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Social networking sites use and college students' academic performance: testing for an inverted U-shaped relationship using automated mobile app usage data

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Abstract

With the widespread adoption of social networking sites among college students, discerning the relationship between social networking sites use and college students' academic performance has become a major research endeavor. However, much of the available research in this area rely on student self-reports and findings are notably inconsistent. Further, available studies typically cast the relationship between social networking sites use and college students' academic performance in linear terms, ignoring the potential moderating role of the intensity of social networking sites use. In this study, we draw on contrasting arguments in the literature predicting positive and negative effects of social networking sites use on college students' academic performance to propose an inverted U-shaped relationship. We collected data on social networking sites use by having college students install a tracking app on their smartphones for 1 week and data on academic performance from internal college records. Our findings indicate that social networking sites use indeed exhibits an inverted U-shaped relationship with college students' academic performance. Specifically, we find that spending up to 88.87 min daily on social networking sites is positively associated with academic performance, but beyond that, social networking sites use is negatively associated with academic performance. We discuss the implications of our findings.

Keywords: Social media, Mobile applications, Academic performance, Inverted U-shape, Curvilinear relationship

Introduction

With the widespread adoption of social networking sites among college students, discerning the relationship between social networking sites use and college students' academic performance has become a major research endeavor (Doleck & Lajoie, 2018; Koranteng et al., 2019; Liu et al., 2017; Tafesse, 2020). Numerous studies have been published on this topic to date and the relevant literature is accumulating rapidly (Doleck & Lajoie, 2018; Masrom et al., 2021). However, findings have been highly inconsistent (Astatke et al., 2021), with some studies documenting a negative relationship between

social networking sites use and academic performance (e.g., Junco, 2015; Karpinski et al., 2013; Tafesse, 2020) and others documenting a positive relationship (e.g., Park et al., 2018; Samad et al., 2019; Sarwar et al., 2019).

Notably, much of the available research relies on student self-reports to measure social networking sites use (Astatke et al., 2021; Doleck & Lajoie, 2018). Students are asked to self-report the frequency or duration of their social networking sites use. Because students have been shown to substantially underestimate their social networking sites use, however, self-report data is prone to measurement error, thereby potentially biasing the magnitude and direction of reported findings (Felisoni & Godoi, 2018; Giunchiglia et al., 2018; Wang et al., 2015). To overcome these limitations, researchers have begun to employ software programs and mobile applications that can automatically track the frequency and duration of social networking sites use, which enables precise measurement (e.g., Felisoni & Godoi, 2018; Giunchiglia et al., 2018; Wang et al., 2015). Coupled with the use of institutional records to measure students' academic performance, these latter studies have managed to overcome the measurement difficulties afflicting self-reported data. However, even these more recent efforts typically cast the relationship between social networking sites use and academic performance in linear terms. That is, social networking sites use is proposed to linearly co-vary with academic performance.

In the current study, we maintain that the linear relationship typically tested in the literature may not fully capture the complex interplay between social networking sites use and academic performance. We contend that the relationship between social networking sites use and academic performance can be characterized as an inverted U-shape. The fact that both positive and negative effects have been reported in the literature (Astatke et al., 2021; Masrom et al., 2021; Raza et al., 2020) points to the possibility that social networking sites use might produce both positive and negative academic outcomes depending on the intensity of their use. For instance, heavy use of social networking sites can be detrimental to academic performance by having college students reallocate time away from academic work or requiring them to multi-task (Alt, 2015; Junco, 2015; Kapriniski et al., 2013; Marker et al., 2018). Modest use of social networking sites, on the other hand, might contribute positively to academic performance by facilitating collaborative learning and offering informational and entertainment values (Al-Qaysi et al., 2021; Hoi, 2021; Lampe et al., 2015; Lemay et al., 2020; Raza et al., 2020). Prior studies have suggested that not all social networking sites use is maladaptive (Lemay et al., 2020).

We combine the positive and negative effects of social networking sites use reported in the literature into an inverted U-shaped relationship by positing the intensity of social networking sites use as a moderating variable. The inverted U-shaped model fits the data better than the linear model, highlighting the crucial role that the intensity of social networking sites use plays in shaping the relationship between social networking sites use and college students' academic performance. By demonstrating that social networking sites can be associated with both negative and positive academic outcomes depending on their intensity of use, our approach serves to reconcile empirical inconsistencies observed in the literature (Astatke et al., 2021). Further, the findings serve to synthesize the contrasting theoretical perspectives offered in the literature––some arguing for a positive effect of social networking sites use, others arguing for a negative effect––into a coherent curvilinear relationship. Overall, our findings contribute to a more nuanced

understanding of the relationship between social networking sites use and college students' academic performance.

Literature review

Social networking sites: an overview

Ellison and Boyd (2013) defined social networking sites as "a networked communication platform in which participants (1) have uniquely identifiable profiles that consist of user-supplied content, content provided by other users, and/or system-level data; (2) can publicly articulate connections that can be viewed and traversed by others; and (3) can consume, produce, and/or interact with streams of user-generated content provided by their connections on the site" (p. 180). This definition emphasizes three defining features of social networking sites.

First, social networking sites allow users to create uniquely identifiable profiles animated by both user- and system-supplied information. Examples of these user- and system-supplied information that define a user's profile on social networking sites include biographic details, self-descriptions, photos, interests and activities (Ellison & Boyd, 2013). These pieces of information facilitate online peer-to-peer networking by revealing users' identities (Kane et al., 2014; Zhang & Leung, 2015). Second, social networking sites allow users to articulate connections that can be viewed and traversed by others. These connections are typically manifested in the form of friends lists, followers lists, group memberships, liked pages and so on. These publicly stated connections enable users to discern other users' social connections, further facilitating peer-to-peer networking activities on the platforms (Ellison & Boyd, 2013). Zhang and Leung (2015) maintained that the ability to traverse and view other users' connections and activities is an innovative feature of social networking sites that is virtually unknown in traditional forms of communication. Finally, social networking sites allow users to consume, produce and interact with the streams of user-generated content provided by their connections (Kane et al., 2014). Users create their content by combining text, images, videos, emoticons, animations and so forth—all languages of social networking sites (Dumpit & Fernandez, 2017). As well as sharing their own content, users can consume and interact with other users' content, by liking, sharing and commenting on them, thereby creating a dynamic and continuous cycle of online interaction and engagement, which is essential to the vitality of social networking sites (Masrom et al., 2021; Smith, 2017).

College students rely heavily on social networking sites for their daily communication, entertainment and information needs (Ansari & Khan, 2020; Doleck et al., 2018; Ifinedo, 2016; Lemay et al., 2020). Studies tracking college students' social media habits have indicated that students spend a significant amount of time daily, switching between multiple social networking sites such as Facebook, Twitter, Instagram, YouTube and Snapchat (Alhabash & Ma, 2017; Dumpit & Fernandez, 2017; Felisoni & Godoi, 2018; Smith, 2017; Wang et al., 2015). College students use social networking sites for various purposes including opinion sharing, information acquisition, entertainment, self-documentation, self-expression and social interactions, among others (Alhabash & Ma, 2017; Chawinga, 2017; Lemay et al., 2020). Educational use of social networking sites, such as accessing course information, organizing group work, receiving feedback and interacting

with instructors, have also been noted in the literature (Al-Qaysi et al., 2021; Al-Rahmi et al., 2020; Ansari & Khan, 2020; Hoi, 2021; Raza et al., 2020; Smith, 2017).

Review of the empirical literature

The pervasive adoption and use of social networking sites among college students have spurred a flurry of research into how social networking sites use influences academic performance (Masrom et al., 2021). Several studies have been published and the relevant literature has accumulated over the past years. In response, several systematic literature reviews (e.g., Astatke et al., 2021; Doleck & Lajoie, 2018; Masrom et al., 2021) and meta-analyses (e.g., Huang, 2018; Liu et al., 2017) have been carried out. Yet, these reviews and meta-analyses document major inconsistencies in the literature. Despite the expanding literature and efforts to consolidate it, results remain inconsistent. Below, we present a summary of representative works.

In an early study, Karpinski et al. (2013) looked at the relationship between social networking sites use and academic performance among college students in the USA and Europe. They find that social networking sites use is negatively associated with college students' academic performance both in the US and European samples, but the association is stronger for the US sample. In another widely cited study, Junco (2015) investigated the relationship between social networking sites use and college students' academic performance by considering class standing as a moderating variable. The researcher finds that freshmen suffered the highest decline in academic performance from increased social networking sites use, while seniors were less severely affected. Recently, Tafesse (2020) finds that increased use of social networking sites is negatively associated with academic performance both directly, and indirectly, via decreased student engagement.

In a study that examined the relationship between social networking sites use and student engagement among Korean college students, Park et al. (2018) reported a positive relationship. But when used for purposes such as image management and social pressure, social networking sites use tends to reduce student engagement. Similarly, Sarwar et al. (2019) find that social networking sites use contributes positively to college students' academic performance both directly, and indirectly, by enabling collaborative learning. Finally, Al-Rahmi et al. (2020) find that college students' increased perceptions of social presence, interest, perceived enjoyment and perceived usefulness of social networking sites are positively associated with collaborative learning.

Despite their contributions to a deeper understanding of how social networking sites use influence academic performance, the reviewed studies relied on student self-reports to measure both social networking sites use and academic performance, which might introduce measurement errors by, for instance, eliciting socially desirable answers or artificially inflating the correlation among measured variables due to common method bias (Podsakoff et al., 2003). To overcome these measurement issues, researchers have begun to deploy software programs and mobile applications that are installed on students' PCs or smartphones to automatically track the frequency and duration of social networking sites use (Felisoni & Godoi, 2018; Giunchiglia et al., 2018; Wang et al., 2015). Increasingly also, researchers are obtaining data about students' academic performance from institutional records instead of student self-reports. Collecting data from multiple

sources is one of the most effective procedural remedies against common method bias (Podsakoff et al., 2003).

Pertinent among this latter group of studies is a pioneering investigation by Wang et al. (2015), which tracked the social media behavior of college students in the USA for one week by having them install a software program on their PCs and smartphones. The researchers subsequently divided their sample into heavy versus light users and compared their perceptions of how social networking sites use affect academic performance. Their findings suggest that heavy users felt more distracted and fell behind on schoolwork relative to light users. Although the researchers did not formally test the moderating effect of the intensity of social networking sites use, their findings reveal sharp differences in perceptions between heavy and light users.

In a more recent study, Giunchiglia et al. (2018) measured social networking sites use by having college students install a mobile usage tracking app on their devices and run it for a week. In addition, they employed time diaries to measure social networking sites use during lecture hours and study time. Their findings indicate that increased social networking sites use during lecture hours and study time is negatively predictive of semester GPA. Conversely, social networking sites inactivity during lecture hours and study time is positively predictive of semester GPA. In another study, Felisoni and Godoi (2018) tracked college students' overall smartphone use for one week using a tracking app. They find a negative relationship between increased smartphone use and semester GPA.

Following the latter group of studies, we measured social networking sites use by having college students install a mobile usage tracking app on their smartphones and run it for one week and students' academic performance using semester and cumulative GPAs obtained from internal college records. However, we departed from previous studies by testing for an inverted U-shaped relationship. Extant studies typically model the relationship between social networking sites use and academic performance linearly, which ignores the potential moderating role of the intensity of social networking sites use. By testing for an inverted U-shaped relationship, we demonstrate the moderating role of the intensity of social networking sites use in the relationship between social networking sites use and college students' academic performance.

Theoretical perspectives

Two main theoretical perspectives are put forth in the literature to explain the relationship between social networking sites use and college students' academic performance: the time-displacement/multitasking argument; and the collaborative learning argument.

The first perspective holds that social networking sites distract students from attaining deeper engagement with their academic study (Alt, 2015; Astatke et al., 2021; Cao et al., 2018; Doleck et al., 2018; Junco, 2012; Karpinski et al., 2013). Two important theoretical mechanisms are proposed to explain this negative relationship: time displacement and multitasking. The time displacement explanation is based on the notion that time is inelastic and daily human activities are scheduled around a fixed, 24-h cycle. The introduction of a new activity, therefore, comes at the expense of other established activities as less time would be available for them (Nie, 2001; Tokunaga, 2016). According to the time displacement argument, time spent on social networking sites is time reallocated

from important academic activities such as studying, attending classes or doing assignments (Doleck et al., 2018; Tafesse, 2020). By forcing the reallocation of time from academically productive to academically nonproductive tasks, social networking sites use is argued to adversely affect students' academic performance (Alt, 2015; Cao et al., 2018; Tafesse, 2020).

The multitasking explanation, on the other hand, suggests that attending to two or more tasks at the same time can result in cognitive overload, which reduces students' ability to correctly and completely execute the tasks at hand (Junco, 2012; Junco & Cotton, 2012; Karpinski et al., 2013; Lau, 2017). The multitasking argument implies that trying to accomplish academic tasks while staying on social networking sites reduces students' attention span and their cognitive ability to effectively engage in academic work, thereby adversely affecting their academic performance (Junco, 2012; Karpinski et al., 2013; Lau, 2017; Lepp et al., 2015).

The second perspective holds that social networking sites can be harnessed to facilitate collaborative learning and motivate students into a more constructive learning engagement (Eid & Al-Jabri, 2016; Hoi, 2021; Lampe et al., 2015; Liu et al., 2017; Raza et al., 2020). Researchers subscribing to this perspective point to the fact that the interactive and social features of social networking sites can be utilized to exchange information, arrange group work, receive feedback and facilitate interaction with instructors (Al-Rahmi et al., 2020; Ansari & Khan, 2020; Chawinga, 2017; Lampe et al., 2015; Smith, 2017). Social networking sites emphasize collaboration and group engagement as opposed to individual learning, thereby allowing students to become active partners and socially engaged in the process of exchanging information, discovering knowledge and solving problems, which should increase their overall learning and academic performance (Ansari & Khan, 2020; Astatke et al., 2021; Lampe et al., 2015; Sarwar et al., 2019; Smith, 2017).

With the growing role of social networking sites as a platform for opinion sharing and information exchange at a societal level (Ellison & Boyd, 2013), exposure to social networking sites can further widen students' perspectives and introduce them to diverse worldviews (Alloway et al., 2013; Chawinga, 2017; Park et al., 2018). Social networking sites could also offer students relief from demanding academic tasks by availing entertaining content, such as funny videos, jokes and memes, which can increase their motivation for subsequent tasks (Ansari & Khan, 2020; Eid & Al-Jabri, 2016; Phua et al., 2017; Raza et al., 2020).

We draw on the two contrasting perspectives presented above to propose an inverted U-shaped relationship between social networking sites use and college students' academic performance. The proposed model anticipates a positive relationship between social networking sites use and academic performance when the intensity of social networking sites use is low and a negative relationship when the intensity of social networking sites use is high.

Methodology

Sampling and data collection

The current study was carried out at a large public university in an Eastern African country in 2019. The study targeted undergraduate students studying business and economics

subjects. Business and economics students were chosen for the simple reason that the researchers involved in the study were affiliated with the Business and Economics College. The necessary ethical clearance was obtained from the Office of the Vice-Dean to conduct the study.

Data on students' social networking sites use was collected by asking voluntary students to install "App Usage"—a freely available mobile usage tracking app—on their smartphones in the Spring 2019 semester. Although we evaluated several candidate mobile usage tracking apps for the purpose of our study, we settled on App Usage for two reasons. First, App Usage offers an accurate measurement of users' smartphone activities. We installed App Usage on our smartphones, personally checked its accuracy and we were satisfied with the result. Second, App Usage has an intuitive and convenient feature for downloading and sharing one's app usage history either via email or messaging apps. Because usage history is rendered in a CSV file format, it facilitates faster data capture and processing. An example of custom reports produced by App Usage is presented in the Appendix.

Due to the sensitivity of the data we were after, we resorted to a snowball approach to recruit participants. We start by recruiting an initial batch of students based on personal rapport and solicited their voluntary participation. We then asked this initial batch to recruit additional participants. Through this process, we recruited about 51 voluntary participants. To minimize the effect of social desirability bias, we excluded students attending any one of our classes. Subsequently, we familiarized the participants with the basic functionality of App Usage and asked them to install it on their smartphones. To increase the number of valid responses from the participants, we took several confidence-building steps. First, we limited the applicable usage history to only one week. Second, we excluded weekends since social media use during weekends can be particularly personal relative to weekdays. Likewise, to minimize the potential impact of installing App Usage on students' smartphone habits, we let the participants run App Usage for three weeks before asking them to submit their usage history in the fourth week. Further, we let students install App Usage after three weeks into the Spring semester. This allowed us to avoid tracking students' smartphone activities during exam periods, which might underreport their smartphone behavior.

Eventually, 40 students submitted valid app usage data. The remaining 11 students failed to send in their usage data despite our best efforts. Although relatively small, the final sample (N = 40) was representative of the student population in terms of departmental affiliation (accounting = 47%; management = 28%; marketing = 25%), gender-mix (male = 60%; female = 40%) and academic year (second year = 62%; third year = 38%). Notably, first-year students were underrepresented in our data. This is because the initial batch of participants we approached were all second-and third-year students. However, the departmental affiliation and gender proportion in the data map well to the departmental affiliation and gender proportion of the student population. Table 1 summarizes the sample characteristics.

Measurement of variables

The usage history submitted by the students contained details including the names of the mobile apps they used, the amount of time they spent on each mobile app and the

Table 1 Sample characteristics

Sample characteristics	N (%)
Gender	
Male	24 (60%)
Female	16 (40%)
Department	
Accounting	19 (47%)
Management	11 (28%)
Marketing	10 (25%)
Academic year	
Second-year	25 (63%)
Third-year	15 (39%)

start and end dates of the usage history. We constructed two relevant variables from this data. The first was daily average minutes spent on social networking sites, which was used to measure the intensity of students' social networking sites use (Felisoni & Godoi, 2018; Giunchiglia et al., 2018). The second variable was daily average minutes spent on smartphone, which was used to measure the amount of time students spent on their smartphones overall. This second variable was used as a control variable.

In order to construct daily average minutes spent on social networking sites, we first had to identify those applications that would qualify as social networking sites. For this purpose, we turned to the definition by Ellison and Boyd (2013) discussed in "Social networking sites: An overview". We analyzed the usage history of each student and identified those mobile apps that offer social networking affordances as explicated in Ellison and Boyd's definition. This process resulted in the identification of about 24 mobile apps, many of them household names around the world and their official variants, such as Facebook (Facebook Lite), Twitter, Instagram, YouTube (YouTube Go), Messenger (Messenger Lite, + Messenger), Telegram (Telegram+ , Telegram X), IMO, WhatsApp, Viber and Google+ . Some of the less-known names we came across include VidMate, Mobogram and Russogram. Our coding scheme is also consistent with previous categorization of social networking sites. For instance, Smith (2017) identified several social networking sites used in undergraduate learning, many of these sites are included in our coding.

Data on students' academic performance were collected from the Office of the Vice-Dean, which is responsible for storing students' academic records at the college level. We gathered semester and cumulative GPAs. Both GPAs were measured on a four-point scale (0.0 to 4.0). We also gathered information about participants' departmental affiliation, academic year and gender from the same official source. Table 2 reports the descriptive statistics and pairwise correlation of the measured variables.

Analysis strategy

Traditionally, an inverted U-shaped relationship is empirically established by adding a squared term to the predictor variable of interest—in our case, social networking sites use—to a standard linear regression equation, as shown below:

Table 2 Descriptive statistics and pairwise correlation of study variables

Variables	Mean	St. dev	Min	Max	(1)	(2)	(3)
(1) Semester GPA	3.24	0.52	1.46	4.00	1		
(2) Daily average minutes spent on social networking sites	86.28	64.60	5.61	280.50	− 0.457***	1	
(3) Daily average minutes spent on social networking sites squared	11,512.73	17,461.01	31.53	78,680.25	− 0.554***	0.949***	1
(4) Daily average minutes spent on smartphone	257.45	111.635	26.97	479.39	− 0.188n.s	0.632***	0.588***

***P < .01; n.s. = not significant

$$y_i = \beta_0 + \beta_1 X_i + \beta_2 x_i^2 + \beta_j Z_{ij} + \varepsilon_i \quad (1)$$

where y_i is the semester GPA for student$_i$; X_i is the daily average minutes spent on social networking sites by student$_i$; x_i^2 is the squared term of daily average minutes spent on social networking sites by student$_i$; Z_{ij} is the $j's$ control variable for student$_i$ including daily average minutes spent on smartphone, gender, academic year and departmental affiliation; β_0, β_1,..., β_j are parameters to be estimated; and ε_i is a normally distributed error term.

If β_2 from Eq. 1 is negative and statistically significant, an inverted U-shaped relationship can be claimed. However, this traditional approach has come under growing criticism for being simplistic and lacking in rigor (Haans et al., 2016; Simonsohn, 2018). Lind and Mehlum (2010) proposed a stricter approach that requires three necessary and sufficient conditions for establishing an inverted U-shaped relationship. The first condition is β_2 from Eq. 1 should be negative and statistically significant. The second condition is the turning point in Eq. 1 should fall within the data range (i.e., between the minimum and maximum values of the dependent variable). The turning point is arrived at by taking the first derivative of Eq. 1 and setting it to zero, which yields $-\beta_1/2\beta_2$. The third and final condition is the slope at the lower half of the data should be positive and statistically significant and the slope at the upper half of the data should be negative and statistically significant. This condition can be tested by dividing the dataset into two parts, typically by using the turning point as a cutoff point, and estimating two separate linear regression equations for each part of the dataset (Simonsohn, 2018).

In addition to Lind and Mehlum's (2010) three conditions, one also needs to establish that the quadratic regression model fits the data better than the linear model. If adding the squared term to the linear model leads to a significant improvement in model fit, as measured by a statistically significant R^2 change, for instance, the quadratic regression model should be retained (Weisberg, 2005). Otherwise, it has to be rejected in favor of the more parsimonious linear regression model. We analyzed the data according to the three conditions outlined above.

Results

We started off our analysis by estimating the linear regression model. To correct for heteroscedasticity, we reported White's heteroscedastic consistent standard errors (White, 1980). The linear regression model was statistically significant ($F = 5.844$;

Table 3 Estimation result of the linear regression model

Variables	Unstandardized coefficients	Std. error	Sig. level
Daily average minutes spent on social networking sites	− 0.0041	0.002	0.014
Daily average minutes spent on smartphone	0.0002	0.001	0.787
Gender (male = 1, female = 0)	0.438	0.137	0.001
Academic year (second year = 0, third year = 1)	0.079	0.158	0.614
Department			
Accounting dummy (reference category)	–	–	–
Management dummy	0.168	0.151	0.265
Marketing dummy	0.286	0.212	0.176
Intercept	3.136	0.207	0.000

Model summary: No of observations = 40, $R^2 = 0.40$, F = 5.84, p < 0.000

Table 4 Estimation result of the quadratic regression model

Variables	Unstandardized coefficients	Std. error	Sig. level
Daily average minutes spent on social networking sites	0.0083	0.003	0.002
Daily average minutes spent on social networking sites squared	− 0.0000467	0.000	0.000
Daily average minutes spent on smartphone	− 0.0001	0.001	0.868
Gender (male = 1, female = 0)	0.477	0.111	0.000
Academic year (second year = 0, third year = 1)	0.015	0.168	0.929
Department			
Accounting dummy (reference category)	–	–	–
Management dummy	0.244	0.141	0.083
Marketing dummy	0.588	0.221	0.008
Intercept	2.584	0.219	0.000

Model summary: No of observations = 40, $R^2 = 0.61$, F = 12.75, p < 0.000

$p < 0.01$), attaining $R^2 = 0.401$ and adjusted $R^2 = 0.293$. Likewise, the regression coefficient for daily average minutes spent on social networking sites was negative and statistically significant ($\beta_1 = -0.004$; $p < 0.01$). Table 3 reports the estimation results of the linear regression model.

Second, we estimated the quadratic regression model (Eq. 1). As in the linear model, we reported White's heteroscedastic consistent standard errors. The quadratic regression model was also statistically significant ($F = 12.75$; $p < 0.01$). It attained $R^2 = 0.609$ and adjusted $R^2 = 0.524$. The *F-change* from the linear model ($F_{lin} = 5.844$; $p < 0.01$) to the quadratic model ($F_{qdr} = 12.75$; $p < 0.01$) was statistically significant at $p < 0.01$. We, therefore, retained the quadratic regression model as it offered a better fit to the data than the linear model (Weisberg, 2005). Table 4 reports the estimation results of the quadratic regression model.

Importantly, the squared term for the daily average minutes spent on social networking sites in the quadratic regression model was negative and statistically significant ($\beta_2 = -0.0000467$; $p < 0.01$). This result satisfied the first condition of Lind and Mehlum's (2010) test, thereby offering initial evidence for an inverted U-shaped relationship between social networking sites use and academic performance.

Table 5 Estimation results of the linear regression model for the low user group

Variables	Unstandardized coefficients	Std. error	Sig. level
Daily average minutes spent on social networking sites	0.005	0.003	0.103
Daily average minutes spent on smartphone	− 0.000	0.001	0.986
Gender (male = 1, female = 0)	0.381	0.149	0.011
Academic year (second year = 0, third year = 1)	0.202	0.247	0.413
Department			
Accounting dummy (reference category)	–	–	–
Management dummy	0.134	0.191	0.482
Marketing dummy	0.351	0.301	0.244
Intercept	2.770	0.224	0.000

Model summary: Number of observations = 25, $R^2 = 0.396$, F = 2.898, $p < 0.037$

Table 6 Estimation results of the linear regression model for the high user group

Variables	Unstandardized coefficients	Std. error	Sig. level
Daily average minutes spent on social networking sites	− 0.0097	0.002	0.000
Daily average minutes spent on smartphone	0.0005	0.315	0.753
Gender (male = 1, female = 0)	0.461	0.228	0.043
Academic year (second year = 0, third year = 1)	− 0.137	0.200	0.494
Department			
Accounting dummy (reference category)	–	–	–
Management dummy	0.444	0.298	0.137
Marketing dummy	0.556	0.408	0.173
Intercept	3.891	0.579	0.000

Model summary: No of observations = 15, $R^2 = 0.74$, F = 10.49, $p < 0.002$

The turning point (i.e., $-\beta_1/-2\ \beta_2 = -0.0083\ /-2 \times 0.0000934$) occurred at 88.87 min, which is approximately one and half hours of daily average social networking sites use. This turning point lies well within the data range for daily average minutes spent on social networking sites (minimum daily average minutes spent on social networking sites = 5.62 min, maximum daily average minutes spent on social networking sites = 280.5 min), hence satisfying the second condition of Lind and Mehlum's (2010) test.

To test the third condition, we grouped the students into two: low users (n = 25) and high users (n = 15). The turning point was used to create the two groups (i.e., students who spent a daily average of 88.87 min or less were categorized into the low user group; students who spent a daily average of 88.87 min or more were categorized into the high user group). Subsequently, we estimated two linear regression equations for each group. The estimation results are summarized in Tables 5 and 6. The slope for the low user group was positive and statistically significant ($\beta_1 = 0.005$; $p < 0.1$), whereas the slope for the high user group was negative and statistically significant ($\beta_1 = -0.0097$; $p < 0.01$). Because of the limited observation in both the low and high user groups, we find it reasonable to reject the null hypothesis at $p < 0.1$. The statistically significant and positive slope for the low user group and the statistically

significant and negative slope for the high user group satisfied the third and final condition of Lind and Mehlum's (2010) test.

To summarize, we find strong evidence for an inverted U-shaped relationship between college students' social networking sites use and academic performance. We should further note that we conducted regression diagnostics (e.g., QQ plots, residual plots) for all estimated models and found that the models were well-behaved. Figure 1 visualizes the regression plots for the linear and quadratic regression models.

Robustness check

We implemented a robustness check to examine whether the inverted U-shaped relationship holds under different specifications of the dependent variable. Specifically, we replaced semester GPA with cumulative GPA as the dependent variable. While semester GPA captures academic performance in a single semester, cumulative GPA captures academic performance for several semesters. Therefore, cumulative GPA offers a more stable measure of academic performance. The results from the main model were fully replicated when cumulative GPA was used as the dependent variable. Specifically, the quadratic regression model fit the data better than the linear model ($R^2_{lin} = 0.3$ vs. $R^2_{qdr} = 0.39$; $F_{lin} = 3.57$, $p < 0.01$ vs. $F_{qdr} = 5.34$, $p < 0.01$). The *F-change* was significant at $p < 0.05$. As in the case of semester GPA, the squared term for daily average social networking sites use was negative and statistically significant ($\beta_2 = -1.21$; $p < 0.05$). Finally, the linear regression coefficient for the low user group was positive and statistically significant ($\beta_1 = 0.29$; $p < 0.1$), while it was negative and statistically significant for the high user group ($\beta_1 = -0.62$; $p < 0.01$). Overall, the results from the semester GPA model were fully replicated when cumulative GPA was employed as the dependent variable, suggesting that the inverted U-shaped relationship remained robust to a different measure of academic performance.

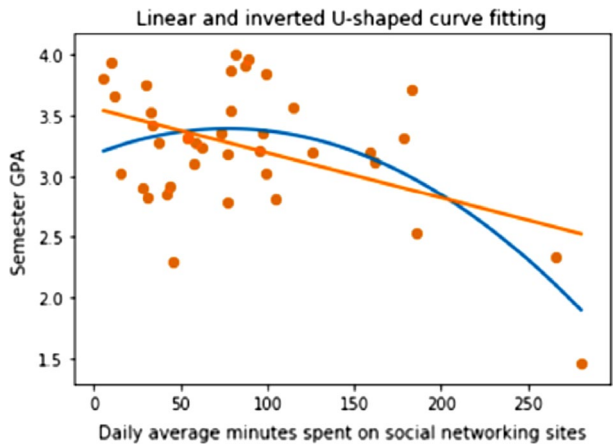


Fig. 1 Regression plots

Discussion

The pervasive adoption of social networking sites among college students has spurred a stream of research into the implications of social networking sites use for college students' academic performance (Doleck & Lajoie, 2018; Koranteng et al., 2019; Masrom et al., 2021). Reported findings have been highly inconsistent, however, with some studies reporting negative relationships and others reporting positive relationships (Astatke et al., 2021; Masrom et al., 2021). Against this backdrop, we proposed and found support for an inverted U-shaped relationship. Following recent advances in the literature (Felisoni & Godoi, 2018; Giunchiglia et al., 2018), we measured social networking sites use with the help of a tracking app installed on students' smartphones. Further, we measured students' academic performance using semester and cumulative GPAs obtained from internal college records. By employing a combination of automatically tracked and institutional data, we avoided the measurement error common in self-reported data (Podsakoff et al., 2003).

Our main finding reveals that the inverted U-shaped relationship fits the data better than the linear relationship. The turning point on the inverted U-shaped regression curve occurred at 88.87 min, suggesting that spending up to 88.87 min daily on social networking sites (about an hour and a half) is positively associated with students' academic performance, while spending more than 88.87 min daily on social networking sites is negatively associated with students' academic performance. This finding was robust to an alternative specification of academic performance.

It thus appears that, when used modestly, social networking sites are positively associated with students' academic performance. Modest use is less likely to interfere with students' academic performance as they will be forced neither to reallocate time away for academic tasks nor to multi-task (Chawinga, 2017; Wang et al., 2015). In fact, modest use of social networking sites might boost students' academic engagement (Al-Rahmi et al., 2020; Masrom et al., 2021). For instance, social networking sites have been shown to facilitate collaborative learning, where students engage in socially interactive learning by completing group work, receiving feedback, sharing course material and interacting with each other and their instructors (Al-Qaysi et al., 2020; Eid & Al-Jabri, 2016; Hoi et al., 2021; Lampe et al., 2015). Similarly, social networking sites offer students access to information and entertaining content that might contribute to improved academic performance (Alloway et al., 2013; Ansari & Kahn, 2020; Lepp et al., 2015; Masrom et al., 2021; Raza et al., 2020). This last point is particularly poignant in the national context of our study, where the media infrastructure is neither well developed nor widely accessible to satisfy college students' demand for information and entertainment (Tafesse, 2020). Social networking sites thus double as a source of information and pastime for the college students in our sample (Alhabash & Ma, 2017; Chawinga, 2017).

In contrast, heavy use of social networking sites can interfere with students' academic activities (Koranteng et al., 2019; Tafesse, 2020). With heavy use, students will be forced either to divert time away from crucial academic tasks or to multi-task, which will eventually hamper their academic performance (Kapriniski et al., 2013; Lepp et al., 2015). In fact, heavy social networking sites use can degenerate into compulsive behavior, such as excessive use and addiction, which can detriment not only students' academic

performance but also their overall well-being (Alt, 2015; Cao et al., 2018; Hsiao et al., 2017; Masrom et al., 2021).

Overall, our work contributes to a more nuanced understanding of the relationship between social networking sites use and academic performance among college students. The inverted U-shaped relationship that we proposed and validated serves to reconcile the empirical inconsistencies observed in the literature in terms of positive and negative effects of social networking sites use (Astatke et al., 2021; Masrom et al., 2021). As our findings demonstrate, social networking sites can produce both positive and negative academic outcomes depending on the intensity of their use. What is crucial to the relationship is the intensity of use, which can easily be captured by an inverted U-shaped model.

Finally, our study comes with a set of limitations that must be considered while interpreting the findings. First, the study relied on a small set of observations sampled using a snowball approach. As such, the sample may not offer an accurate representation of the total student population. The personal and highly sensitive nature of the data we gathered meant that we had to settle with the small number of participants we were able to recruit. However, the sample size we used is not unusual for studies of this nature. For instance, Felisoni and Godoi's (2018) study, which tracked college students' cellphone use in Brazil, was based on 42 observations. Second, we exclusively studied business and economics students. Since students from other disciplines were not included in our study, the findings may not extend to these other disciplines. Third, our sample is taken from a setting that has its own peculiarities. For instance, students at public universities in our setting live on campus for the entire academic year, have access to free WIFI connection and are connected to the internet almost exclusively by way of their smartphones. The students thus connect to social networking sites—and the internet more generally—at no personal cost to them, which might incentivize heavier use. Moreover, the mainstream media infrastructure in the country is rather underdeveloped, which amplifies the informational and entertainment value of social networking sites for college students. These combinations of factors must be considered when efforts are made to extend the findings to new settings.

Conclusion

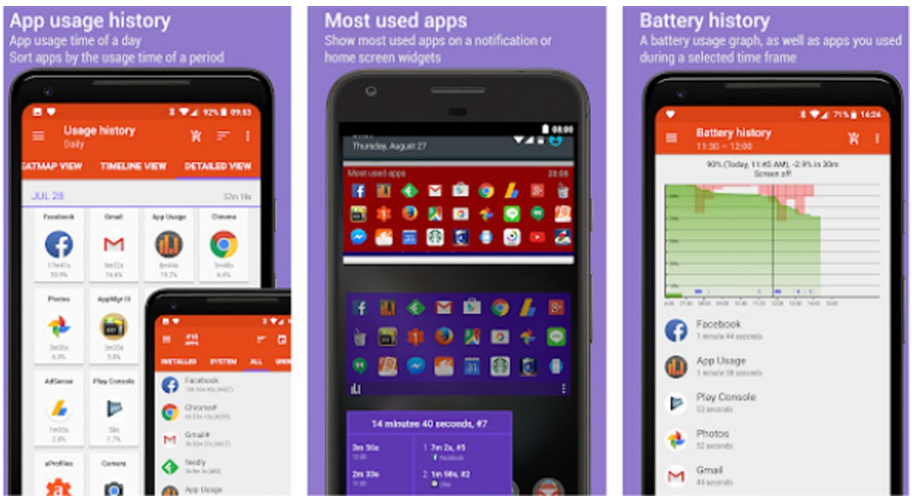
With the pervasive adoption and use of social networking sites among college students, probing their relationship with college students' academic performance has become an important research priority. Building on the extant literature, we proposed and validated an inverted U-shaped relationship between social networking sites use and college students' academic performance. In so doing, we departed from the more traditional approach that casts the relationship between the two in linear terms.

As our findings suggest, moderate use of social networking sites is positively associated with academic performance, while heavy use is negatively associated with academic performance. These findings highlight the crucial role that the intensity of social networking sites use play in shaping the influence of social networking sites on college students' academic performance.

To our knowledge, our study is the first to test and find support for an inverted U-shaped relationship between social networking sites use and college students'

academic performance. As such, the proposed model should be validated using fresh data, preferably from new contexts, to develop further confidence in the findings. With further validation, the findings can help in the continued effort to harness social networking sites for productive academic purposes in higher education settings (Masrom et al., 2021; Smith, 2017).

Appendix: Illustration of custom reports produced by App Usage



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Availability of data and materials
No data will be publicly available for this study since the data was collected after assuring students that their data will not be publicly shared.

Declarations

Competing interests
The authors declare that they do not have any competing interest.

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