Associating Internet Usage with Depressive Behavior among College Students

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Abstract — **Depression is a mental health problem affecting a large population of college students. Since college students are active users of the Internet today, investigating associations between symptoms of depression and Internet usage has been an active area of research. While existing studies do provide critical insights, they are limited due to the fact that Internet usage of subjects is characterized by means of self-reported surveys only. In this paper, we report our findings on a month long experiment conducted at Missouri University of Science and Technology on associating depressive symptoms among college students and Internet usage using *real* Internet data collected continuously, unobtrusively and preserving privacy. In our study, 216 undergraduates were surveyed for depressive symptoms using the CES-D scale. We then collected their on-campus Internet usage via Cisco NetFlow records. Subsequent analysis revealed that several Internet usage features like *average packets per flow, peer-to-peer (octets, packets and duration), chat octets, mail (packets and duration), ftp duration, and remote file octets* exhibit a statistically significant correlation with depressive symptoms. Additionally, Mann-Whitney U-tests revealed that *average packets per flow, remote file octets, chat (octets, packets and duration)* and *flow duration entropy* demonstrate statistically significant differences in the mean values across groups with and without depressive symptoms. To the best of our knowledge, this is the first study that associates depressive symptoms among college students with continuously collected *real* Internet data.**

Keywords - depression, internet, mental health, college students

I. INTRODUCTION

Depression is a serious mental health problem affecting a large segment of society today, and particularly college students. In a survey by the Centers for Disease Control (CDC) in 2009, 26.1% of students nationwide reported feeling so sad or hopeless almost every day for 2 or more weeks in a row that they stopped doing some usual activities [32]. Similar statistics are also reported in mental health studies by the American College Health Association, and by independent surveys [1, 2]. Although there are treatments for depression, many victims do not recognize symptoms, and many may be reluctant to seek help [24, 25]. If left untreated, depression can cause appetite loss, sleep disorders, fatigue and anxiety, along with poor academics and higher dropout rates. Detecting depressive symptoms early is hence a critical need today in our colleges today. In this paper, we report our findings on a month long experiment conducted at Missouri University of Science and Technology on associating depressive symptoms among college students with Internet usage using *real* campus Internet data collected *continuously, unobtrusively* and *preserving privacy*.

A. *Internet usage as a marker for Depressive Symptoms*

Recent studies show that more than 90% of college students in the US actively use the Internet [23, 26]. While the benefits of Internet for academic learning, research, business and social networking are well known, studies conducted by the Psychological Sciences community have focused on exploring relationships between Internet use and students' mental health. Studies in [3, 4, 6, 7] demonstrated that students with depressive symptoms used the Internet much more than those without symptoms. It was also shown that when the Internet was utilized for activities like shopping, depressive symptoms among students increased [5]. Excessive online video viewing [18, 19, 20], social networking [31], gambling [9, 10], frequent visits to health websites [11], late-night Internet use [12, 13] and online chatting [21, 22] have also been associated with symptoms of depression among young people. With excessive Internet use, students replace real-life interactions with online socializing, leading to increased social isolation and anxiety in their physical environments [8].

While all of the above studies do provide critical insights into how Internet associates with depressive symptoms among college students, the information they convey is limited. This is because student Internet usage in existing studies has been assessed by means of self-reported surveys only. In other words, students themselves reported their volume and type of Internet activity. This method has limitations. First, the volume of collected Internet usage data is limited during surveying because people's memories fade with time. There may be errors and social desirability bias when students report their own Internet usage. An accurate characterization of Internet usage requires representations of significantly higher dimensionality, and clearly the number of dimensions that can be captured via surveys is limited.

B. *Contributions of this Paper*

We conducted a study in 2011 for associating depressive symptoms among college students with their *real* Internet usage data collected *continuously, unobtrusively* and *preserving privacy* [1] at Missouri S&T. To the best of our knowledge, this is the first study to do so. The study consisted of the following steps:

- **Participant Selection and Surveying:** We recruited 216 students from three undergraduate classes at Missouri S&T in February

[1] This research was proposed to the Institutional Review Board (IRB) at Missouri S&T, and received approval under Exempt Category 4: "*Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that participants cannot be identified, directly or through identifiers linked to the participants*".

2011. The depressive symptoms of participants were quantified using the Center for Epidemiologic Studies Depression (CES-D) scale [14]. In our survey, 30% of students met the minimum CES-D criteria for exhibiting depressive symptoms, which compares well with many recent mental health surveys [1, 2, 32].

- **Internet Usage Feature Extraction:** The Internet usage activity of participants was obtained in the form of Cisco NetFlow records collected over the Missouri S&T campus network. For each participant, we derived a number of Internet usage features divided into three broad categories. The *Aggregate* category captures raw aggregates of Internet usage like flows, packets, octets, durations etc. The *Application usage* category captures application specific Internet usage features like chatting, peer-to-peer, email, ftp, http etc. The *Entropy* based features captures randomness in Internet usage from the perspective of flows, octets, packets, durations etc.
- **Statistical Analysis:** Subsequent statistical analysis revealed that the following Internet usage features correlate with depressive symptoms: *average packets per flow, peer-to-peer (octets, packets and duration), chat octets, mail (packets and duration), ftp duration, and remote file octets*. Additionally, Mann-Whitney U-tests revealed that *average packets per flow, remote file octets, chat (octets, packets and duration)* and *flow duration entropy* demonstrate statistically significant differences in their mean values across groups with and without depressive symptoms.
- **Interpretation of Results:** We present preliminary interpretations to our findings by integrating them with existing research in Psychological Sciences on associations between depressive symptoms and Internet usage among college students.

C. Paper Organization

The remainder of this paper is organized as follows. Section II describes the participant selection, CES-D survey, and privacy preserving mechanisms. The Internet data collection process and all pre-processing techniques are detailed in Section III. Section IV describes Internet features extraction process. Results from statistical analysis are presented in Section V. Interpretations and applications of our findings are presented in Section VI, and the paper is concluded in Section VII.

II. PARTICIPANT SELECTION AND CES-D SURVEY

In our study, the participant pool consisted of 216 undergraduate students at Missouri S&T from three classes: Psych 50 (General Psychology), CS 284 (Operating Systems) and CS 153 (Data Structures). Psych 50 is taken by students from all departments, while CS 284 and 153 are taken by students from many engineering departments. The survey was preceded by a consent form, and there was a minimum age of at least 18 years to participate. The survey was conducted in February 2011.

The levels of depressive symptoms among participants were quantified with a one-time survey based on the Center for Epidemiologic Studies Depression (CES-D) scale. The CES-D scale was developed by Lenore Radloff of Utah State University and is used to measure depression levels in the general population [14]. It consists of 20 questions rated on a 4-point Likert scale. Possible scores range from 0 to 60, with higher scores indicating greater levels of depressive symptoms. In general, a score of 16 or above on the CES-D scale is considered indicative of depressive symptoms. The CES-D scale is widely used and has been extensively tested and validated. It has been shown to be reliable when testing adolescents in high schools and colleges [15, 16]. In order to minimize demand characteristics (where participants form an interpretation of the experiment's purpose and unconsciously change their behavior accordingly), the survey was titled "*Recent Affective Experiences Questionnaire,*" and additional items were embedded into the original CES-D questionnaire, although only the CES-D items were scored. Table I summarizes our participant pool.

TABLE I. SUMMARY OF OUR PARTICIPANT POOL

	Computer Science	Psychology	CES-D ≥ 16	CES-D < 16
Male	120	68	54	134
Female	8	20	10	18
Totals	128	88	64	152

To ensure privacy of participants, appropriate anonymization techniques were enforced during participant selection, surveying and collecting Internet usage data. The IT department at Missouri S&T provided unique pseudonyms for each participant, and the associations were not disclosed to the research team. Students who completed the CES-D survey did so using only their pseudonyms, which were tied to their recorded CES-D scores. The IT department remained unaware of the CES-D scores. Additionally, the IT department provided the on-campus Internet usage data indexed only by pseudonyms. The only associations available to the researchers were between Internet usage data and CES-D scores. In our study, IP addresses were not processed, since the focus was on broad Internet statistics alone [2]. Also, the contents of emails, chat and ftp uploads/downloads were not recorded due to privacy considerations.

III. INTERNET DATA COLLECTION AND PREPROCESSING

The main source of "Internet Usage" data for this study was NetFlow. Cisco NetFlow technology is a protocol for collecting IP traffic information and is popular. NetFlow data consists of several *flows*. In our study, NetFlow V5 was used, which contains the following eight fields for each flow after preprocessing: 1) Source IP address, 2) Destination IP address, 3) Source port, 4) Destination port, 5) Protocol, 6) Octets, 7) Packets and 8) Duration.

The IT department at Missouri S&T collects NetFlow data of all users for troubleshooting network connections and policy enforcement. The Missouri S&T campus has a connection to both the standard commodity Internet and the Internet 2 education research network. Both Internet and Internet 2 traffic pass through the same router where NetFlow statistics recording and exporting are enabled. Every five minutes, these flows are exported from the router to a collector where they are stored for a period of 45 days for analysis purposes before being discarded automatically.

In order to obtain the NetFlow data of participants, the flows pertaining to each participant were identified based on the *source IP* field, and subsequently filtered and logged to a secure remote server at the end of every month. As the Missouri S&T campus uses a DHCP (Dynamic Host Configuration Protocol) to provide IP address, the IP address used by a participant at one time could be used by someone else later. Therefore, the extraction process begins by creating a mapping file and associating each user with a set of assigned IP addresses, along with the start and end time stamps. This information is used by a backup daemon to extract user-specific NetFlow information by filtering flows based on the *source IP* field. The mapping file is created by analyzing DHCP logs that include a participant's *user-id*, which is that participant's campus email address. Note that this process, summarized in Figure 1, was executed by the Missouri S&T campus IT department. This process was completely automated. Subsequently, the Internet usage of each participant

[2] Since we do not process IP addresses, websites visited were not accessed. Hence associations between visits to Social Networking sites like Facebook, Twitter etc. and depressive symptoms were not investigated in this study. This is part of future research.

indexed by appropriate pseudonyms (as discussed in Section II) was delivered to the research team. In this study, the Internet data used was the one collected in February 2011, the month in which the depressive symptoms of participants were surveyed.

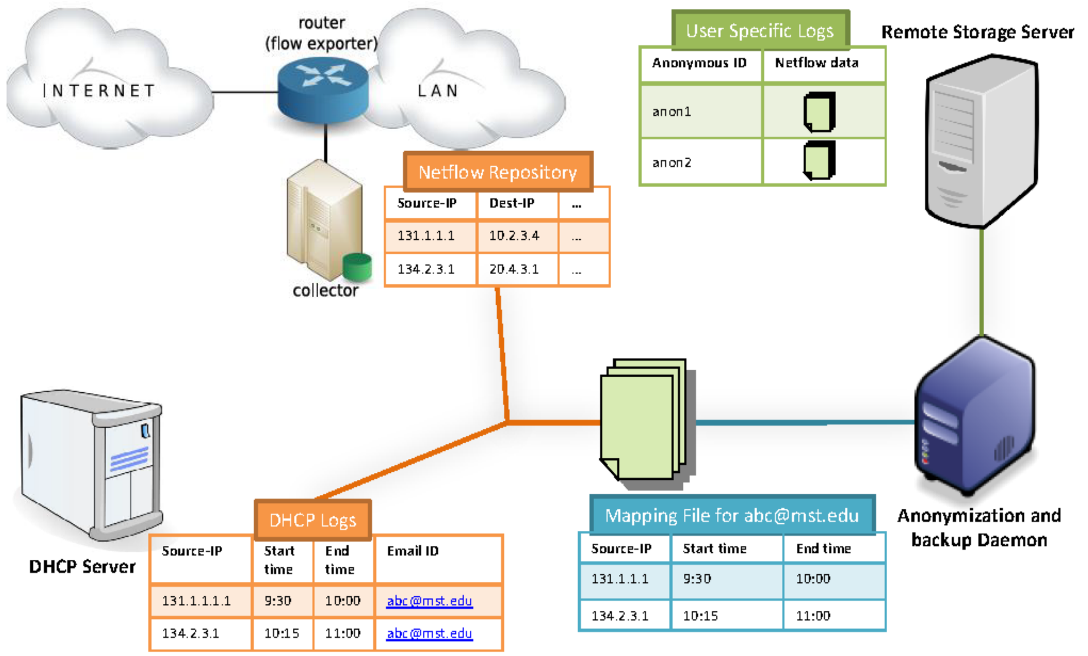

Figure 1: Illustration of the overall NetFlow data logging process

IV. INTERNET FEATURES EXTRACTION

A Sample of NetFlow data for a single participant is shown in Table II. Each row in the table corresponds to a *flow.*

TABLE II. SAMPLE NETFLOW DATA PER PARTICIPANT

srcIP	dstIP	Prot	Srcp	dstp	oct	pkts	Dur
131.151.x.x	208.78.x.x	6	65055	80	1187	13	158
131.151.x.x	208.78.x.x	6	65058	80	1141	12	166
131.151.x.x	208.78.x.x	6	65042	80	402	5	67
131.151.x.x	208.78.x.x	6	65062	443	1533	9	196

NetFlow data in its natural form is unsuitable for statistical analysis. In order to derive meaningful statistics, we have to preprocess NetFlow data $D=\{flow_i\}_{i=1:k}$ for each participant into an N-dimensional feature vector. Also, as the number of rows associated with a participant approaches millions when aggregated over a month, preprocessing also compresses the data into manageable proportions. As the space of all possible feature vectors is large, care must be taken to extract features that are likely to associate with depressive symptoms. Inspired by related research in the Psychological Sciences community (as discussed in Section I-A), we derived three broad features of Internet usage presented below.

A. Aggregate Traffic Features

The simplest feature is a representation of overall aggregate traffic statistics, such as total packets, flows and octets. Although the granularity is low, these features can be used to answer questions like: "*Does more Internet usage associate with increased depressive symptoms*"? In our study, aggregate flow statistics were derived using the *flow-report* in the *flow-tools* suite. Additionally, bash scripting was used to extract the data and convert it into a feature vector, one per participant. In total, 14 features were derived as summarized in Table III.

B. Application Level Features

Traffic aggregation alone has low granularity. For example, an aggregate of high email and low chatting may appear similar to an aggregate of low email and high chatting. Application-level statistics capture more information by sub-categorizing aggregate traffic features by application. In other words, traffic features such as flows, octets, packets and duration are derived per application such as http, email, peer-to-peer (p2p), chat, etc.

A total of 61 applications were identified by filtering flows based on set combinations of *destination port* and *destination protocol* fields, as allocated by IANA (Internet Assigned Numbers Authority) [17]. Since NetFlow data was only logged for on-campus Internet usage, some application categories like socks, squid, and blubster, showed little or no activity. Universities tend to block such services due to security and copyright issues, and students also tend to limit such activities on campuses. In our study, 25 applications were hence retained. These applications were further grouped into eight categories, as summarized in Table IV.

TABLE III. AGGREGATE FEATURES

Feature	Description
flows	Total Flows
oct	Total Octets
pkts	Total Packets
timeflows	Total Time (1/1000 secs) (flows)
durreal	Duration of data (realtime)
durdata	Duration of data (1/1000 secs)
aftime	Average flow time (1/1000 secs)
apsize	Average packet size (octets)
afsize	Average flow size (octets)
apflow	Average packets per flow
afsec	Average flows / second (flow)
afsecreal	Average flows / second (real)
akbits	Average Kbits / second (flow)
akbitsreal	Average Kbits / second (real)

TABLE IV. CATEGORIES OF APPLICATION FEATURES

Category	Applications
p2p	File-sharing applications based on peer-to-peer architecture (edonkey, neomodus, winmx)
http	HyperText Transfer Protocol applications (http, https)
streaming	Stream media applications (shoutcast, real, winmedia, stream-works, audiogalaxy)
chat	Instant messaging applications (aim, irc, carracho)
email	Email traffic (IMAP, POP3, SMTP)
ftp	File transfer applications (snmp, ftp)
gaming	Massively multiplayer online games (battlenet, quake, starseige, portzero, halflife, gamespyarcade, directx)
remote file access	Remote file system access (afs, nfs)

C. Entropy Based features

Difficulty concentrating or making clear decisions is a symptom of depression among college students [27]. We capture randomness in Internet usage via *Shannon Entropy* (*H*). Intuitively, entropy estimates the average uncertainty of a series of discrete events. Given a discrete random variable *X*, Shannon entropy H(*X*) is:

$$H(X) = -\sum_x P(x) \log (P(x)), \quad (1)$$

where, P(x) is the probability that X is in state x.

In our study, we compute the Entropy for all eight fields in a NetFlow record: 1) Source IP address, 2) Destination IP address, 3) Source port, 4) Destination port, 5) Protocol, 6) Octets, 7) Packets and 8) Duration.

V. RESULTS FROM STATISTICAL ANALYSIS

Statistical analysis was performed to correlate the Internet usage data collected, with CES-D scores (both collected in February 2011). For each feature derived, Pearson's, Spearman Rho, and Kendall tau-b correlation coefficients were determined. Additionally, T-tests were attempted to identify Internet usage features that significantly differentiated participants exhibiting depressive symptoms from those that did not. The T-test assumes a normal data distribution and homogeneity of variance. Normality was verified by observing P-P plots, while Levene's test was used to assess the equality of variance. If the data deviated from a normal distribution, the non-parametric Mann-Whitney U-test was used.

Table V contains Internet usage features that correlate statistically with depressive symptoms (i.e., CES-D score ≥ 16). Results from Mann-Whitney U-test are presented next.

TABLE V. INTERNET USAGE FEATURES THAT STATISTICALLY CORRELATE WITH DEPRESSIVE SYMPTOMS (CES-D SCORES ≥ 16)

Internet Features	Pearson	Spearman Rho	Kendall tau-b
average packets per flow	.056	.137*	.198*
p2p octets	.173*	.075	.111
p2p packets	.236**	.106*	.160*
p2p duration	.265**	.098	.143
chat octets	.267**	.100	.145
mail packets	.164*	.050	.068
mail duration	.202**	.048	.064
ftp duration	.267**	.100	.145
remote file octets	.281**	.117*	.172*

**Correlation is highly significant at 0.01 level (2-tailed)
*Correlation is significant at 0.05 level (2-tailed)

Mann-Whitney U-test revealed statistically significant difference in the mean values of *average packets per flow* across subjects with and without depressive symptoms (U (216) = 2231, Z = -2.384, ρ (2-tailed) = 0.017). Subjects with depressive symptoms have higher *average packets per flow* (μ = 168.47, σ = 46.11) compared to those without symptoms (μ = 110.91, σ = 14.51).

Among Application features, Mann-Whitney U-test revealed statistically significant differences in the mean values of *remote file octets* across participants with and without depressive symptoms (U (216) = 2343, Z = -1.989, ρ (2-tailed) = 0.047). Participants with depressive symptoms have higher *remote file octets* ($\mu = 1.17 \times 10^{10}$, $\sigma = 1.88 \times 10^{10}$) when compared to those without symptoms ($\mu = 5.90 \times 10^{9}$, $\sigma = 5.97 \times 10^{9}$). Additionally, Mann-Whitney U-test revealed significant mean value differences in *internet relay chat (irc) octets* (U (216) = 2602, Z = -2.225, ρ (2-tailed) = 0.026); *packets* (U (216) = 2596, Z = -2.269, ρ (2-tailed) = 0.023); and *duration* (U (216) = 2608, Z = -2.182, ρ (2-tailed) = 0.029).

For the entropy based features, Mann-Whitney U-test revealed statistically significant mean value differences for *flow duration entropy* across subjects with and without depressive symptoms (U (216) = 2337.5, Z = -2.008, ρ (2-tailed) = 0.045). The results are summarized in Table VI.

TABLE VI. INTERNET USAGE FEATURES WITH SIGNIFICANT MEAN VALUE DIFFERENCE ACROSS SUBJECTS WITH AND WITHOUT DEPRESSIVE SYMPTOMS FROM MANN-WHITNEY U-TEST

Internet Features	U (216)	Z	ρ (2-tailed)
Average packets per flow	2231	-2.384	0.017
Remote File Octets	2343	-1.989	0.047
IRC (Chat) octets	2602	-2.225	0.026
IRC (Chat) packets	2596	-2.269	0.023
IRC (Chat) duration	2608	-2.182	0.029
Flow Duration Entropy	2337.5	-2.008	0.045

VI. Interpretations and Possible Applications of our Findings

A. *Interpretations of our Findings*

In this section, we present some practical interpretations to our findings by integrating them with existing research in the Psychological Sciences community on associations between depressive symptoms among college students and Internet usage.

Average packets per flow: The average packets per flow is high when a large number of packets are generated per flow. Larger number of packets per flow is typical under Internet streaming and downloading, which is common when watching videos and gaming. This is intuitive, as gaming and video watching are common symptoms of Internet addiction that have been shown to associate with depressive symptoms [18, 19, 20].

Peer-to-Peer usage: The correlation observed between peer-to-peer usage and depressive symptoms is intuitive. Sharing files like music, movies, photos etc. are primary reasons for using peer-to-peer services. Students are prone to be addicted to such kinds of content, which may explain this trend.

Chatting: Excess online chatting can affect the psychology of young people in terms of causing social isolation and loneliness in the real world, potentially leading to depressive symptoms [21, 22]. People with depression are also known to join "Depression Chat Rooms" to overcome feelings of isolation. This may explain Chat octets being significantly high for students with depressive symptoms.

Email: Excessive email usage identified in our study as statistically correlating with depressive symptoms is supported by studies in [22]. Frequent email checking may relate with high levels of anxiety, which in-turn correlates with depressive symptoms. It is also theorized that email addiction is a form of impulsive-compulsive disorder in the sense that victims (especially young people) suffer from a compulsive and irresistible need to check messages (often even in the middle of the night).

Flow Duration Entropy: As discussed before, difficulty concentrating or making clear decisions are symptoms of depressive behavior among students [27]. When Flow Durations have high entropy, it is likely a result of frequent switching among multiple Internet applications, which is likely to result in highly variable flow durations, and hence high Entropy. Frequent switching may also reflect an attempt to elevate feelings in the face of Anhedonia, when there is desperation to find something - an interesting article, an e-mail, a pleasing video, etc., to derive a momentary spark of pleasure and elevate mood.

Ftp and Remote File usage: It is not completely clear why ftp duration and remote file octets correlate with depressive symptoms. One interpretation could be that since excess ftp usage and remote file octets are indicative of excess file transfers, this could indicate addiction to certain types of files that may associate with depressive symptoms. In our study, we do not access the content of files exchanged, and hence we are limited in the nature of conclusions derived here. Interestingly though, ftp packets and ftp octets did not show statistically significant correlations; only the ftp duration did. Our on-going studies attempt to further explain these trends based on more discussions with counselors, clinical psychologists and educators, and with more experiments with larger subject sizes.

B. *Applications of our Findings*

There are a number of applications of our methodology and findings from this paper. We present three below.

Investigating associations between other mental health disorders and Internet usage: Our methodology is general and can be used to study associations between Internet usage and other mental health disorders like anorexia, bulimia, ADHD, schizophrenia etc. We could also investigate associations between other Internet features like visits to social networking sites, late night Internet use, and randomness in Internet usage times etc. with depressive symptoms.

Proactively discovering depressive symptoms from passive and unobtrusive Internet usage monitoring: Using the correlating Internet usage features derived in our study, we are currently investigating algorithmic techniques to proactively discover depressive symptoms among students by passive, unobtrusive and run-time monitoring of Internet usage. To do so, we are planning to conduct more large scale studies. However, there are practical concerns in terms of false positives and negatives, along with concerns on ethics and privacy of subjects in the realm of detection. While we believe that the techniques developed can assist in early, personalized and (possibly) in-home mental health care, we believe that a number of stakeholders from multiple disciplines and organizations need to be involved prior to their practical deployment.

Designing Internet (or Computer) based interventions for depression: There are many recent studies exploring Internet based intervention strategies for alleviating depression [28, 29, 30]. Our findings in this paper could yield new insights on designing and administering effective Internet based interventions for mental disorders. Our work can also enable run-time adaptation of intervention strategies based on severity of symptoms for a subject. Furthermore, our findings will impact the evaluation of Internet based intervention strategies. With our findings, one could easily test the efficacy of Internet based intervention strategies by verifying corresponding changes in correlating Internet usage features identified in this study. This, we believe will positively impact the design of effective Internet based interventions in the future.

VII. Conclusions

In this paper, we report findings from a study conducted at Missouri S&T on associating depressive symptoms among college students with their Internet usage. We have identified that *average packets per flow, peer-to-peer (octets, packets and duration), chat octets, mail (packets and duration), ftp duration, and remote file octets* show statistically significant correlations with depressive symptoms. Additionally, Mann-Whitney U-tests revealed that *average packets per flow, remote file octets, chat (octets, packets and duration)* and *flow duration entropy* demonstrate statistically significant differences in the mean values across groups with and without depressive symptoms. To the best of our knowledge, this is the first study associating Internet usage with depressive symptoms among college students using *real* Internet data collected in an *continuously, unobtrusively* and *preserving privacy*.

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