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Examining the relationship between problematic internet use and impulsivity in adolescents and young adults: a longitudinal study

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EXAMINING THE RELATIONSHIP BETWEEN PROBLEMATIC INTERNET USE AND IMPULSIVITY IN ADOLESCENTS AND YOUNG ADULTS: A LONGITUDINAL STUDY

by

RASIKA SINGH

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Approved by

First Reader ______________________________

Matthew D. Layne, Ph.D.
Associate Professor of Biochemistry

Second Reader ______________________________

Meredith Gansner, M.D.
Child Psychiatrist
Cambridge Health Alliance, Harvard Medical School

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EXAMINING THE RELATIONSHIP BETWEEN PROBLEMATIC INTERNET USE AND IMPULSIVITY IN ADOLESCENTS AND YOUNG ADULTS: A LONGITUDINAL STUDY

RASIKA SINGH

ABSTRACT

Background: With the ubiquity of digital media and smartphone use in the lives of adolescents and young adults, it is critical to determine the effects that excessive amounts of internet use may have on this mentally developing population. Problematic internet use (PIU) is defined as excessive or uncontrolled internet use and is often associated with psychiatric impairment or distress. With adolescents who suffer from PIU likening the experience to common psychiatric disorders such as substance use or gambling disorders, researchers are exploring characteristics that PIU may have in common with these existing psychiatric disorders such as impulsivity, anxiety, and depression. This study uses novel smartphone app-based ecological momentary assessment to assess whether there is an association between in-the-moment reports of PIU and impulsivity in adolescents and young adults, and secondarily to examine the relationships between PIU and psychiatric symptoms such as anxiety and depression, as these are factors associated with impulsivity. We hypothesize that the adolescents and young adults in our study population will have a significant relationship between daily PIU-SF-6 and BIS-BRIEF scores, suggesting a temporal relationship between severity of PIU and impulsivity. As PIU habits have also been suggested to develop as a way to manage uncomfortable affective symptoms, we hypothesize that the adolescents and young adults in our study population will also have significant relationships between PIU-SF-6 scores and both PHQ-8 and GAD-7 scores. Contrasting with prior methodologies used in PIU studies, ecological momentary assessment allows for an increased ability to capture rapid shifts in mood and behavior states in a teenager's home environment. If adolescents and young adults are reporting higher impulsivity in the same moments where they are reporting higher levels of PIU, it may, in part, explain how device separation leads to such psychiatric crises. **Methods:** This study enrolled 30 participants aged 13-22 who received outpatient mental health care at a community hospital within the greater Boston area and have access to Wi-Fi. Participants utilized the mental health phone application mindLAMP for 6 weeks to answer surveys assessing daily problematic internet use and weekly depression and anxiety. **Results:** Individual daily PIU-SF-6 and BIS-BRIEF scores for each participant were assessed to determine if there were associations between in-the-moment PIU severity and impulsivity measurements. A significant relationship was observed between BIS-BRIEF and PIU-SF-6 scores ($p = 0.00$). Age, gender, psychiatric diagnosis, mean GAD-7 and PHQ-8 scores were also compared to mean PIU-SF-scores to identify potential relationships between these variables and PIU, but no significant relationships were observed. **Conclusion:** The findings from this study suggest that strong associations between PIU severity and impulsivity may exist, supporting the expected primary hypothesis and suggesting comorbidity between the two variables. Results also suggest that there are no significant associations between PIU severity and psychiatric symptoms such as anxiety and depression, contradicting the expected secondary hypothesis. However, issues posed by sample size, participant adherence, and subjectivity of impulsivity

measurements should be considered when drawing conclusions from the data analyses. Future research should aim to increase sample size and adherence, and consider objective measurements so that collected data may be used more effectively.

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LIST OF ABBREVIATIONS

ADHD	Attention Deficit Hyperactivity Disorder
ANOVA	Analysis of Variance
BART	Balloon Analogue Risk Task
BIS-BRIEF	Barratt Impulsiveness Scale Brief
CBT	Cognitive Behavioral Therapy
DSM	Diagnostic and Statistical Manual
EHR	Electronic Health Record
EMA	Ecological Momentary Assessment
GAD	General Anxiety Disorder
GAD-7	Seven Item General Anxiety Disorder Scale
HIPAA	Health Information Portability and Accountability Act
IAS	Internet Addiction Scale
ICF	Informed Consent Form
IRB	Institutional Review Board
IGD	Internet Gaming Disorder
LAMP	Learn, Asses, Manage, Prevent
MDD	Major Depressive Disorder
MI	Mental Illness
PGNG	Parametric Go/No Go Task
PHQ-8	Eight Item Patient Health Questionnaire
PIU	Problematic Internet Use

PIU-SF-6	Problematic Internet Use Short Form Six
PTSD	Post-Traumatic Stress Disorder
SSRI	Selective Serotonin Reuptake Inhibitor

CHAPTER 1: INTRODUCTION

Problematic Internet Use and the DSM

Problematic internet use (PIU) is defined as excessive or uncontrolled internet use and is often associated with psychiatric impairment or distress[1]. As ongoing discussions and research emerge about the validity of PIU as a "discrete mental disorder," it has been proposed that PIU be included in future editions of the Diagnostic and Statistical Manual of Mental Disorders (DSM), with researchers suggesting classification and diagnostic criterion[2,3]. Internet gaming disorder (IGD), similar to PIU but with a focus specifically on only pathological gaming, was included in the DSM-5 but only as a condition for further research[4,5].

Despite PIU not being recognized as a formal disorder by the DSM, PIU shares characteristics with many disorders that are recognized in the DSM, including compulsive and substance use disorders. Neurobiological studies utilizing magnetic resonance imaging, positron emission tomography, and other imaging methods assessing components of the brain have found that, similarly to those with substance use disorders, individuals with PIU/IGD display structural and functional impairments in the areas of the brain associated with reward, motivation, and memory[6]. Excessive internet use has also been associated with the decreased sensitivity of reward networks seen in substance use disorders, further suggesting that PIU and addictive disorders may share a similar pathophysiology[7].

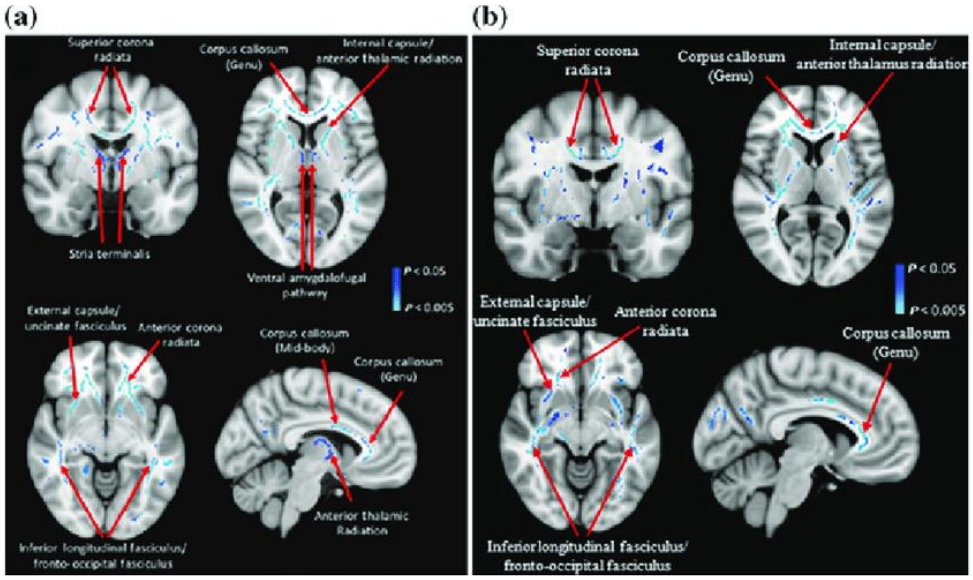

Figure 1. White matter of individuals with internet addiction and opiate addiction. Comparison of white matter abnormality in (a) individuals with internet addiction and (b) individuals with opiate addiction by fractional anisotropy. Red arrows emphasize areas of similar abnormalities between the two groups. Adapted from Lin & Lei, 2017[8].

Studies have also shown an association between PIU and compulsive disorders. A cross-sectional study on Iranian university students found that participants with diagnosed compulsive buying behavior scored significantly higher on measures of PIU, suggesting that there may be a relationship between PIU and compulsive disorders[9]. In a 2016 study by Li et al., PIU symptoms were compared to the DSM-V diagnostic criteria for substance abuse disorder, gambling disorder, and IGD[10]. Per the results of the study, significant overlap could be seen between subjective PIU symptoms and the DSM-V criteria for compulsive and addictive disorders such as: withdrawal upon cessation of use, uncontrolled use despite the knowledge that the behavior is problematic, and the inability to stop the behavior[10].

Problematic Internet Use and the Adolescent Population

Research of PIU in adolescent subjects is critical. Adolescence is an especially important time for neurodevelopment, wherein changes to both internal and external forces such as neurological, biological, cultural, and social changes can have lasting effects that shape the adolescent as they venture into adulthood[11,12]. The plasticity of the adolescent brain is not enough to prevent development of mental illnesses (MI), as adolescence is a critical developmental period that can impact both onset and persistence of MI[13,14]. According to studies on the adolescent brain, one in five people who experience MI onset at this stage will have their MI persist into adulthood[13]. Peak ranges of onset age for common psychiatric illnesses can be seen in **Figure 2** from Paus et al.'s 2008 study on the tendency of disorders to present during adolescence. According to the figure, it can be observed that the onset age of several disorders tend to start and end during the period of adolescence[15].

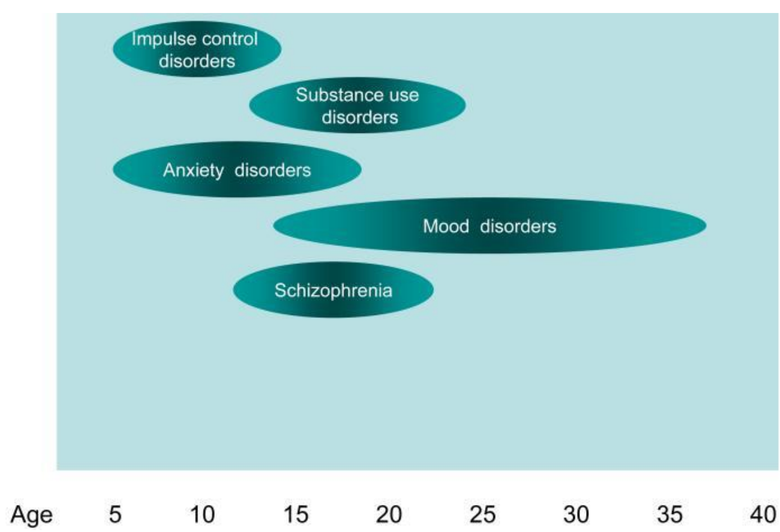

Figure 2. Onset age of common psychiatric disorders. Age range in years of the onset of several common psychiatric disorders. Taken from Paus et al., 2008[15].

Thus, it is vital to understand the consequences of external factors that may impact adolescent development. Internet and digital media use are particularly significant external factors, with their popularity amongst both adolescents and the rest of the population skyrocketing in recent years. According to a 2018 survey by the Pew Research Center on adolescent digital media habits, 95% of teenagers had access to a smartphone and 45% state that they are online constantly[16]. This ubiquity of smartphones and online activity in adolescents' lives has made determining the effects of screen time and PIU on the adolescent population especially important. Studies on the potential effects of excessive internet use have noted growing concern about long term adverse effects of PIU, such as poorer well-being, decreased emotional stability, and higher rates of psychiatric diagnoses[17,18].

There is also interest in whether PIU is wholly negative or if it may also have positive effects on the adolescent population. The perception of excessive internet use tends to be negative, but studies have shown that youths who receive mental health treatment may benefit from periods of higher PIU through temporary improvements to their anxiety and depression symptoms[19].

Additionally, there is evidence that not all forms of digital media may be detrimental; for example, social media, online forums, research databases, and telehealth platforms allow internet users to reach out and seek help when they are struggling mentally[20]. In a 2018 study, Kelleghan et al. examined various subtypes of internet use, ranging from checking social media to reading the news. Their objective was to see if any associations could be made between PIU and initiation of cannabis or tobacco use. This study took the focus beyond PIU as a whole and delved into specific types of digital media exposure – ranging from checking social media to reading the news – and revealed that different forms of digital exposure conferred different likelihoods of initiation of cannabis or tobacco product use. The study found that while checking social media was associated with an increased likelihood of drug initiation, browsing of news articles lowered the likelihood of initiation, and online shopping increased the likelihood of e-cigarette use only. These findings may suggest that the effects of PIU and digital media may be both detrimental and protective[21]

Potential Impact of Impulsivity on Problematic Internet Use and its Treatments

Research on PIU and impulsivity is an important and novel focus, as impulsivity is known to be a central feature of several psychiatric disorders[22]. Several studies aiming to understand impulsivity in psychiatric disorders have suggested that there is an association between impulsivity and psychiatric symptoms such as anxiety and depression[22,23]. However, it is unclear as to whether individuals with impulsivity are simply more predisposed to the development of anxiety, depression, and PIU, or if impulsivity and PIU symptoms worsen simultaneously. This is particularly important as separation from the Internet has been tied to impulsive actions such as self-aggression and aggression towards other, precipitating hospital admission[24].

Clarifying relationships between these factors may help guide clinical practice, with mental health providers having a greater understanding of comorbid risks present in psychiatric patients who present with high levels of PIU. Treatments for PIU should focus not only on helping patients cope with real-life experiences without the use of the internet, but also address the comorbidities that could be exacerbating the usage and effects of excessive usage.

Lastly, treatment recommendations for PIU are fairly limited, including selective serotonin reuptake inhibitors (SSRI) and cognitive behavioral therapies (CBT)[25]. SSRIs are a class of medication commonly used to treat depression by inhibiting the reuptake of serotonin by presynaptic neurons, thereby allowing the neurotransmitter to stay in the synaptic space longer and restoring serotonin levels in the brain[26]. CBT is a therapeutic approach that uses the ideology of cognitive factors maintaining mental disorders and psychiatric distress to create interventions that change maladaptive cognitive factors and therefore lessen emotional distress and problematic behaviors[27].

In a 2008 study by Dell'Osso et al., the SSRI escitalopram was prescribed as a treatment for 19 patients who presented with PIU based on scores on the Yale-Brown Obsessive Compulsive Scale, modified for internet use. In this 19-week study, all of the participants were treated with the antidepressant for 10 weeks and then split into two groups: a treatment group who continued to be administered escitalopram for the last 9 weeks and a placebo group that whose administration of escitalopram ceased at the 10 week mark. Results suggested that treatment of PIU with escitalopram resulted in a significant decrease of internet use, however no difference was noted in internet use between the treatment and placebo groups following the last 9 weeks of the study.[28]

A study on the therapeutic efficacy of CBT on Korean adolescents with PIU was conducted by Kim et al. in 2018. In the study, 17 participants between the ages of 12 to 17 who met the criteria of having PIU based on Young's Internet Addiction Scale (IAS) were recruited to participant in eight CBT group sessions. IAS score, depression level, and anxiety level were collected at the beginning of the study and post-intervention. Results of the study suggested that CBT is an appropriate treatment for PIU in adolescents, as the total IAS score of the group had decreased significantly from the baseline score. Post-intervention evaluations also showed a significant decrease in the depression and anxiety levels of participants, suggesting that CBT may also function to target comorbidities of PIU.[29]

However, a study on Chinese adolescents with PIU conducted by Du et al. in 2010 produced dissimilar results that may point to the shortcomings of CBT as a treatment for PIU. In the study, 56 participants between the ages of 12 to 17 who met the criteria of having PIU based on Beard's diagnostic criteria for internet addiction were recruited and separated into either an active treatment group or a clinical control group. Participants in the active treatment group were treated with eight CBT group sessions, while participants in the clinical control group received no interventions. Internet use, emotional, cognitive, and behavioral measures were collected at the beginning and end of the study. Results showed that both groups had a decrease in internet usage time regardless of intervention, while only the active treatment group showed improved emotional, cognitive, and behavioral symptoms. In the case of this study, CBT did not prove to effectively treat PIU in adolescents, although did appear to treat some of the comorbidities related to PIU.[30] Thus, further recognition of factors associated with PIU may allow for the exploration and testing of additional treatment options, for example through use of medications or therapy that specifically targets impulsivity.

Ecological Momentary Assessment

Designed to assess factors that influence real-life behaviors, ecological momentary assessment (EMA) is an in-the-moment research method that involves repeated sampling of participants in their natural environments across an extended period of time[31]. Commonly used in psychiatric studies, this methodology allows for data collection on mood and behavior that is close in time to the participants' experiences, thereby minimizing recall bias and maximizing validity when assessing patients[32]. EMA is also advantageous in that its repeated sampling per person over time allows for analyses on within-person effects, giving researchers the opportunity to see how study variables may change with and influence each other.

EMA was originally conducted through traditional methods such as diaries and daily mailed questionnaires, but has progressed to personal digital devices and most recently via cell phones[33]. Cell phone administration of EMA can be done through surveys conducted by phone call or text, or smartphone applications that are designed to send surveys to participants at specified times. The movement toward conducting EMA through cell phones instead of paper comes with many advantages, such as ease on the participant as well as timestamps that allow study personnel to be aware of entries that may be more predisposed to recall bias and thus decide how to manage these data accordingly during data analyses.

Specific Aims and Objectives

Utilizing the novel methodology of EMA, this study aims to assess temporal relationships between PIU and impulsivity in adolescents and young adults. It has been well established that impulsive youths and young adults appear to be at higher risk of developing PIU, as evidenced by both cross-sectional studies that connect greater impulsivity in internet addicted individuals and strong associations between PIU and disorders where impulsivity is a key component, like attention deficit hyperactive disorder[34–37]. To improve upon past studies that may have been limited by cross-sectional administration, this study examined repeated associations between moment-by-moment self-reported perceptions of impulsivity and PIU rather than just whether impulsive youths and young adults are more likely to exhibit PIU. From a clinical perspective, it is critical to understand if youth and young adults may actually be more impulsive in the moments where they are reporting PIU symptomatology rather than simply more prone to impulsivity at baseline; the use of ecological momentary assessment helps us to make this distinction.

As noted above, limited research and anecdotal evidence suggests that symptoms of PIU or dependency on the internet may trigger psychiatric crises such as aggression toward self or aggression toward others, particularly when restrictions are placed on use of digital devices[19]. If adolescents and young adults are reporting higher impulsivity in the same moments where they are reporting higher levels of PIU, it may, in part, explain how device separation leads to such psychiatric crises. We hypothesize that the adolescents and young adults in our study population will have a significant relationship between daily

PIU-SF-6 and BIS-BRIEF scores, suggesting a temporal relationship between severity of PIU and impulsivity.

Secondary to studying the temporal relationship between daily PIU and impulsivity measures, this study also examined the relationships between PIU and psychiatric symptoms of anxiety and depression, as these symptoms have also been associated with impulsivity[22,23]. By determining if psychiatric symptoms are also exacerbated during periods of higher PIU, clinicians can target anxiety or depression symptoms that may accompany PIU. As PIU has also been suggested to develop as a way to manage uncomfortable affective symptoms, we hypothesize that the adolescents and young adults in our study population will also have significant relationships between PIU-SF-6 scores and both PHQ-8 and GAD-7 scores[38].

CHAPTER 2: METHODS

Participant Recruiting and Enrollment

Our study recruited 30 adolescents and young adults between the ages of 13 to 22 who received outpatient mental health treatment within a community hospital in the greater Boston area, owned a smartphone with the capability to run the study application, and had Wi-Fi access. Study procedures were submitted to and approved by the associated hospital's institutional review board (IRB) under IRB Protocol IRB-1100/11/18. Exclusionary criteria when screening for participants included lack of parental consent for subjects under the age of 18, reading below a sixth-grade level, and not being English speaking, as the phone application is currently only available in English.

Power Calculations

Digital phenotyping (DP) is a new research method that is similar to EMA in that utilizes personal digital devices and smartphones to quantify moment-by-moment human phenotypes in-situ[39]. Due to the novelty of smartphone-based EMA and DP methodology, power and sample size analyses for DP and EMA in psychiatric research are limited[40]. However, multiple proof-of-concept studies conducted in the field and have found evidence that DP studies are still adequately powered to detect clinically meaningful results using sample sizes less than 100. Assuming 75% adherence to account for missing data, a study period of 42 days and 2 active surveys taken daily for our primary outcome, we expected 42*2*0.75=63 longitudinal data points per subject[41]. Using a power calculator specifically designed for DP studies, with 40 total subjects to test our primary hypothesis, we would be 80% powered to detect a small/medium effect size using linear mixed-effects models (LMM) at an alpha level = 0.05[41].

Recruitment

Recruitment of study participants was conducted in three different ways: fliers in waiting rooms for self-referrals, clinician referral, and active recruitment by study team members. Fliers were posted in outpatient clinics associated with the community hospital, contained a brief description of the study, listed the major inclusionary criteria, and provided the study team's contact information. Subjects who saw the flier and were interested would then reach out to the study team to receive more information on the study and potentially proceed to enrollment. Mental health care providers in the clinic were also made aware of the study and would inform eligible participants of the study; if the patient was interested and consented to having their information shared, the provider would forward the patient's name and contact information to the study team.

Due to the COVID-19 pandemic and movement to telehealth visits, remote active recruitment was introduced to the study and became the primary recruitment strategy. In remote active recruitment, approved study personnel utilized the associated hospital's electronic health record (EHR) system EPIC to contact eligible participants and their guardians via e-mail, sending an advertisement for the study. In addition to sending the study advertisement to eligible participants, study team members would also reach out to these potential participants via phone.

Consent and Enrollment

Subjects who expressed interest in the study participated in an intake phone call that explained the study via an age-appropriate informed consent form (ICF), and then proceed to enrollment if desired. ICFs were age-based and divided into 4 age groups (11-13, 14-17, 18+, parent or guardian), with each version delivering information about the study using language based on developmental age to ensure that the basis of the study was fully understood prior to seeking consent. If a potential participant was under the age of 18, a parent or guardian would also be invited to attend the call and would review the ICF with the study personnel. To better serve and represent the patient population that the study team was recruiting from, ICFS were translated into the three most common languages present aside from English – Portuguese, Haitian Creole, and Spanish. Hospital telephone interpreters were also utilized to discuss the ICF with the guardian when English was not the guardian's primary language. The content of the ICF included: purpose of the study, study procedures, expectations of participants, risks and benefits of participation, as well as contact information for various study personnel. Due to the pandemic, the need for written informed consent was waived by the hospital's institutional review board (IRB-1100/11/18). After obtaining informed assent and consent, a copy of the ICF document was emailed to the parent/guardian or participant (if >18 years of age) for reference.

Upon receiving verbal consent to participate in the study, the study team member helped participants download and set up the study application on their smartphones. At the end of the enrollment call, participants were compensated with an initial $50 Amazon gift card.

Materials

mindLAMP

For the 6-week duration of the study, participants used the mindLAMP (Learn, Asses, Manage, Prevent) phone application to answer daily surveys uploaded by the study team. LAMP is an open and free digital research platform created to provide researchers with a dual smartphone application and online portal service to collect study-related data[42]. The app has been previously used in research to assess multiple psychiatric disorders; for example, researchers have utilized mindLAMP to evaluate strengths and weaknesses of previous studies on smartphones for schizophrenia and to compare active and passive data collection to learn more about social rhythms[43,44].

Upon registration and installation onto the participant's phone, mindLAMP was programmed to send daily push notifications at 8 pm EST which reminded participants that their daily surveys were available to complete, as seen in **Figure 3**. Clicking on daily notifications directed participants to the appropriate activities for the day.

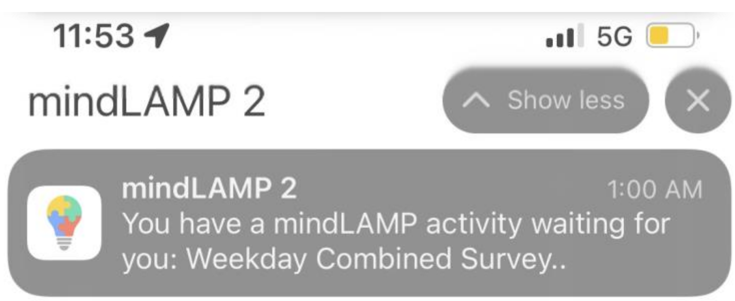

Figure 3. Daily mindLAMP activity reminder notifications. Every day at 8pm EST, mindLAMP sends users a push notification informing them of their daily activities for the specific study day. Users may follow the notification string to take them directly to the associated task, or go into to the mindLAMP application and select from the activity options.

The application interface housed Assess and Feed tabs. The Assess tab included all the activities associated with the study, while the Feed tab included a calendar that stated exactly which study activities to complete based on the day. If a participant were to clear the push notification or desired to complete their activities early, they could navigate to the Feed tab to determine which activities to complete and then go to the Assess tab to select and complete the appropriate activities.

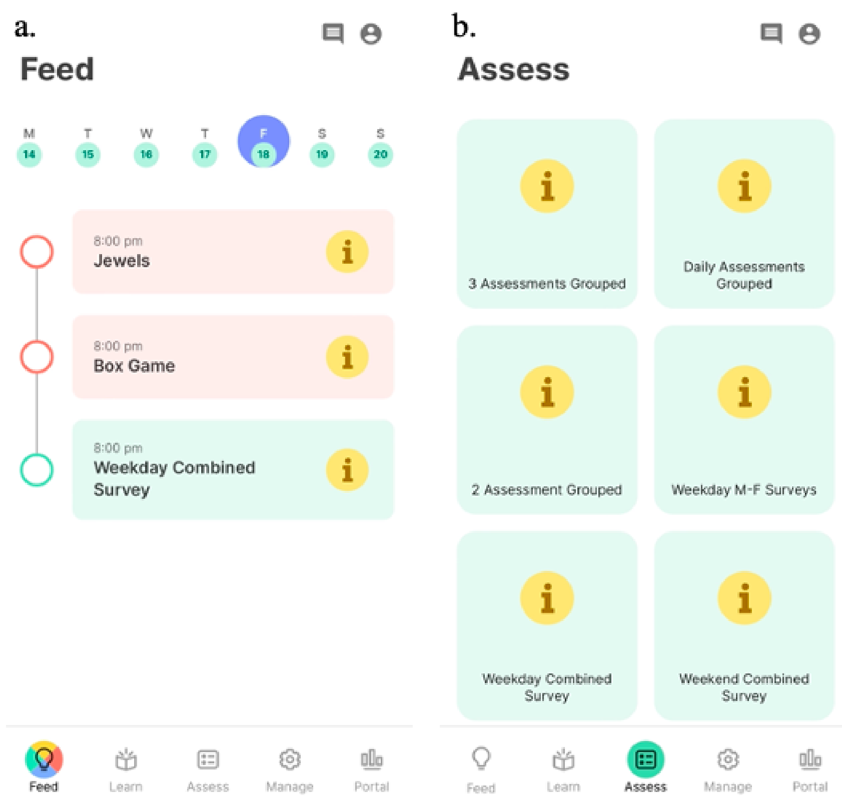

Figure 4. Interface of the mindLAMP application. The mindLAMP phone application has several tabs, with the Feed (a) and Assess (b) tabs highlighted in the figure.

All information collected from the mindLAMP application was encrypted in a HIPAA (Health Information Portability and Accountability Act)-compliant manner, coded and stored in industry-standard hospital servers. Every time the application had Wi-Fi access, the collected data would be sent and stored onto the associated hospital's server. Collected data included survey answers, date of survey completion, and time of survey completion. Study team personnel were able to access data on the LAMP online portal, which has a dashboard with further navigating capabilities such as adding multiple studies, adjusting study activities, and viewing data in a longitudinal graph that allows researchers to quickly spot trends. Seen below in **Figure 5** is an example of a summary view of a participant's data; the sum of all survey scores plotted on a timeline of the study period. The data portal also includes the option to look at data in other views, such as longitudinal plots of all surveys individually.

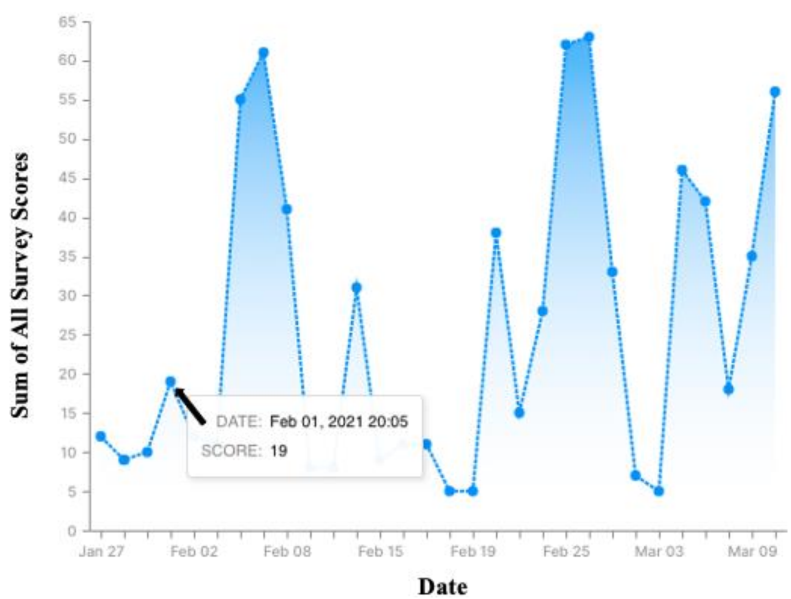

Figure 5. Participant data summary from the LAMP online portal. Longitudinal plot of a full study period summary that depicts changes in survey score totals throughout the 42-day study period. Example of how data is presented on the mindLAMP portal.

Daily Survey Questions

The contents of the daily surveys varied dependent on weekday or weekend and aimed to assess PIU, impulsivity, and psychiatric symptoms of anxiety and depression. The purpose of spacing out the symptom scales rather than assess each one daily was to reduce the overall burden of content per day in attempts to increase survey adherence. All of the surveys were modified in language to account for the 24 hours before survey completion and to fit into Likert-scale format, presented in an ordinal scale format that allows participants to select the degree to which they are or disagree with the survey question[45].

On weekdays, participants were responsible for filling out the Problematic Internet Use Short Form Six (PIU-SF-6) and the Barratt Impulsiveness Scale Brief (BIS-BRIEF) surveys. The PIU-SF-6 is the shortened, 6 question version of the Problematic Internet Use Questionnaire and is validated to assess PIU in adolescent and young adult populations[46]. Answers were scaled from 1 (never) to 5 (always/almost always) and survey scores ranged from 6 to 30, with scores above the statistically established cut-off of 15 classifying participants as at-risk for excessive internet use[46]. The BIS-BRIEF survey is an 8 question version of the Barratt Impulsiveness Scale that is considered more appropriate for youth and young adult populations due to its exemption of survey questions based around situations that do not normally apply to younger subjects[47]. Answers were scaled from 1 (never) to 4 (always/almost always) and survey scores ranged from 8 to 32, with higher scores indicating more impulsiveness in the participants[47].

On weekends, participants were responsible for filling out the eight item Patient Health Questionnaire depression scale (PHQ-8) and the seven item General Anxiety

Disorder scale (GAD-7) to assess weekly anxiety and depression. The PHQ-8 is a validated diagnostic survey for depressive disorders that omits question 9 of the Patient Health Questionnaire-9, which pertains to suicidality[48,49]. The purpose of using this modified and shortened PHQ is due to the fact that survey answers are not constantly monitored, making it difficult to respond and provide coping resources to participants in a timely manner; this version of the PHQ has been standardized in the United States[49]. Answers were scaled from 0 (not at all) to 3 (nearly the whole week) and survey scores ranged from 0 to 24, with scores above the cut-off of 10 signifying depression[48]. The GAD-7 is a validated seven question diagnostic tool for anxiety disorders, developed for use in primary care settings and approved for assessment of adolescents[50,51]. Answers were scaled from 0 (not at all) to 3 (nearly the whole week) and survey scores ranged from 0 to 21, with scores above the cut-off of 10 identifying cases of GAD. Additional to the cut-off score of 10 for PHQ-8 and GAD-7, a scale consisting of cut-points scores of 5, 10, and 15 can be interpreted as mild, moderate, and severe levels of symptomology, respectively[52]. The contents of the weekday and weekend surveys were grouped into single assessments, so that participants were completing all survey questions at once and in the same order every time.

Electronic Health Record

The associated hospital's EHR, EPIC, was utilized throughout the study. Information found on the snapshots of patient profiles were used to contact potential participants during remote active recruitment. After consenting and enrolling into the study, a participant's full EHR was accessed twice – at the beginning and end of the study.

Demographic information was pulled from EHR profiles, including age, gender identity, and primary diagnosis. Primary diagnosis information was obtained through the notes in the participant's outpatient mental health encounter that occurred most recently to enrollment and exit from the study. After completion of the study period was marked, the study team forfeited access to full EHR profiles.

Study Procedure

This study took place over a 6-week period, with participants answering daily survey questions via the mindLAMP phone application. Participants received application notifications every day at 8pm EST to remind them of their daily activities but had the ability to complete them at any point during the day. Information obtained from the daily surveys was associated with a de-identified user-identification number, encrypted, and uploaded via Wi-Fi to a secure server. Only the study team had access to this de-identified data. Information connecting participants to their study identification number was stored on a secure server that was available only to central study personnel who needed the information to carry out their tasks.

At the end of the 6-weeks, participants would partake in an exit phone call that notified them of the completion of their study period. Participants then deleted the mindLAMP application from their phones, halting any further data collection from the user. Completion of the study was compensated in the form of a second $50 Amazon gift card. Compensation was not dependent upon level of adherence to study protocol and all participants were given a gift card at this call.

Data Analysis

Statistical analyses were run on R Studio Version 2022.02.0[53]. Data describing the demographics of the participants have been presented as numbers and percentages of the total group. Because of the small sample size, primary diagnoses were classified into 5 broader categories; however, the distribution of actual primary diagnoses has also been presented for reference. Mean scores of each participant's PIU-SF-6 were calculated by taking the arithmetic average of each participant's individual PIU-SF-6 survey scores, providing 30 points of data as there were 30 participants. This same strategy was used to compute mean scores for the remaining symptom scales, GAD-7 and PHQ-8. Unlike PIU-SF-6 which provided 30 points of data, GAD-7 and PHQ-8 only provided 27 due to lack of survey scores from three participants in the weekend surveys. For all analyses, significance was determined by a p-value < 0.05.

Mixed-effect linear regression models were used to test for potential significant relationships between all of the PIU-SF-6 and BIS-BRIEF scores for each participant throughout the length of their study period. LMMs are favored in longitudinal studies where the same data is collected multiple times from the same participant, as they allow for within-person analyses. Different from standard linear regressions which only have fixed-effects, LMMs have both fixed-effects and random-effects. A fixed-effect is a factor for which data has been collected at all possible levels and is believed to have no variance between variables, while a random-effect is a factor for which some levels of data have been measured and is believed to have a degree of randomness that should be accounted for if the data is meant to be generalized to a broader population[54,55]. In this study, the individual participants were random-effects because we expected a degree of random effect from each individual and, though the study population is solely clinical, the findings of the study are meant to be generalized beyond the clinical population. Additionally, LMMs account for the multi-level, hierarchical nature that is common of psychiatric studies; in the case of this study, survey scores from the same participant are the lowest level and would not be considered independent due to the expectation that within-participant scores would be similar, while scores from different participants are the highest level and would be considered indepdendent[56]. In this analysis, every participant's individual weekday survey score was accounted for and a single *p*-value is presented as the relationship between PIU severity and impulsivity for each individual participant in the study population.

Standard linear regression models were used to test for potential significant relationships that mean PIU-SF-6 survey scores may have with mean PHQ-8 scores and mean GAD-7 survey scores. Processed averages of the participant PIU-SF-6 scores were analyzed with mean PHQ-8 and mean GAD-7 survey scores and these regressions are presented as individual figures.

Secondary analyses also examined associations between gender, age and existing psychiatric diagnoses and mean PIU-SF-6 score. Relationships between gender and average survey scores were computed using one-way analysis of variance (ANOVA) and two-tailed t-tests, testing for potential significant relationships between participant gender and average scores on the weekday survey. When evaluating if a significant relationship between participant primary diagnosis category and mean PIU-SF-6 score existed, two tailed t-tests were utilized. In this situation, ANOVA was not used as we were not testing between all diagnosis categories but instead between whether a participant's primary diagnosis is or is not in the focus diagnostic category. As variances between groups could not be assumed to be homogenous, Welch's t-test was opted for over Student's t-test. This choice was made as Welch's t-test has been known to better control for type 1 errors in situations where variances are not likely equal, as was the situation with this set of data[57]. Linear regressions were conducted to test for potential significant relationships between age and average PIU-SF-6 scores, aiming to see if increasing age had a relationship with the survey score.

CHAPTER 3: RESULTS

The main goal of this study was to assess and determine if temporal relationships between PIU and impulsivity exist in adolescents and young adults. Based on existing literature and preliminary data from pilot studies, we hypothesized that adolescents and young adults in our study population would have a significant relationship between daily PIU-SF-6 and BIS-BRIEF scores, suggesting comorbid PIU and impulsivity. We also assessed for associations between PIU and psychiatric symptoms of anxiety and depression, as they are symptoms that have been associated with impulsivity. We hypothesized that we would find a significant temporal relationship between PIU and impulsivity symptoms (i.e. when PIU symptoms were high, participants would also report more severe impulsivity symptoms) and significant relationships between mean PIU-SF-6 scores and mean PHQ-8 and/or mean GAD-7 scores. By determining if PIU changes with impulsivity and if psychiatric mood symptoms are comorbid with these periods of high PIU, the results of these assessments could aid clinicians in targeting psychiatric symptoms that accompany PIU and creating personalized interventions to avoid psychiatric crises that tend to follow device separation.

Sample survey responses of Participant 13 are plotted below in **Figure 6**. Participant 13 had the highest response rate, completing 40 out of 42 days of surveys and therefore providing the most complete visual representation of a full study period.

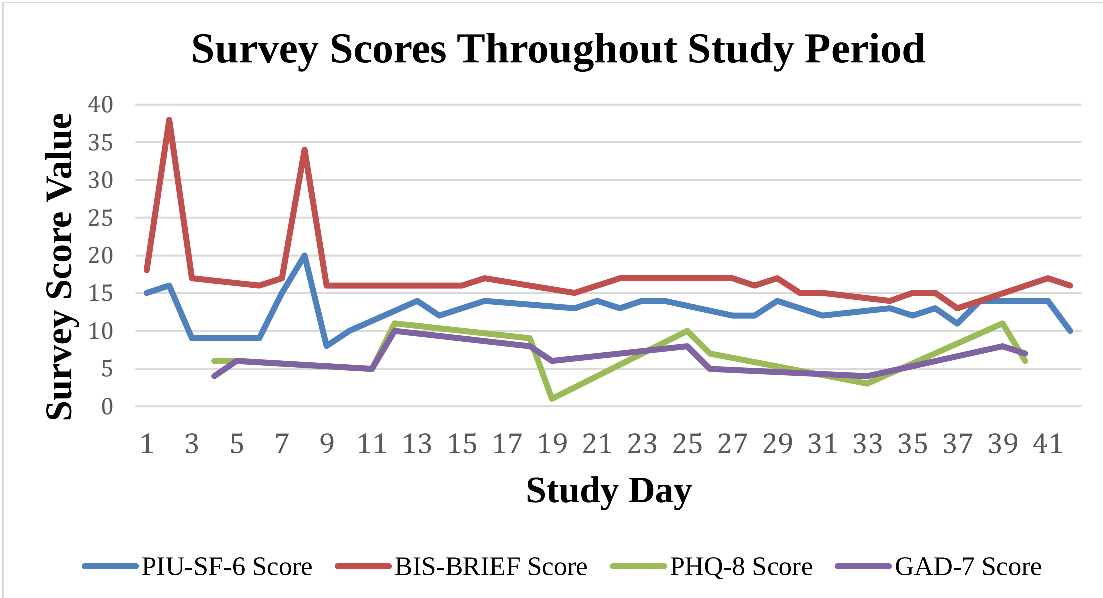

Figure 6. Participant 13's survey scores throughout the full study period. Study Participant 13's PIU-SF-6, BIS-BRIEF, PHQ-8, and GAD-7 survey scores throughout the 42-day study period. Graph was formatted to fill in gaps between values, to account for missing survey scores or days where a survey was not meant to be completed (example: PIU-SF-6 or BIS-BRIEF on the weekend). PIU-SF-6: PIU-SF-6: problematic internet use short form six. BIS-BRIEF: Barratt impulsiveness scale brief. PHQ-8: eight item patient health questionnaire. GAD-7: seven item general anxiety disorder scale.

Demographics

Demographics of the participant population are represented below in **Table 1.** As seen in the gender identity distribution of the 30 consented adolescents, 80% were females, 16.67% were males, and 3.33% were transgender. At 60%, the majority of participants had a primary diagnosis of a mood disorder, with the remaining diagnosis categories represented as 20% anxiety disorders, 10% trauma disorders, 6.67% attention deficit hyperactive disorder (ADHD), and 3.33% gender dysphoria. The mean patient age in the study was 16.5 years, with ages ranging from 13 – 22.

Table 1. Demographic data of participant population. The distribution of age, gender, and primary diagnosis across the study population. Gender has been divided into male, female, and transgender participants. Primary diagnoses of the participant were noted and classified in one of five categories – mood disorder, anxiety disorder, trauma disorder, ADHD, or gender dysphoria. Information on age is presented as the mean age of the participants, with supplements of the standard deviation and full range of ages. ADHD: attention deficit hyperactivity disorder.

Demographic Data (n = 30)	n (% of total n)
Mean Age in Years [range, SD]	16.5 [13-22, 2.00]
Gender	
Male	5 (16.67)
Female	24 (80)
Transgender	1 (3.33)
Primary Diagnosis Type	
Mood Disorder	18 (60)
Anxiety Disorder	6 (20)
Trauma Disorder	3 (10)
ADHD	2 (6.67)
Gender Dysphoria	1 (3.33)

As all of the participants' primary diagnoses were classified into the five categories depicted above (mood disorder, anxiety disorder, trauma disorder, ADHD, gender dysphoria), **Figure 7** has been provided to show the distribution of all of the primary diagnoses before stratification.

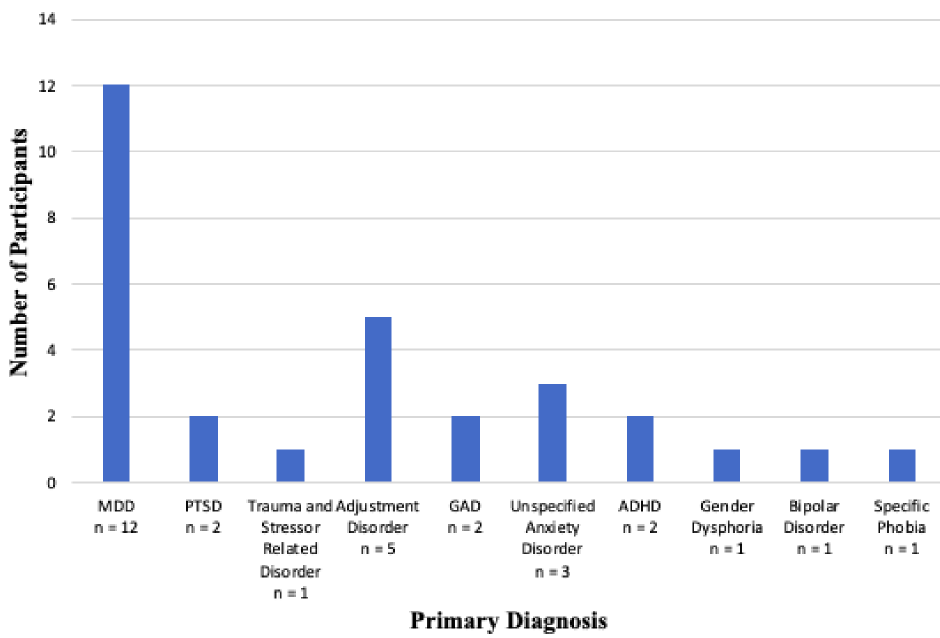

Figure 7. Frequency of participant primary diagnoses, pre-stratification. Primary diagnoses of participants, stratified by categories – mood disorder, anxiety disorder, trauma disorder, ADHD, or gender dysphoria. Presented above are the primary diagnoses before this stratification. MDD: major depressive disorder. PTSD: post-traumatic stress disorder. GAD: general anxiety disorder. ADHD: attention deficit hyperactivity disorder.

Relationship Between PIU-SF-6 and BIS-BRIEF Survey Scores

Mixed-effect linear regressions assessed the significance of the relationship between all of the participants' individual PIU-SF-6 and BIS-BRIEF scores throughout the length of the study period. **Table 2** represents the regression value calculated for the study population. A significant relationship was observed between PIU severity and impulsivity, with the regression producing a *p*-value of 0.00. Based on this outcome, we also looked at the coefficient (β) value, which suggests that a change in 1 standardized "unit" of PIU severity would result in a same-direction change of 0.66 "units" of impulsivity. Lastly, we looked at the standard (*z*) score of the data, which suggests that this observation falls 18.45 standard deviations from the mean.

	PIU-SF-6 Score		
	β	*z*	*p*
BIS-BRIEF Score	0.66	18.45	0.00*

Table 2. PIU-SF-6 by BIS-BRIEF. Relationship between all participants' individual PIU-SF-6 and BIS-BRIEF scores throughout their 42-day study period using mixed-effect linear regression models. $p < 0.05$ is considered significant. * = significant relationship. β = Coefficient. z = standard score. PIU-SF-6: problematic internet use short form 6. BIS-BRIEF: Barratt impulsiveness scale brief.

Relationship Between PIU-SF-6 and PHQ-8 Survey Scores

The relationship between mean PIU-SF-6 and mean PHQ-8 survey scores was assessed by linear regression. Gender and age were controlled for in this regression, due to known relationships between age, gender and depressive disorders. The regression plots for this analysis can be seen in **Figure 8**. Significant relationships were not seen between PIU-SF-6 and PHQ-8 ($p = 0.16$). According the R^2 values, the predictability between the two variables was 30%.

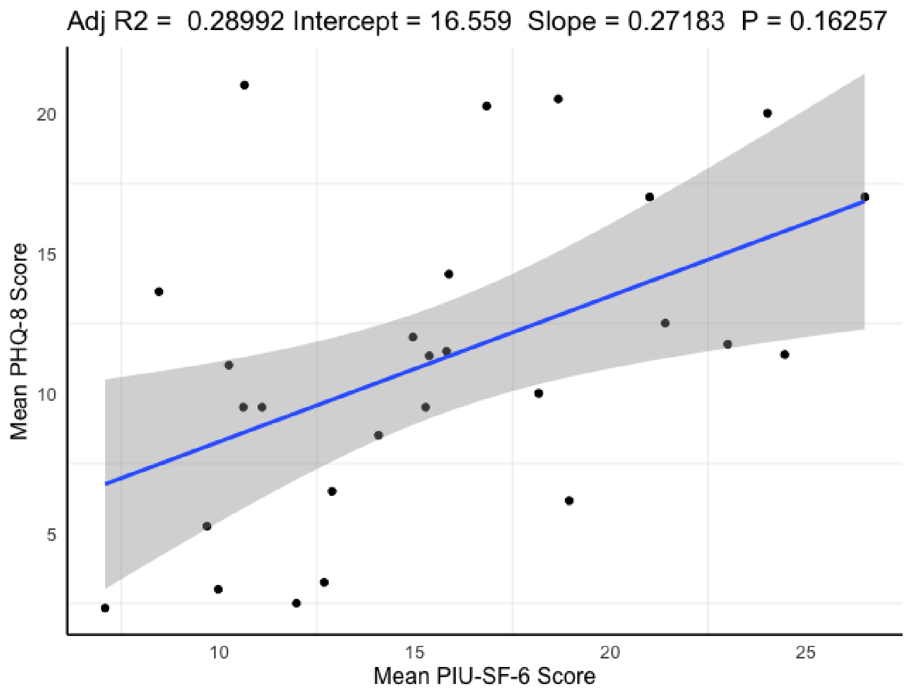

Figure 8. Mean PIU-SF-6 survey scores by mean PHQ-8 survey scores. Linear regression of mean PIU-SF-6 survey scores by mean PHQ-8 scores. Gender and age were controlled for in this regression. A *p*-value < 0.05 would be considered significant. A 95% confidence interval is represented by the grey region. PHQ-8: eight item patient health questionnaire. PIU-SF-6: problematic internet use short form six.

Relationship Between PIU-SF-6 and GAD-7 Survey Scores

Linear regressions were also conducted to assess if there was a significant relationship between mean PIU-SF-6 and mean GAD-7 survey scores. Gender and age were controlled for in this regression, due to known relationships between age, gender and depressive disorders. The regression plot for this analysis can be seen in **Figure 9**. Significant relationships were not seen between mean PIU-SF-6 and GAD-7 scores (p = 0.09). According the R^2 values, the predictability between the two variables was 31.9%.

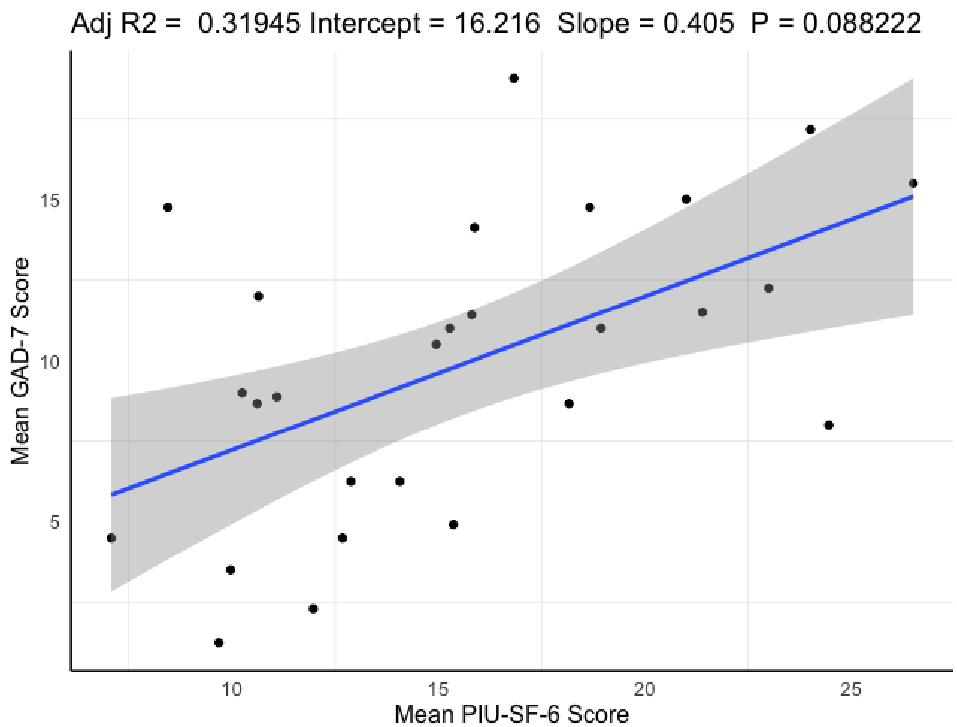

Figure 9. Mean PIU-SF-6 survey scores by mean GAD-7 survey scores. Linear regression of mean PIU-SF-6 survey scores by mean GAD-7 scores. Gender and age were controlled for in this regression. A *p*-value < 0.05 would be considered significant. A 95% confidence interval is represented by the grey region. GAD-7: seven item general anxiety disorder scale. PIU-SF-6: problematic internet use short form six.

Relationship Between PIU-SF-6 and Gender Identity

The potential significant effect of gender identity on PIU-SF-6 scores was assessed using a single factor ANOVA in **Table 3**. The purpose of this ANOVA was to test for significance between the three gender identity groups. The relationship between the three groups and PIU-SF-6 was approaching significance (p = 0.06).

This potential relationship was also assessed within gender groups in the Welch's *t*-test in **Figure 10**, which accounted for the unequal sample sizes between the three gender identity groups. To do this assessment, groups were separated by those who do identify with the gender and those who do not, and the following mean PIU-SF-6 scores were used for the calculations: male (11.77±4.45), non-male (16.51±5.06), female (16.20±4.92), non-female (13.816.39), transgender (24.01), and non-transgender (15.44 ±5.06) participants. Standard deviations could not be calculated for the transgender population, as the n was 1.

The *p*-value approached significance for a relationship between male gender identity and PIU severity ($p = 0.08$), but not for female gender identity ($p = 0.42$). We were unable to perform *t*-tests on the transgender patient population, as the n was 1.

Table 3. ANOVA of mean PIU-SF-6 survey scores by gender identity. Mean PIU-SF-6 survey scores by gender, assessed by ANOVA. The p-value for this test was 0.06. A *p*-value < 0.05 was considered significant. ANOVA: one-way analysis of variance. PIU-SF-6: problematic internet use short form six.

	Male Participants n = 5	**Female Participants n = 24**	**Transgender Participants n = 1**
Mean PIU-SF-6 Score	11.77	16.2	24.02
SD	4.45	4.92	N/A

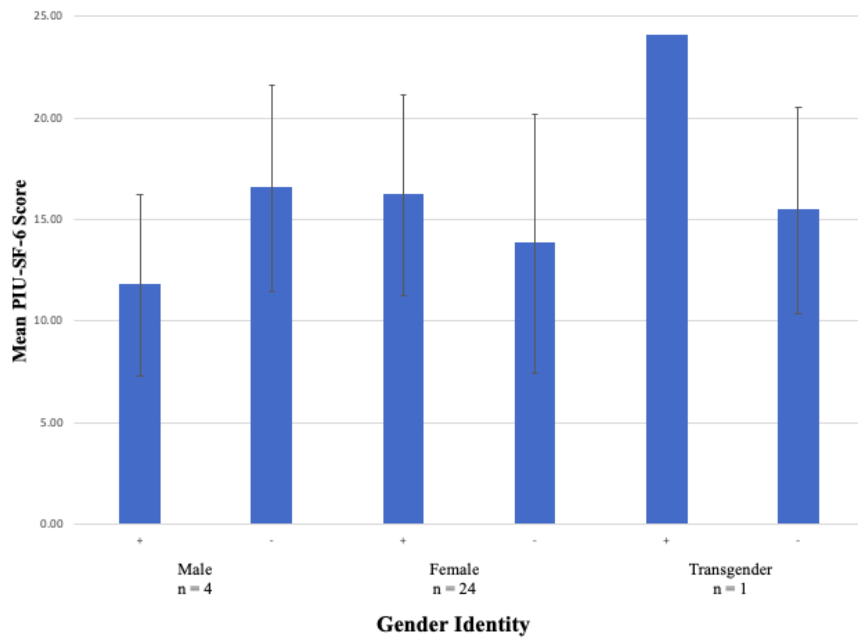

Figure 10. Mean PIU-SF-6 survey scores by gender identity. *t*-tests of participant gender with mean PIU-SF-6 survey scores. Gender was divided into identifying as the gender (+) and all other participants (-). A p-value < 0.05 would be considered significant. PIU-SF-6 = problematic internet use short form six.

Relationship Between PIU-SF-6 and Primary Diagnosis Category

t-tests were also utilized to determine if there was a significant relationship between diagnostic category and mean PIU-SF-6 survey scores as presented in **Figure 11.** Again, due to the unequal sample sizes of the categories, Welch's *t*-tests were used. To do this assessment, groups were separated by presence of the primary diagnosis category and absence of the primary diagnosis category, and the following mean PIU-SF-6 scores were used for the calculations: mood disorders (16.53±5.22), without mood disorders (14.51±5.19), with anxiety disorders (13.91±3.15), without anxiety disorders (16.18±5.57), with trauma disorders (15.88±6.58), without trauma disorders (15.71±5.19), with ADHD (9.54±3.48), without ADHD (16.16±5.07), with gender dysphoria (24.02), and without gender dysphoria (15.44±5.06). Standard deviations could not be calculated for the gender dysphoria population as the n was 1.

When evaluating PIU-SF-6 by primary diagnosis category, no significant relationship was seen between PIU and mood disorders (p = 0.31), anxiety disorders (p = 0.21), trauma disorders (p = 0.97), or ADHD (p = 0.19). We were unable to perform *t*-tests on the gender dysphoria patient population, as the n was 1.

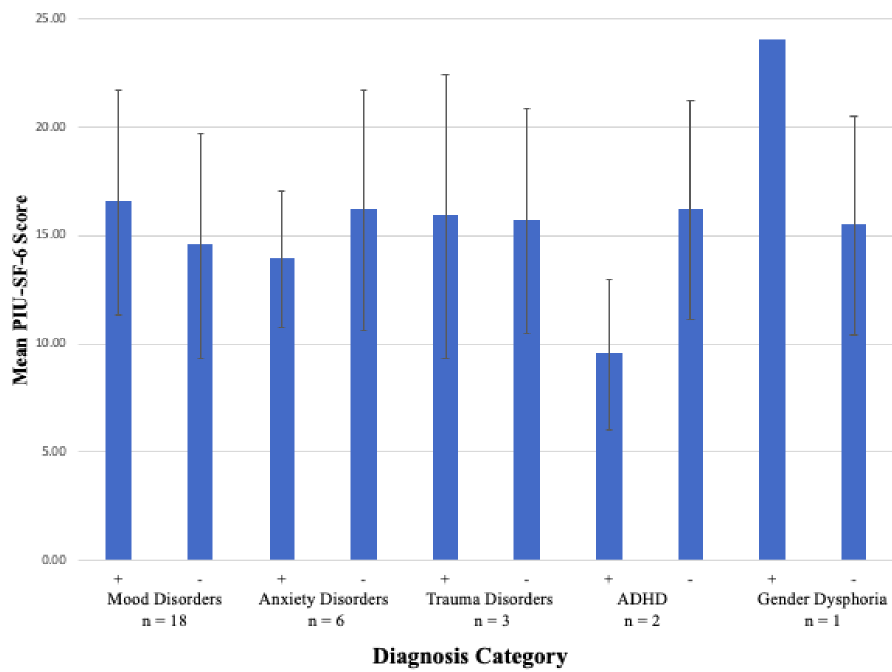

Figure 11. Mean PIU-SF-6 survey scores by primary diagnosis category. *t*-tests of primary diagnosis category with mean PIU-SF-6 survey scores. Primary diagnosis category was divided into presence of the primary diagnosis (+) and absence of the primary diagnosis (-). A p-value < 0.05 would be considered significant. * = p < 0.05. ADHD: attention deficit hyperactive disorder. PIU-SF-6: problematic internet use short form six.

Relationship Between PIU-SF-6 and Age

Linear regressions were used to assess if there was a significant relationship between increasing age and mean PIU-SF-6 survey scores. The regression was controlled for gender, to ensure that age was the only variable being assessed with PIU severity in this assessment. The associated regression plot is seen below in **Figure 12**. No significant relationship between participant age and mean score was observed for PIU-SF-6 ($p = 0.11$).

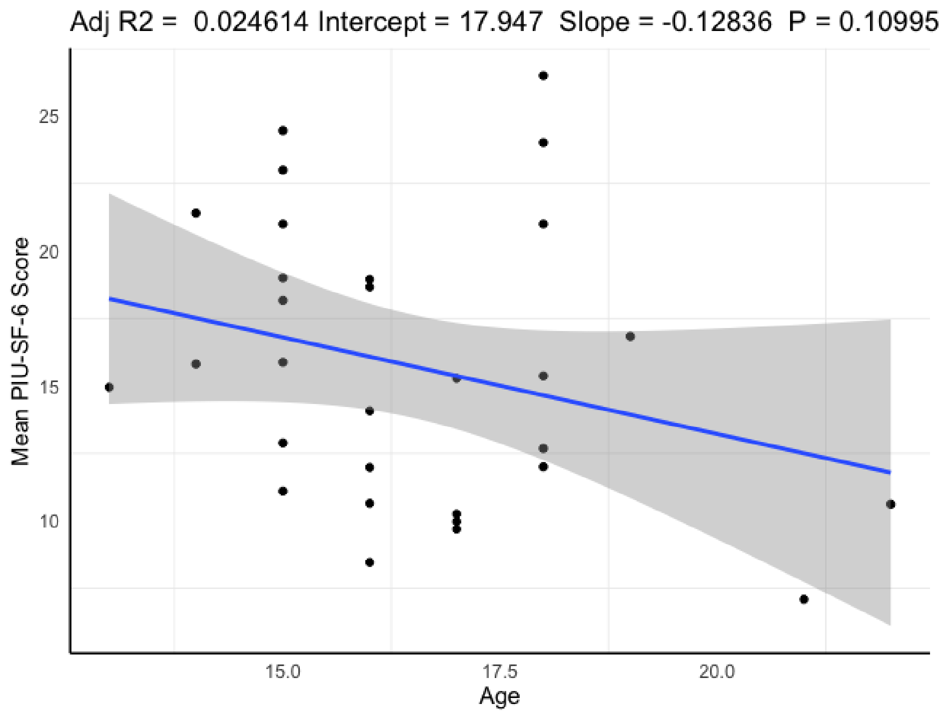

Figure 12. Mean PIU-SF-6 survey scores by age. Linear regression of participant age with mean PIU-SF-6 survey scores, controlled for gender. A *p*-value < 0.05 would be considered significant. A 95% confidence interval is represented by the grey region. PIU-SF-6: problematic internet use short form six.

CHAPTER 4: DISCUSSION

Relationship Between PIU Severity and Impulsivity

When assessing the relationship between daily PIU-SF-6 and BIS-BRIEF scores in our study population, we determined that there was a very strong association between PIU severity and impulsivity ($p = 0.00$). This supported our expected hypothesis that the youth in our study population had a significant relationship between daily PIU-SF-6 and BIS-BRIEF scores, suggesting that a temporal comorbidity between PIU severity and impulsivity consistently exists.

Prior cross-sectional studies examining the relationship between PIU and impulsivity support the findings of our study and suggest an association between the two variables. According to a 2018 study by Chamberlain et al. that focused on the impact of comorbid impulsive disorders on PIU, researchers found that higher levels of impulsivity were identified in PIU when participants already had impulsive comorbidities[58]. Similarly, other studies have stated that excessive internet use in the form of PIU or internet addiction have been considered to be associated with or even strongly related to lower levels of impulse control[36,37,59,60].

Depression and anxiety have also been associated with impulsivity in youths and young adults, which may contribute to more severe impulsivity in participants whose depression and anxiety symptoms are worse[22,61]. Moreover, studies hypothesize that anxiety and depression symptoms may precede PIU[38,62]. Therefore, it was also important to identify a worsening in anxiety and depressive symptoms in our participants, as this influences both PIU severity and impulsivity.

Relationship Between PIU Severity and Anxiety/Depression Symptoms

When assessing mean PIU-SF-6 scores with the weekday survey scales for significant relationships, we determined that there were no associations between PIU severity and depression ($p = 0.16$) or PIU severity and anxiety ($p = 0.09$). Predictability values for changes in PIU with the mentioned variables were found to be 30% with PHQ-8 and 31.9% with GAD-7. This contradicted our secondary expected hypothesis, which posited that the adolescents and young adults in our study population would have significant relationships between PIU severity and the psychiatric symptomatology of both anxiety and depression. This finding was surprising, as multiple studies conducted on the adolescent population have connected anxiety and depression symptomatology to increased PIU severity[38,63,64]. Additionally, PIU has been associated with and named as a predictor of depression, while anxiety has been named a predictor of PIU when controlled for depression and GAD[65,66].

With this being an exploratory study, such results should be analyzed for potential protocol design flaws that can be adjusted in future iterations of the study. We hypothesize that the lack of significance in the evaluated relationships might be due to the scheduling of symptom scale collection. Administration of the survey scales was spaced out in an attempt to reduce survey burden and increase adherence; however, this choice may have been more costly to our analyses than beneficial. Information on PIU severity was collected on the weekdays, while anxiety and depression symptomatology information was only collected on the weekends. With PIU severity being assessed on different days than when psychiatric symptoms were assessed, it was difficult to determine the extent of the influence that the psychiatric symptoms may have on PIU severity. Particularly because our study assessed youth, weekends may have represented a time of improved depression and anxiety symptomatology, thus impacting a participant's ability to objectively reflect on psychiatric symptoms during the week, and obscuring a potentially existing temporal relationship between psychiatric symptoms and PIU. Additionally, the effects of missing survey data were compounded; a lack of weekend survey data could mean comparing multiple weeks of PIU-SF-6 scores to one weekend. Therefore, it would also benefit future studies to collect all four of these symptom scales on the same days.

Relationship Between PIU Severity and Gender Identity

When evaluating mean PIU-SF-6 scores by gender identity by ANOVA, no significant relationship was observed between the three groups ($p = 0.06$), though the *p*-value was trending towards significance. Similarly, when Welch's *t*-tests were performed, no significant relationship was observed between PIU and females ($p = 0.42$) or transgender participants (no *p*-value calculated), while the relationship between PIU and males was trending towards significance ($p = 0.08$). Based on the *p*-values of the ANOVA and *t*-test, it can be posited that the gender identity that pushed the ANOVA towards significance was male, as its *p*-value was also trending towards significance. This finding is supported by existing literature on the subject, which suggest that males use the internet more excessively than females[67]. Several studies comparing PIU severity between male and female participants have found that PIU severity is higher in men in many different samples, including populations of Chinese, Indian, and Romanian participants[68–70].

This relationship has also been observed in adolescents: in a 2019 study that observed internet habits among British children aged 10-16, it was noted that males were more likely to score higher on PIU severity scales than females[71]. It is possible that, despite the similar age group, our study did not observe as strongly significant associations because of our sample size. Additionally, our lack of significant findings may be due to the fact that our participant were adolescents receiving outpatient mental health care rather than the general adolescent population. Studies assessing PIU in outpatient adolescent populations have not supported prior findings on non-clinical populations, observing no correlation between PIU severity and gender or observing significantly higher PIU severity in female participants[38,72]. Future studies may want to focus more on variations in PIU subtype between genders rather than the absolute presence or absence of the phenomenon. For example, greater proportions of women use the internet for social networking, while greater proportions of men tend to use the internet for online games, multiplayer roleplay games, and adult-content websites[73].

Finally, it is worth noting that, unlike many other studies that look at gender and PIU, this study had a transgender participant. The focus of gender studies tends to fall on cis-gendered individuals with little information on mediating factors that affect transgender populations, so there is a gap in existing research that pertains to PIU severity of transgender, nonbinary, and gender diverse people[74]. Despite having a transgender participant in this study, analyses to determine if there is significance between a transgender gender identity and PIU still could not be performed due to the fact that the sample size was 1. It is important to work to fill this gap, as studies have shown that transgender youths and young adults are at higher risk of psychiatric morbidities as compared to their cis-gendered counterparts[75].

Relationship Between PIU Severity and Primary Diagnosis Category

When assessing mean PIU-SF-6 survey scores by primary diagnosis category, no significant relationship was observed for mood disorders ($p = 0.31$), anxiety disorders ($p = 0.21$), trauma disorders ($p = 0.97$), ADHD ($p = 0.19$), or gender dysphoria (no *p*-value calculated).

Despite prior cross-sectional studies finding associations between specific psychiatric disorders and PIU, our results suggest that these prior associations may be more related to active psychiatric symptomatology rather than absence or presence of specific diagnostic categories[76]. Youth and young adults with psychiatric comorbidities may have a more complicated relationship with internet use than youth without such comorbidities, due to being more predisposed to developing behavioral or substance dependencies or reliance on the Internet as a coping mechanism, such that all youth and young adults in psychiatric distress, regardless of diagnosis, may be predisposed to PIU development[62,77]. As noted above in regards to gender, because PIU may have specific subtypes (e.g. internet surfing, online shopping, social networking) that were not assessed here, future studies may want to examine the relationships between subtypes and specific psychiatric conditions[78].

Relationship Between PIU Severity and Age

No significant relationship was observed between mean PIU-SF-6 scores and age, as determined by the *p*-value of 0.14. This finding contrasts with Ioannadis et al.'s 2018 study, where participants of older ages were found to display higher levels of PIU[78]. There are differences between that study and ours which may account for this dissimilarity, such as age range and sample size. The 2018 study focused on adults, with an age range of 18 to 77 and a mean of 29, and had 1749 participants[78]. This could suggest that the discrepancy in our findings versus theirs was due to our small sample size and the age demographic that was targeted for participants. Studies that have focused specifically on adolescents have produced both similar results suggesting that there are no observable differences between PIU severity by age, as well as contrasting results where clinically significant PIU scores were associated with younger participants[19,72].

Limitations

The present study had several limitations that may have impeded our ability to identify significant relationships between PIU and other assessed variables. The small sample size of 30 participants did not allow for an in-depth analysis of the relationship that demographic factors may have had on our study results. Primary psychiatric disorders were classified into broader categories, as using the specific diagnoses resulted in multiple subgroups with an n of 1. Despite implementing a more generalized disorder classification system, we encountered a primary diagnosis category (gender dysphoria) with an n of 1.

In addition, the unequal distribution of participant demographic data made it difficult to determine the generalizability of our results. Of the 30 participants, 80% were female. This value contrasts greatly with the census data of the greater Boston area, which states that the split between females and males is 51 and 49 percent, respectively[79]. The distribution of diagnoses among the participant population was also uneven, with more than half having mood disorders. A study on mental health surveillance among children and adolescents reported that the most prevalent mental health disorders among this population are ADHD and anxiety, with estimates of ever being diagnosed being 9.8% and 9.4% respectively[80]. This contrasts with our participant population, where only 6.67% had ADHD as their primary diagnosis. Lastly, because our study looked specifically at adolescents and young adults receiving outpatient mental healthcare, the generalizability is restricted to the clinical population.

Protocol adherence by participants was also a major roadblock that the study team encountered. None of the participants completed all the study activities, with the most complete being two participants (13 and 26) who achieved 95% (40 out of 42 days) completion of their surveys. This lack of study protocol adherence from participants resulted in the inability to analyze certain pieces of data, with most participants not consistently answering surveys beyond the first few study days, as seen by the three missing values when computing average PHQ-8 and GAD-7 scores. The linear regression analyses only required four sets of observations to be computed, but most researchers agree that a minimum of 10-15 sets of observations is more appropriate, with some going as far as stating that the number of observation should be 20 times greater than the amount of variables being observed in the study[81]. Considering that some participants did not meet the required four observation sets and even more likely did not meet the suggested 10-15 observation sets, it is difficult to assess the validity of the linear regression results on PIU severity and the other variables.

Lastly, due to the nature of the subjective metrics collected for the study, self-reported measures have a high likelihood of introducing bias[82]. In a 2016 study by Althubaiti, the effects of social desirability bias and recall bias in research as well as how to overcome these issues was assessed[83]. Social desirability is the tendency of participants to underreport or misreport socially undesirable behaviors in order to avoid embarrassment and to maintain a more positive sense of self[84]. Social desirability bias in this study could lead to participants attempting to answer their surveys in ways that would lower impulsivity and PIU severity scale scores. Recall bias is when study participants do not remember events accurately or omit pieces of information, and this could potentially be present in our study in participants who did not recall the last 24 hours well enough to appropriately answer survey questions[83].

Future Directions

In response to the limitations mentioned above, it would be advantageous for future studies to implement changes that circumvent the data collection and analysis issues noted in this study, as well as add more analyses to further utilize collected data. In order to better understand just how anxiety and depression influence the association between PIU severity and impulsivity, future studies should conduct mediation and moderation analyses in order to see if rapid fluctuations in mood (e.g. worsened anxiety or depression symptomatology) mediate or moderate the relationship between PIU-SF-6 scores and BIS-BRIEF scores. Mediation and moderation analyses are often performed in order to better understand the mechanism of observed relationships between predictors and outcomes, and could therefore show researchers the extent of the influence that anxiety and depression may have[85]. For this study, anxiety and depression symptoms were only assessed on the weekends, making it difficult to determine the influence they may have on PIU severity and impulsivity during the weekdays. Therefore, it would also benefit future studies to collect all four of these symptom scales on the same days.

Regarding the issues surrounding the small patient population, the study team should reevaluate the desired sample size. The goal should not be to simply increase the sample size, but rather to procure a larger sample with equal demographic distributions based on gender identity and age[86].

With adherence posing as the largest issue that limited our abilities to perform the desired data analyses, the study team should investigate ways to promote increased study activity participation. One means of achieving this could be to connect compensation to adherence – rather than provide a $50 Amazon gift card at both enrollment and study's completion, the second gift card could be tied to protocol adherence.

Objective Measures

While we found a significant relationship between impulsivity and PIU, future studies could also consider incorporating smartphone-based objective measures of impulsivity. Firstly, adding objective measures could help with adherence limitations, as these tend to be more engaging to participants than filling out surveys. Metrics such as the Balloon Analogue Risk Task (BART) and the Parametric Go/No Go Task (PGNG) can be adapted and presented as games, which our study population might find easier to complete than daily questionnaires. Additionally, objective measures are also less susceptible to the recall issues or self-report biases that are commonly associated with subjective measures[87,88]. As noted above, one objective test for impulsivity is the Balloon Analogue Risk Task, a computerized tool that simulates risk-taking behaviors to assess and identify risk-taking behaviors in young adults[88]. In a 2003 study by Lejuez et al., BART was tested on an adolescent sample and was found to correlate with scores on established risk-related measures such as impulsivity; the findings from this study suggest that BART could be an effective measurement tool for future iterations of this study[89].

The Parametric Go/No Go Task is an adapted version of the computerized Go/No Go test that is used to examine response inhibition as it relates to impulsivity by having participants use a keyboard to click through predefined target stimuli (the “go” response) and refrain from clicking when an unknown stimuli have been presented (the “no go” response)[90]. In a PGNG-focused study conducted by Weidacker et al., researchers found that participants who scored higher for impulsivity significantly experienced more difficulty when performing response inhibition, suggesting that PGNG is a suitable measurement for impulsiveness[91].

In a 2021 study on the effects of the COVID-19 pandemic restrictions on children in Israel, objective physical and behavioral measures such as amount of physical activity, time spent outdoors, and sleep parameters were assessed to circumvent limitations caused by the subjectivity of survey questionnaires; the researchers found this methodology to be successful[92]. Similar to our study, other studies have found success in using digital-media-related objective metrics such as screen time values and sleep duration as assessed by a smartphone to supplement their data, suggesting that implementation of objective measures could be applied to this research as well.

Conclusions

Using smartphone based ecological momentary assessment methodology, our findings suggest that strong temporal associations between PIU and impulsivity exist, as evident by the significant tandem increases in daily PIU-SF-6 and BIS-BRIEF scores in our study population. This supported our primary hypothesis that PIU severity and impulsivity would be temporally related, suggesting a consistent comorbidity between these variables. Our results, however, did not find a significant association between PIU severity and psychiatric symptoms of anxiety and depression.

Despite being unable to prove our secondary hypothesis, this study has provided direction on how we may better assess confounding factors that have been noted to influence the relationship between PIU and impulsivity, such as depression and anxiety symptomatology. As an exploratory study, the successes and shortcomings of this study's protocol can be utilized to inform future iterations of this research. Future research should aim to increase sample size and adherence when using EMA methodology, so that collected data may be analyzed more effectively. Additionally, it may be beneficial to replace subjective measures with objective measures, when possible, to circumvent issues of bias and adherence. Overall, this study serves as a meaningful starting point for assessing PIU with impulsivity, depression symptomatology, and anxiety symptomatology, offering future studies guidance in building effective EMA protocols to study PIU.

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