nesbit & Adesope, 2006). Data were analyzed using Comprehensive Meta-Analysis software 2.2.048 (Borenstein, Hedges, Higgins, & Rothstein, 2009) and IBM SPSS version 24 for windows. Before we entered data to CMA and SPSS, coded variables were systematically laid out in excel. For each outcome measure, we extracted Pearson Correlation Coefficient (r). All effect sizes generated from eligible studies were converted to correlation coefficient (r).

In order to generate the summary effect size, the correlation coefficient was transformed to the Fisher's Z scale. Hence, all analyses were conducted using the transformed values on a comprehensive meta-analysis software. Pearson correlation was used to measure the effects of smartphone addiction on learning because it helps to understand how strong a relationship is between two variables. Also, we used SPSS to examine the normality distribution of effect sizes. The transformed effect sizes were imported to SPSS to examine normality distribution.

Results

A total of 44 studies included (45 effect sizes) in the analysis consist of 147,943 students from 16 countries (e.g., Brazil, China, Italy, Lebanon, Nigeria, Turkey, United States). Fig. 2 shows the distribution of effect sizes. The overall result and moderator analyses were organized and presented around the research questions to provide coherence of the presentation. In all reported analyses, negative correlation (r) indicates a

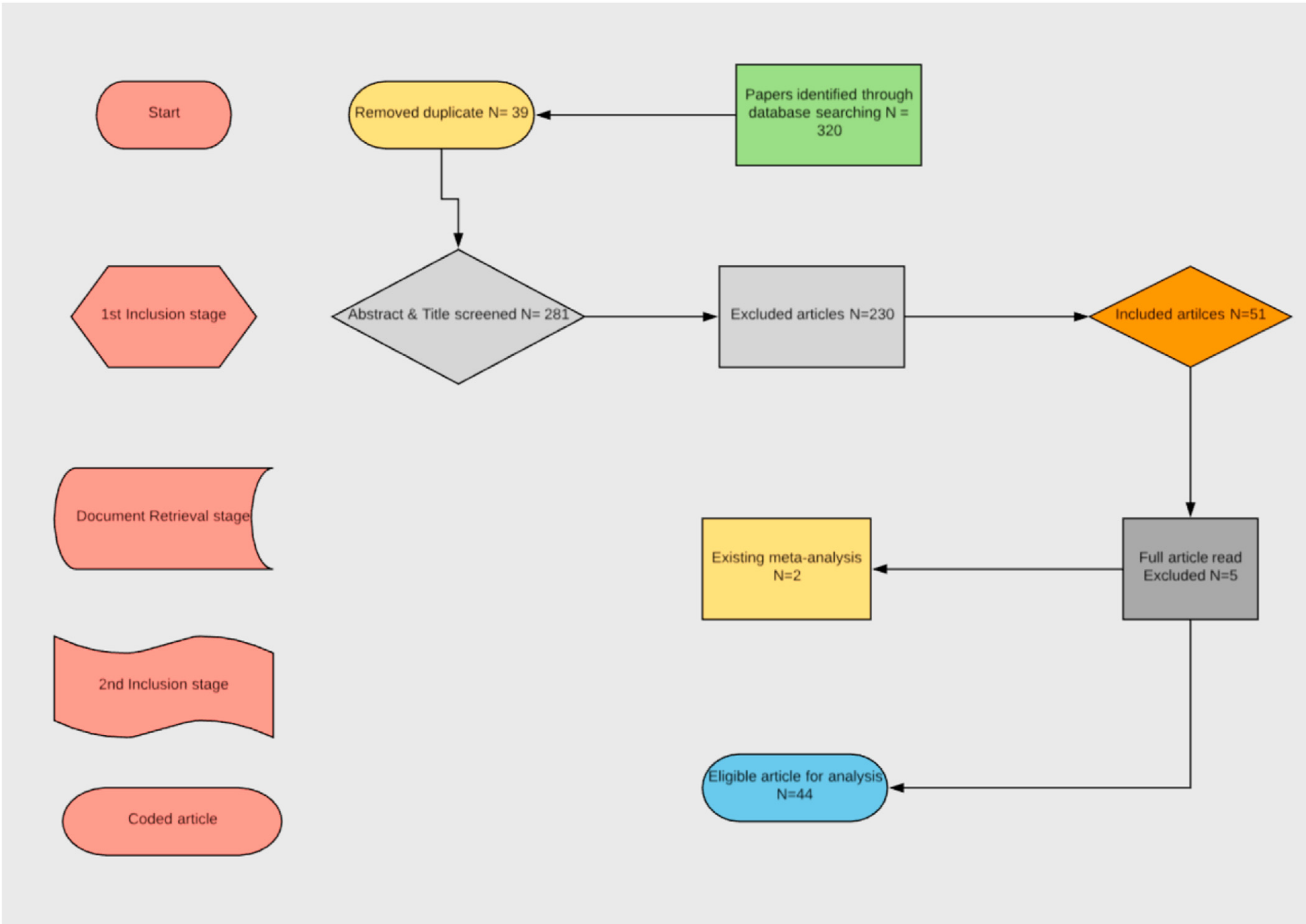

Fig. 1. *Flowchart for selection of studies.*

negative relationship between smartphone addiction and learning. That is, smartphone addiction has negative consequences on students' academic performance. Tables of results include the number of participants (N) in each category, number of findings (k), effect sizes (r), standard error (SE), 95% lower and upper confidence interval, results of a test of homogeneity (Q) with its associated degrees of freedom (df), and the percentage of variability that could be attributed to true heterogeneity or between-studies variability (I^2).

How do past research on smartphone addiction and academic performance demonstrate the relationship?

In this meta-analysis, negative effect sizes indicate a deleterious effect of smartphone addiction on academic performance. Table 1 indicates an overall analysis of the correlation of all statistically independent effect sizes and the results of smartphone addiction on academic performance. As shown in Table 1, under the random-effects model, the overall mean effect size was statistically significant, indicating a negative effect of smartphone addiction on students' academic performance ($r = -0.12$, $p < .001$). Besides, the overall sample was heterogeneous, Q (43) = 711.87, $p < .001$, $I^2 = 0.94$. The total variability that could be attributed to true heterogeneity or between-studies variability was 94%. These results indicate that study-level covariates could explain 94% of the variance, and 6% of the variance was within-study variance based on sampling error.

This result shows significant variability in the individual effect sizes that constitute the overall result. Hence, there is a need to conduct moderator analyses to investigate factors responsible for such variability in study characteristics.

What factors moderate the relationship between smartphone addiction and academic performance as demonstrated by past research?

To answer this research question, we examined the possible moderating effects of the following variables: (a) source, (b) region, (c) sampling group, (d) purpose of use, (e) GPA predictor, (f) smartphone construct, (g) test format, and (h) research design, (i) test instrument, and (j) grade level.

Overall, Table 2 shows that smartphone addiction was associated with statistically significant effect sizes. Under the fixed-effect model, there was a statistically significant difference between the weighted mean correlation of the dissertation ($r = -0.26$) and journal ($r = -0.06$). The between-levels difference was statistically significant, Q_B (1) = 27.65, $p < .001$, and findings showed that studies from the dissertation produced a statistically significant negative effect that is different and lower than the effect produced with studies from the journal.

Also, regardless of continent, the use of smartphone was associated with significant deleterious effects, Africa ($r = -0.20$); Asia ($r = -0.05$); Europe ($r = -0.06$); North America ($r = -0.07$); and South America ($r = -0.14$). The between-levels difference was statistically significant, Q_B (4) = 16.30, $p < .05$, and results showed that studies conducted in Africa produced a statistically significant negative effect that is different and lower than the effects produced with studies from Asia, Europe, North America, and South America.

Table 3 shows the results of the moderator analysis based on grade level. Under the fixed-effects model, the between-level was not statistically significant, Q_B (1) = 1.01, $p > .05$, indicating no difference between the groups.

However, there were statistically significant effects regardless of grade level, university students ($r = -0.07$) and k-12 students ($r = -0.06$).

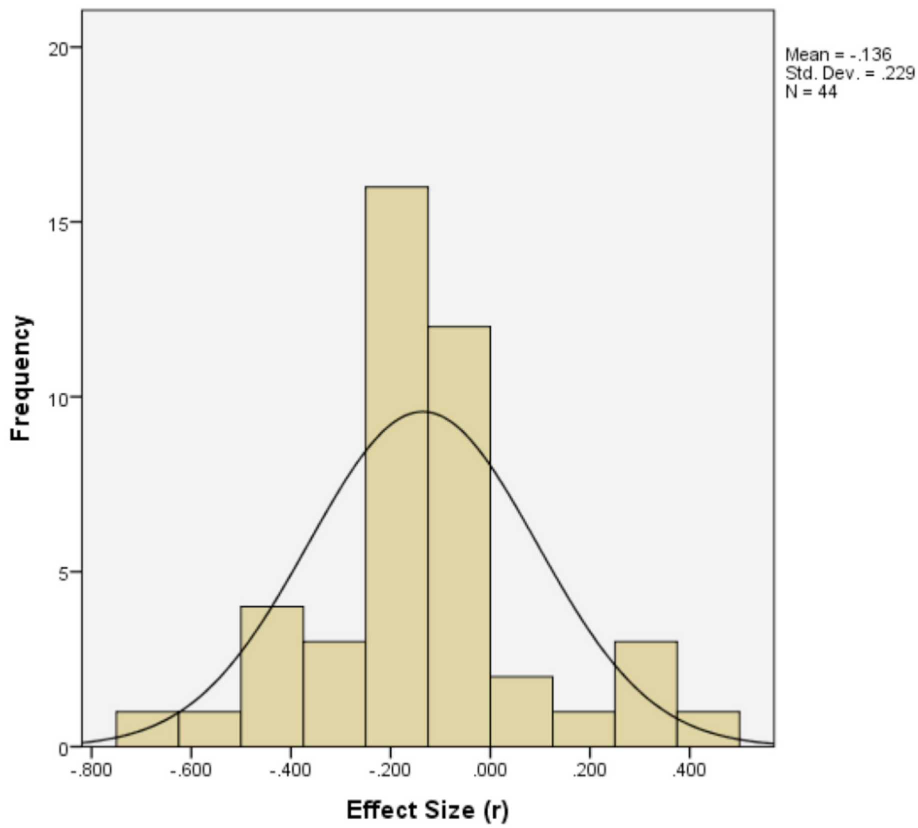

Fig. 2. *Distribution of 45 independent effect sizes obtained from 44 studies (M = -0.14, SD = 0.23).*

Table 1
The overall weighted mean size.

			Effect size	95% CI		Test of heterogeneity			
Model	*N*	*k*	*R*	Lower	Upper	*Q*	*df*	*p*	$I^{2(\%)}$
Fixed-effects model	147,943	44	−0.06	−0.07	−0.06	711.87	43	<.001	94
Random-effects model	147,943	44	−0.12	−0.17	−0.08				

*$p < .05$

Table 2
Summary statistics for moderators.

Effect size				95% Confidence Interval		Test of heterogeneity		
Moderator	*N*	*K*	*R*	Lower	Upper	*Q*	*df*	I^2 (%)
Between-levels (Q_B)						27.65*	1	
Source								
Dissertation	648	3	−0.26*	−0.34	−0.19	5.43	2	63.17
Journal	147,295	41	−0.06*	−0.07	−0.06	678.79*	40	94.11
Between-levels (Q_B)						16.30*	4	
Continents								
Africa	286	2	−0.20*	−0.28	−0.12	0.08	1	0
Asia	6084	14	−0.05*	−0.07	−0.03	414.87*	13	96.88
Europe	1815	5	−0.06*	−0.07	−0.06	55.85*	4	92.84
North America	6095	21	−0.07*	−0.10	−0.05	224.51*	20	91.10
South America	1113	2	−0.14*	−0.23	−0.05	0.26	1	0

*$p < .05$

Table 3 also shows that the weighted mean of entertainment did not produce significant effects under a fixed-effects model. However, talking and chatting, text messaging, texting and socializing, and video gaming produced statistically deleterious effects. The results showed that video gaming induced a higher weighted mean effect ($r = -0.17$) than texting and socializing ($r = -0.13$), talking and chatting ($r = -0.10$), and text messaging ($r = -0.06$). The between-levels difference was statistically significant, Q_B (4) = 30.00, $p < .001$, and findings showed that video gaming produced a statistically significant negative effect that is different and lower than the effects produced with texting and socializing, talking and chatting, and text messaging.

Table 4 shows that regardless of GPA predictors, smartphone use was associated with significant deleterious effects. Multitasking during class ($r = -0.16$), excessive texting ($r = -0.06$), time spent on smartphone

Table 3
Summary statistics for moderators.

Effect size				95% confidence interval		Test of heterogeneity		
Moderator	*N*	*K*	*r*	Lower	Upper	*Q*	*df*	I^2 (%)
Between-levels (Q_B)						1.01	1	
Grade Level								
K-12	135,367	6	−0.06*	−0.07	−0.06	66.71*	5	92.51
University	12,576	38	−0.07*	−0.09	−0.05	644.15*	37	94.26
Between-levels (Q_B)						30.00*	4	
Purpose of Use								
Entertainment	730	2	−0.30	−0.10	−0.04	3.77*	1	73.50
Talking & Chatting	140,604	4	−0.10*	−0.15	−0.05	8.86*	3	66.13
Text messaging	1424	22	−0.06*	−0.07	−0.06	293.46*	21	92.84
Texting & Socializing	4464	14	−0.13*	−0.16	−0.10	375.56*	13	96.54
Video Gaming	716	2	−0.17*	−0.24	−0.10	0.22	1	0

*$p < .05$

Table 4
Summary statistics for moderators.

Effect size				95% confidence interval		Test of heterogeneity		
Moderator	*N*	*K*	*r*	Lower	Upper	*Q*	*df*	I^2 (%)
Between-levels (Q_B)						22.27*	3	
GPA Predictor								
Excessive phone use	135,019	12	−0.06*	−0.07	−0.06	107.72*	11	89.79
Excessive texting	6,101	11	−0.06*	−0.09	−0.04	204.58*	10	95.11
Multitasking in-class	1240	5	−0.16*	−0.22	−0.11	10.91*	4	63.33
Time spent on phone	446	16	−0.10*	−0.12	−0.07	366.40*	15	95.91
Between-levels (Q_B)						3.21	3	
Smartphone construct								
Smartphone Addiction	8371	21	−0.07*	−0.09	−0.05	543.44*	20	96.32
Frequency of use	136,442	19	−0.06*	−0.07	−0.06	154.77*	18	88.37
Smartphone dependency	2647	3	−0.08*	−0.12	−0.04	10.43*	2	80.82
Smartphone usage	483	1	0.01*	−0.08	0.10	0.00	0	0

*$p < .05$

activities ($r = -0.10$), and excessive smartphone uses ($r = -0.06$). The between-levels difference was statistically significant, Q_B (3) = 22.27, $p > .001$, indicating that the weighted effect sizes differed significantly between the group. Specifically, multitasking in class was associated with a significant deleterious effect that is significantly different from excessive texting and excessive phone use.

Table 4 also shows that the between-levels difference was not statistically significant, Q_B (3) = 3.21, $p > .05$. The result indicates that there was no difference between the group. However, there were statistically significant effects regardless of smartphone constructs. Smartphone dependency ($r = -0.07$), smartphone addiction/problematic use ($r = 0.06$), and frequency of use ($r = -0.06$) all produced statistically significant deleterious effects. Besides, smartphone usage produced positive weighed mean effects and was not statistically significant ($r = 0.01$, $p > .05$).

How do the effects of smartphone addiction vary with characteristics of research design and methodological features of past research?

Table 5 shows the pattern of effect sizes according to the methodological features of the studies included in this meta-analysis. The study was categorized according to research design, test formats, and test instruments. Under the fixed-effects model, regardless of test format, smartphone use was associated with significant deleterious effects with experiments ($r = -0.03$) and surveys ($r = -0.06$). However, the between-levels difference was not statistically significant (Q_B (1) = 1.68, $p > .05$). The results indicate that there was no difference between the group.

Table 5
Summary statistics for moderators.

Effect size				95% confidence interval		Test of heterogeneity		
Moderator	*N*	*K*	*r*	Lower	Upper	*Q*	*df*	I^2 (%)
Between-levels (Q_B)						1.68	1	
Test Format								
Experiment	1307	8	−0.03*	−0.08	0.03	81.42*	7	91.40
Survey	146,363	36	−0.06*	−0.07	−0.06	628.77*	35	94.43
Between-levels (Q_B)						1.84	1	
Research Design								
Correlational-study	146,571	35	−0.06*	−0.07	−0.06	628.60*	34	94.60
Experimental-study	1372	9	−0.03	−0.08	0.03	81.43*	8	90.18
Between-levels (Q_B)						8.06*	1	
Test Instrument								
Researcher-developed	134,718	15	−0.06*	−0.07	−0.06	194.07*	14	92.79
Standardized	13,225	29	−0.09*	−0.10	−0.07	509.74*	28	94.51

*$p < .05$

Table 5 also shows that, under the fixed-effects model, only the correlational study produced a statistically significant effect ($r = -0.06$). However, the between-levels difference was not statistically significant (Q_B (1) = 1.84, $p > .05$).

Table 5 shows that regardless of the test instrument, smartphone use was associated with significant deleterious effects, standardized ($r = -0.09$) and researcher-developed instrument ($r = -0.06$). The between-levels difference was statistically significant, Q_B (1) = 8.06, $p < .05$, and findings showed that standardized test produced a statistically significant negative effect that is different and lower than the effect produced with the researcher-developed test.

Publication bias

All studies in this meta-analysis that met the selection criteria excluding three studies from the dissertation were published in peer review journals, enhancing the potential for publication bias and restraining the possibility of examining the potential moderating effect of the source of the publication.

Two statistical tests were conducted using Comprehensive Meta-Analysis software to evaluate the potential for publication bias. First, a classic fail-safe *N* test was conducted to estimate the number of null effect studies that could be added to this meta-analysis before the result becomes invalid. Results showed that 2787 additional studies would be needed to invalidate the overall effect. Second, Egger's linear regression test (Egger, Smith, Schneider, & Minder, 1997) was used to thoroughly investigate the robustness of the classic fail-safe test by examining the unbiased effect sizes and standard errors.

Results of this test further corroborated the result of the fail-safe test, showing the absence of publication bias (p > .05). Researchers have affirmed that results from meta-analyses are valid and thus resistant to publication bias if the fail-safe *N* reaches the $5k + 10$ limit (Carson, Schriessheim, & Kinicki, 1990; Rosenthal, 1979). Therefore, results from the two computed statistical tests indicate that publication bias does not pose a significant threat to the validity of this meta-analysis since both fail-safe N values are larger than $5k + 10$ limit.

Besides, a test of normality was conducted, and the histogram showed a bell-curved shape. Thus, there was evidence of normality in the distribution. Also, no outliers in the study as the z values range from -2.67 to 2.48 ($< \pm 3.3$; Tabachnick et al., 2007).

Discussion

How do past research on smartphone addiction and academic performance demonstrate the relationships between smartphone addiction and students' learning?

The purpose of this meta-analysis was to examine the effects of smartphone addiction on learning and the extent to which the effects of smartphone addiction are moderated by (a) source, (b) continents, (c) grade level, (d) purpose of use, (e) smartphone construct, (f) GPA predictor, (g) test format, (h) research design, and (i) test instrument. Findings indicate that smartphone addiction has a negative effect (r = - 0.12) on learning. Findings from this meta-analysis align with several studies that found a negative relationship between smartphone addiction and academic performance (Hawi & Samaha, 2016; Junco & Cotton, 2012; Lepp et al., 2014, 2015; Longnecker, 2017; Samaha & Hawi, 2016). These results imply that addicted users show a diminished level of learning.

The findings suggest two important aspects to understanding the effects of smartphone addiction on learning: (1) these results suggest that the greater the use of a phone while studying, the greater the negative impact on learning and academic achievement; (2) the results also suggest that skills and cognitive abilities, that students need for academic success and learning, can be negatively affected by excessive and addictive phone use. The present meta-analysis further reveals that when students have difficulty controlling their smartphone use, there is a potential that they are experiencing smartphone addiction. This issue may require implementing various cognitive-behavioral therapies, clinical interventions, and self-care strategies.

What factors moderate the relationship between smartphone addiction and academic performance as demonstrated by past research?

Moderator analysis was examined to determine the moderating factors between smartphone addiction and academic performance. Results show that source (dissertation vs. journal), continents (Africa, Asia, Europe, North Africa, and South America), and grade levels (k-12 vs. university students) statistically moderated smartphone addiction. Also, the purpose of use (entertainment, talking & chatting, text messaging, texting & socializing) and GPA predictors (excessive phone use, excessive texting, multitasking in-class, time spent on the phone) all yielded statistically significant differences. However, the between-level for grades was not statistically significant. For this moderator variable, evidence is lacking to support the notion that students' grade level moderated the effect of smartphone addiction. In other words, addiction to smartphones produced deleterious effects regardless of the grade levels of students.

In answer to the second research question, results showed that all six moderator variables (source, continent, purpose of use, GPA predictors, and smartphone constructs) produced statistically significant effects of smartphone addiction on learning, excluding grade level. For instance, all the constructs measuring the purpose of use as a moderator variable produced negative weighted mean effects on learning except entertainment. These results reveal that sending text messages, talking and chatting, multitasking in-class, and texting and socializing negatively affect students' academic performance. Findings from this meta-analysis align with results from several studies that found negative effects of text messages in the classroom (Dietz & Henrich, 2014; Harman & Sato, 2001; Kuznekoff & Titsworth, 2013; MacDonald, 2013), multitasking in-class (Jacobsen & Forste, 2011; Junco & Cotten, 2012), and socializing (Junco & Cotton, 2012; Lee, 2015; Kirschner & Karpinski, 2010; Rozgonjuk et al., 2018) on students' academic performance. This result reveals that students need to maintain high levels of attention and self-regulation in their academic pursuits to achieve high academic excellence.

Also, all the constructs measuring GPA predictor as a moderator variable were statistically significant and showed negative effects on academic performance. Excessive smartphone use, time spent on the phone, and excessive texting are all predictors of academic performance (Dos, 2014; Felisoni & Godoi, 2018; Junco & Cotton, 2012; King & Dong, 2017; Lepp et al., 2015). The results reveal that when a student spends time on the phone so that he/she neglects his/her practices of daily life, engages in excessive smartphone use, or excessively texting on the phone, there is a tendency to experience a decline in GPA.

Given this, distraction has been found to have negative effects on academic performance (Burns & Lohenry, 2010; Junco & Cotton, 2012). In other words, past research found that the more a student excessively uses his/her phone, the greater the potential for an addiction he/she could experience, and the greater the potential for adverse effects on academic success.

How do the effects of smartphone addiction vary with characteristics of research design and methodological features of past research?

This meta-analysis also conducted moderator analysis to examine if the effects of smartphone addiction vary with characteristics of research design and methodological features of the research. The results showed that the test instruments (researcher developed and standardized test) yielded statistically significant differences between groups. This meta-analysis found that both instruments have good validity and reliability in moderating the effects of smartphone addiction on learning. However, the between-level for test format (experiment and survey) and research design (correlational study and experimental study) were not statistically significant. The variation in these results may be associated with the types of research designs in empirical studies.

Limitations and direction for future research

This meta-analysis has several limitations. First, the conceptualization of smartphone addiction was a difficult undertaking in this study. Due to the ubiquity of smartphone use and difficulty measuring differences between non-problematic use, problematic use, and addictive use, there is a need for psychometrics development of standardized tools to measure smartphone addiction.

Second, smartphone constitutes a new technology with significant socio-cultural impacts on daily living. Thus, there is limited availability of prior research to explore the effects of smartphone addiction on academic performance. This may have impacted the number of studies available for this meta-analysis. More research is needed to focus attention on the consequences and implications of smartphone use on students' academic performance while providing intervention strategies to ameliorate the negative impacts experienced.

Despite these limitations, several recommendations can be made based on the findings of this meta-analysis. Findings suggest that if smartphone use could be controlled in school settings, it may significantly improve students' academic performance. For instance, experimental studies included in this meta-analysis revealed that students who did not use smartphones in the classroom outperformed students that used their smartphone in the classroom (Dietz & Henrich, 2014; Froeze, 2012a, 2012b; Gingerich & Lineweaver, 2013; Mendoza, 2018a, 2018b).

Based on the findings of this meta-analysis, we recommend that educators consider adopting a policy that will help reduce students' use of smartphones in school settings. The present meta-analysis offers some practical suggestions for students, instructors, or educators. Instructors can include the smartphone rules in their syllabi and inform their students of the adverse effect of smartphone addiction on learning by drawing on this study's findings and extant literature. By so doing, students become aware of the potential negative consequences of their actions.

In addition, educators can provide good strategies by which people can learn through the use of smartphones. Healthy use of smartphones should be encouraged in all educational settings, including minimizing smartphone use because healthy use of smartphones adds to life while smartphone addictions take away from life (Griffiths, 2005).

Educators may carefully consider implementing a policy to reduce the number of hours spent on smartphones for elementary, middle, and high school students. This policy will help to discourage or minimize heavy use of smartphones, especially among elementary students. Specifically, it is recommended that infants under 1 year old should not be exposed to electronic screens. Children under five years old are to limit or eliminate screen use to 1 h per day of high-quality programming with their parents watching and helping the children understand what they are watching (World Health Organization, 2019). This recommendation will improve the children's mental health and well-being and help prevent health-related diseases that may occur later in life.

Future research should explore smartphone addiction, the resulting mental health concerns, and academic impacts with implications for teaching and learning practices and educational policy development.

Conclusion

The findings from this study advance understanding of the negative effects of smartphone addiction on learning. The results of this meta-analysis showed that smartphone addiction has negative effects on students' academic performance. When students spend time on their phones to the extent of neglecting their practices of daily life, engaging in excessive smartphone use, or excessively texting on their phones, there is a tendency to develop behavioral addiction to smartphone use, thereby experiencing a decline in academic performance. Given this, active engagement in exercising control and minimal smartphone use may be beneficial for student learning and academic performance.

In sum, based on the results of this meta-analysis, we suggest that education policies, teacher training, cognitive-behavioral interventions, the development of specific teaching and learning practices that address harm reduction and addiction in smartphone use could help students maximize study time and enhance learning effectively.

Conflict of interest statement

We maintain that none of the authors of this paper have a financial obligation or personal relationship with any person(s) or organizations that could inappropriately influence/bias the content of the paper. We do not receive funding from any person(s) or organization to carry out this research.

Given this, we specifically state that "No Competing interests are at stake and there is No Conflict of Interest" with any person(s) or organizations that could inappropriately influence/bias the content of the paper.

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