

Smartphone Addiction, Sleep, and Mental Health: Exploring Causal Pathways and Behavioral Profiles among University Students

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ABSTRACT

The main aim of the research was to explore relationships between smartphone addiction, mental health conditions such as depression, anxiety, and stress, bedtime procrastination, sleep quality, which were measured using standardized scales, and others among university students in Bosnia and Herzegovina. The research consisted of non-parametric statistical testing, clustering analysis, and causal inference techniques to analyze a dataset of approximately 500 participants, collected at International University of Sarajevo (IUS). The analysis was conducted using Python and appropriate libraries.

CCS CONCEPTS

• Applied computing → Law, social and behavioral sciences → Psychology • Human-centered computing → Ubiquitous and mobile computing → Smartphones • Applied computing → Life and medical sciences → Health informatics

KEYWORDS

Smartphone addiction, Mental health, Sleep quality, Non-parametric statistics, Clustering analysis, Behavioral data, University students, Bosnia and Herzegovina

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1 Introduction

Since their emergence in 2007, smartphones have become vital component of daily life worldwide, with global users increasing from 2.1 billion in 2017 to 2.8 billion by 2020 (Amez et al., 2023). Smartphone addiction is an unhealthy behavior that has evolved in the digital age. Mood tolerance, salience, withdrawal, modification, conflict, and relapse are the behavioral characteristics of smartphone addiction (Choi et al., 2015) which has been shown to have a notable correlation to the poor quality of sleep (Yang et al., 2020). Sleep processes are negatively impacted by excessive worry and recurrent thinking (ruminations) brought on by stress and anxiety. Neurotoxicity may result from stress-response system sensitization, and depression may raise the likelihood of sleep disruptions, with evidence of a bidirectional relationship between psychological stressors and sleep disturbance (Kalmbach et al., 2018). Bedtime procrastination, the delay of intended sleep time, is also associated with reduced sleep quality and impaired emotional self-regulation, potentially leading to depression and anxiety (Geng et al., 2021; Zhang & Wu, 2020). This research aims to investigate the relationship between smartphone addiction, various mental health conditions, bedtime procrastination, and sleep quality using standardized scales where appropriate: the Pittsburgh Sleep Quality Index (PSQI) (Carpenter & Andrykowski, 1998), the Smartphone Addiction Scale Short Version (SASSV) (Kwon et al., 2013), the Bedtime Procrastination Score (BPS) (Kroese et al., 2014) and Depression, Anxiety, and Stress Scale (DASS-21) (Lovibond & Lovibond, 1995). Survey data from approximately 500 university students at International University of Sarajevo (IUS) were analyzed in Python through three methodological approaches: non-parametric group comparisons, behavioral clustering, and causal modelling.

2 Group Comparisons

Mann-Whitney U tests were used due to non-normal distribution of the data and they revealed that self-identified addicts reported

significantly higher depression ($r = -0.15$, $p = 0.003$), anxiety ($r = -0.18$, $p < 0.001$), and stress ($r = -0.13$, $p = 0.015$) scores. While effect sizes were small, anxiety showed the strongest association, which suggests a closer link between perceived smartphone addiction and anxious states. Common Language Effect Sizes (CLES) between 56–59% indicated modest but consistent psychological distress differences. When examining daily screen time differences between males and females, no significant difference was observed regarding gender ($U = 30,115$, $p = 0.900$), with a negligible effect size ($r = 0.006$). A marginal trend suggested that females might use social media more ($U = 27,386.5$, $p = 0.052$). However, females showed significantly higher smartphone addiction scores ($U = 23,814.5$, $p < 0.001$, $r = 0.21$), suggesting a modest gender difference.

3 Behavioral Clustering

A hierarchical clustering analysis was applied to uncover distinct profiles. Gower distance and Ward linkage were applied on five features (SASSVscore, PSQIglobalscore, DASS_D, DASS_A, DASS_S), and three distinct clusters were identified (Cluster 1: $n=296$; Cluster 2: $n=149$; Cluster 3: $n=59$, and n indicates the size of each cluster). Cluster 1 exhibited the lowest psychological distress, whereas Cluster 3 showed elevated addiction, poor sleep quality, and greater mental health symptoms. The clustering exhibited modest separation (Silhouette Score = 0.195), which is common for psychological data. A Random Forest Classifier was trained to predict which cluster a new student would belong to, considering their scores on the relevant five features, which could help the identification of students potentially at risk.

4 Causal Modeling

Directed Acyclic Graphs (DAGs) were constructed to model hypothesized pathways: anxiety \rightarrow smartphone addiction \rightarrow bedtime procrastination \rightarrow sleep quality \rightarrow anxiety. Using the DoWhy library with linear regression estimators and adjusting for confounders (such as gender, age, academic year, and others, depending on which estimator and outcome is being tested), several causal effects were estimated:

1. The estimated causal effect of anxiety on smartphone addiction was 0.27, suggesting that a one-unit increase in anxiety results in a 0.27-unit increase in smartphone addiction, on average.
2. Higher smartphone addiction scores causally increased bedtime procrastination, with an estimated effect size of approximately 0.086–0.103, depending on the adjustment set. When adjusting for demographic confounders (gender, age, academic year) in addition to psychological factors, the causal effect slightly decreased (from 0.103 to 0.086), suggesting that demographic variables partially explain the relationship between smartphone use and bedtime procrastination.
3. The causal relationship from bedtime procrastination to poor sleep quality was also positive (casual estimate=0.17),

meaning that, in the data, higher bedtime procrastination causes worse sleep quality.

4. Additionally, sleep quality was found to cause higher anxiety levels (causal estimate: 0.23), closing the circular pathway proposed initially.

All estimated causal effects in each relationship were statistically significant ($p < 0.001$) and, when tested under placebo treatment refutation tests, showed robustness, implying strong validity of the results. These findings suggest that smartphone addiction may lead to increased bedtime procrastination, which subsequently decreases sleep quality and increases anxiety symptoms. Understanding these cause-and-effect relationships could help understand how to help university students in regards to smartphone addiction (e.g.: having intervention programs that aim to reduce anxiety and improve sleep hygiene).

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