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Problem Smartphone Use, Executive Function, and Academic Achievement of STEM Undergraduate Students

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***Abstract*—Smartphone use has become ubiquitous among college students, with several reports suggesting that students spend over six hours per day on their devices. However, the potential effects of extended engagement with of smartphones on cognitive ability and academic achievement are not well understood. In this research we compared problematic self-report smartphone use in two groups of undergraduate students (STEM and humanities). The groups had very similar demographics in terms of age and sex, and similar mean GPA scores. However, there was a strong negative association between problematic smartphone use and GPA in the STEM students, which was not seen in the humanities students. Furthermore, this association in the STEM students was found to be related to self-reported executive functions- impulse control and sustained attention. We speculate that problematic smartphone use may cause academic problems disproportionately for STEM students because it reduces cognitive resources, which are particularly important to achieve higher grades in fields such as science technology engineering, and medicine.**

Keywords*— *smartphone use, internet dependence, STEM, GPA, academic achievement, executive function, impulsivity

I. INTRODUCTION

The development of the internet in the 20th century brought many changes to how people live their lives. However, the smartphone, first released as the iPhone in 2007 [1], has arguably had the largest impact. The penetration and speed of uptake of this technology has been unprecedented. Just 14 years later it was estimated that more than two-thirds of the global population have mobile phones, around 80% of which are smartphones [2].

University students are recognized as being particularly frequent users of the technology, with self-reported smartphone screen-time exceeding six hours per day, or more than one-third of their time awake [3-5]. The majority of this time is spent with messaging and social media apps [6].

This change in how students interact with each other may have indirect effects on their cognitive ability. For example, instant messenger and social media services provide a constant but unpredictable source of alerts, as many students keep their smartphones close by and turned on permanently, leading to sleep-cycle disruption [7]. These effects appear to be substantial, in one study about 36% of college students reporting daytime tiredness due to nighttime smartphone use, with a similar proportion reporting having slept less than 4 hours at least once due to smartphone use [8].

Simply having one's smartphone nearby and turned on has been shown to negatively impact on 'executive' cognitive functions, as people orient their attention to their phones [9]. On the other hand, in people accustomed to using their smartphones regularly (such as college students), being separated from the smartphone for short periods can induce anxiety which in turn negatively impacts on executive cognitive processes [10].

These findings suggest transient influences of smartphone use that temporarily impair executive functions. By 'executive functions' me mean top-down cognitive control abilities, which include cognitive flexibility, working memory and control of impulses [11]. These are the highest level of thinking abilities, and are essential for intelligent, adaptive behavior.

In addition to the transient distracting effect of smartphones on executive cognitive functions, some have argued that the high levels of screen time may have direct and lasting negative impacts on brain and cognitive functioning [12].

This is important in education, as effects on cognitive functioning will impact on how well individuals can benefit from instruction. Executive cognitive functions related to impulse control are related not only to classroom behavior [13], but also achievement more generally. This is shown in the association between better impulse control and higher grades in high school and university [14-15], and by better workplace performance [16]. Clearly any substantial changes to behavior, that impact on brain and cognitive functioning, as has been seen with the adoption of smartphones, has the potential to impact academic performance.

This may be particularly important for STEM students. Research has shown that cognitive ability is a larger factor in academic attainment in fields such as engineering, than it is for non-STEM studies [17]. The same effect, of cognitive ability being more important for academic achievement in science subjects, compared to arts, has also been observed in high school students [18]. Simply put: having high ability in cognitive tests, such as those of executive functions, is strongly predictive of grades in STEM subjects of adolescents, but it is much less predictive in arts and humanities subjects.

Thus, we hypothesized that heavy use of smartphones could particularly impact university students studying STEM subjects (given that smartphone use is strong distractor of cognitive resources). Furthermore, we hypothesized that this would be related to executive functions such as impulse control and sustained attention.

In the research reported here, we re-analyzed a data set from our previous research which has been made publicly available [19]. We examined how levels of smartphone use are associated with academic achievement of a group of STEM university students, compared to a group of humanities students. We also examined how impulse control and sustained attention may contribute to the associations.

Executive functions can be measured either by cognitive performance tests (derived mainly from neuropsychology), or with self-report questionnaires. We used the latter approach, focusing on impulse control, which also includes the overlapping concept of sustained attention.

II. Method

A. Participants

The raw data analyzed here is publicly available at: http://dx.doi.org/10.23668/psycharchives.2791. That data set contains information on 121 undergraduate students recruited at Universidad San Francisco de Quito in Ecuador. Of those 121, 31 were students of STEM subjects (engineering n = 19, medecine or dentistry n = 6, biology or biochemistry n = 6). The majority (n = 19) were male. We randomly selected a group of 31 humanities students to match the STEM students for sex (i.e, 19 males). These were from a range of majors (psychology n = 16, law n = 6, economics n = 5, international relations n = 3 and other subjects n = 2). The two groups therfore had the exact same male:female ratio. Furthermore, the ages of the two groups were equvilent (STEM mean age = 22.2, SD = 1.5; Humanities mean age = 22.0, SD = 2.3). The groups together should be considered an opportunity sample.

B. Measurments and Assessments

For each participant we analyzed the total grade point average (GPA) as a measure of overall academic achievement. In this university GPA ranges from 0 to 4 (highest). All individual course GPA scores achieved at the university were averaged for each participant.

We also recorded scores on the Mobile Phone Problem Use Scale (MPPUS) [22]. This is a validated measure of behaviors with mobile phones, such as excessive and compulsive use, which could be seen as problematic or likely to lead to addiction. We used a Spanish-language version [23] which has been found to be psychometrically reliable in the context in which we used it [17]. Higher scores indicate more problems with excessive smartphone use.

To measure executive function, we analyzed data from the Barratt Impulsiveness Scale - 15 [24], in a validated Spanish-language version [25]. This 15-item questionnaire measures problems with impulsivity and sustained attention. Statements are endorsed by the participant include 'I act on the spur of the moment' and 'I don't pay attention'. Higher scores indicate worse executive control.

C. Data Analysis

Parametric inferential statistics were used to test null-hypotheses for between-group comparisons and correlations. All statistical tests were two-tailed analyses, with a significance threshold of 0.05.

III. Results

The STEM group scored a mean smartphone use (MPPUS) score of 98.8 (SD = 38.5) which was lower than the humanities group, who scored a mean of 99.9 (SD = 39.2). Though that small difference was not significant ($t(60) = 0.114$, $p = 0.91$). There was also a difference in the proportion in each group who scored in the range indicating dependcence [21]. Of the STEM students, 5/31 (16%) could be considerd dependent, while in the humanities group 7/31 (23%) could be considered dependent. However, the small difference was not significant, X^2 (df = 1) = 0.41, p = 0.52. Nor was there any difference between groups on GPA (STEM mean = 3.1, SD = 0.50; humanities mean = 3.3, SD = 0.37), $t(58) = 1.61$, $p = 0.11$.

Regarding executive control (BIS-15 scores), the STEM student group scored a mean of 33.9 (SD = 6.4), which was significantly higher than the mean score of the humanities students, at 30.5 (SD = 4.4), $t(53.2) = 2.45$, $p = 0.02$. This indicates that the STEM students had worse self-reported executive functions (compared to the humanities students), in particular, impulse control and sustained attention were relatively poor in the STEM group.

In the next stage we explored how smartphone use may be related to GPA. This revealed several significant correlations between problematic smartphone use (MPPUS) scores and GPA. In the full sample, including both STEM and humanities participants, there was a significant negative correlation, $r = -0.33$, $p = 0.01$, indicating that greater problematic smartphone use was linked to lower GPA. This would be considered a 'large' association by standard interpretations of r values [27]. When the STEM students were analyzed independently, the association was even stronger, $r = -0.42$, $p = 0.02$. In the humanities students the association was relatively weak, at $r = -0.26$, $p = 0.17$, and not significant.

In the final step of analysis, we examined a possible mechanism by which smartphone use could be associated with lower GPA in STEM students. As the STEM students had poorer self-reported executive function (BIS-15 scores), and higher cognitive functions appear to be particularly important for academic achievement in STEM [17-18], it may be that individual STEM students with poor executive functioning are more prone to low GPA if they are compulsive users of smartphones. To test this, we repeated the correlations reported above between GPA and problem smartphone use, but we statistically covaried executive function (BIS-15) scores. This allows us to estimate what the correlation values would be, if the participants were not a mix of different executive cognitive abilities.

Interestingly, this removed the statistical association between GPA and smartphone use in the STEM group. With the covariate we found that $r = -0.18$, $p = 0.35$, which is not significant, and substantially lower than it was without the covariate ($r = 0.42$, $p = 0.02$). Adding the BIS-15 scores as a covariate had no observable effect on the statistical association in the humanities group, as the new result indicated that $r = -.24$, $p = 0.22$, which is not much different from the result without the covariate ($r = -0.26$, $p = 0.17$). This indicates that for the STEM students, distractibility, in the form of poor impulse control and sustained attention, is a core component of why GPA is linked to problematic smartphone use.

IV. Discussion and Conclusions

The research reported here aimed to examine the relationship between problematic smartphone use, e.g., excessive use, and academic achievement. In particular, it aimed to examine differences between STEM and non-STEM undergraduate students. We found that there was a large and significant negative association between self-reported problematic smartphone use and GPA in a group of STEM students. This suggests that the students with the highest smartphone use were the worst performing academically. A similar association, though substantially smaller, was observed for the non-STEM (humanities) students. The research is consistent with previous research that has shown that high smartphone use is linked to poor academic achievement [28].

However, the current research adds to what is already known, by showing that the association may be disproportionally larger for STEM students compared to non-STEM students (i.e., those on humanities majors). The association for STEM students, represented in the correlation r value of -0.42, is equivalent to about 18% shared variance between GPA and smartphone use. Another way to think of this is that about 18% of GPA could be predicted from examining scores on the smartphone use questionnaire. In contrast, for humanities students, the equivalent is equivalent figure is only about 7%.

These finding support our first hypothesis, that problematic smartphone use has a greater impact on STEM students than it does on non-STEM students.

Such associations do not allow determination of causality. However, we were able explore one possibility. By using the statistical procedure of covariance, in this case in a partial correlation, we were able to explore whether the smartphone-GPA link in STEM students was dependent on variation in self-reported executive function ability. We found that indeed it was. This suggests that when STEM students have poor executive functions, the extra drain on cognitive resources that results from excessive smartphone use, may have a detrimental effect on their academic grades. Many non-STEM students will not face this additional burden, because of the lower dependence on cognitive ability associated with academic performance in their subjects [17-18].

There is emerging evidence that a principle reason that people develop smartphone dependence may be that it is a generally rewarding experience, which can be become conditioned through basic learning mechanisms [19]. However, once problematic use develops, this places additional burden on cognitive processing through direct and indirect routes.

As mentioned earlier, problematic smartphone use is associated with poor sleep quality in college students [7-8]. Sleep deprivation then produces poorer cognitive processing, particularly for attention [20]. Other indirect effects come from the distraction provided by having a smartphone present [9], and conversely, the anxiety associated with separation from smartphones [10]. Compulsive smartphone use can thus have indirect effects on cognition.

There is also theory and evidence suggesting direct effects [12]. For example, research shows that people use less analytical thinking when they become accustomed to relying on the internet access from smartphones to find information [21]. This could be another reason why smartphone use can be particularly problematic for STEM students, where analytical thinking is an important skill [29].

Thus, we tentatively suggest that STEM students with high and problematic smartphone use may struggle academically because of the indirect (e.g., disturbed sleep, distraction) and possibly direct effects of smartphone use on cognitive resources (e.g., reduction in analytical thinking propensity). This is because cognitive ability has been shown to be much more important for achieving high GPA in STEM subjects, as compared to other non-STEM subjects [17-18]. In non-STEM subjects studied at university level, such as psychology, interpersonal and mood factors may be more important [17].

How could the impact of smartphone dependence on STEM students be reduced? It is debatable that banning smartphones in class would be sufficient, given that some of the impact on performance appears to be chronic, and that smartphone separation is itself associated with reduced cognitive resources. More successful could be programs that attempt to use psychological methods to reduce dependence. These have been found to be effective with adolescents [30]. The authors suggest that tackling compulsive smartphone use, in and out of the classroom, may have beneficial effects of academic achievement.

Some limitations of the current research should be recognized. The sample size is relatively small at 31 participants in each group. However, the research benefited from the fact that these were groups matched for age and sex, such that demographic confounding variables are unlikely to be the cause of the observed effects. Our measure of executive function was also limited, being a self-report questionnaire. Further research could explore the issues with more comprehensive assessments, and perhaps also examine mood and skill development.

Nevertheless, the current suggests some important issues related STEM education at university level. In particular, that STEM students may be disproportionally sensitive to the problems caused by excessive smartphone use, with a noticeable impact on their academic achievement.

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