ABSTRACT
Persons who engage in non-suicidal self-injury (NSSI), often conceal their practices which limits the examination and understanding of those who engage in NSSI. The goal of this research is to utilize public online social networks (namely, in LiveJournal, a major blogging network) to observe the NSSI populations communication in a naturally occurring setting. Specifically, LiveJournal users can publicly declare their interests. We collected the self-declared interests of 22,000 users who are members of or participate in 43 NSSI-related communities. We extracted a bimodal socio-semantic network of users and interests based on their similarity. The semantic subnetwork of interests contains NSSI terms (such as “self-injury” and “razors”), references to music performers (such as “Nine Inch Nails”), and general daily life and creativity related terms (such as “poetry” and “boys”). Assuming users are genuine in their declarations, the words reveal distinct patterns of interest and may signal keys to NSSI.

Author Keywords
Interest, NSSI, Self-Injury, Similarity, LiveJournal

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces—Natural Language

General Terms
Experimentation, Human Factors, Languages

INTRODUCTION
Non-suicidal self-injury (NSSI) is the direct, deliberate destruction of one’s own body tissue in the absence of suicidal intent [11]. It is practiced primarily by adolescents and young adults [4] and is often concealed from others. Common NSSI activities include skin cutting, banging or hitting oneself, and burns [5]. Recent prevalence estimates suggest that 14% to 21% of adolescents and 17% to 25% of young adults have engaged in NSSI at some point in their lives [5, 12]. Furthermore, NSSI is repeatedly found to be associated with significant emotional and behavioral dysfunction (e.g., eating disorders, suicide [10]). These findings highlight the need to enhance understanding and prevention of NSSI and its psychiatric sequelae.

The goal of this research is to find mechanisms that could identify NSSI persons by automatically analyzing secondary data publicly available from massive online social networks (MOSN), without explicitly interacting with the subjects. Many popular MOSNs (e.g., Facebook and LiveJournal) allow users to declare their interests, either explicitly or in the form of “likes.” While these interests are often selected randomly and polluted with “status words,” we found a very significant correlation between interest lists and membership in NSSI online communities in at least one major MOSN—LiveJournal [9, 15], a blogging social network.

This association between interest lists and NSSI community membership suggests that “likes” or interest lists may be serving as identity signals “communicating aspects of individuals (e.g., group membership or other preferences) to others in the social world” [2]. Such identity signals gain greater meaning (i.e., signal value) as their association with group membership strengthens. From an identity-signaling perspective, identity signals with greater signal value can influence others, particularly others who aspire for group membership, to adopt behaviors characteristic of the larger group [2].

To investigate the value of interest lists generated by members of NSSI online communities in LiveJournal, we used the declared interests as nodes and similarities between their users as edges to build a semantic network. The layout of the network consists of four clearly separated word clusters, one of which corresponds to the pathological terms (e.g. “self-injury” and “razor”) and the other three refer to daily life, popular music, and creativity. We expect that the bridge terms that connect the pathology cluster with the remaining three clusters can be used as beacons signaling the potential presence of an NSSI behavior.

The rest of the paper is organized as follows: in Section 1, we describe the data acquisition process; Sections 2 and 3
explain the semantic network generation and the resulting network organization; network comparative assessment is presented in Section 4; in Section 5, we conclude and outline our future research plans.

DATA COLLECTION
Our analysis is based on the data set collected from LiveJournal—a popular massive online blogging social network site (BSN). A BSN allows individual bloggers to form contact lists, subscribe to their friends’ blogs, comment on selected blog posts, declare interests, and participate in communities—collective blogs. Thus, a blogging network is a bimodal venue where users engage in both publishing and social activities. As of Spring 2012, LiveJournal has 32 mln individual and community accounts. A LiveJournal user maintains his/her personal blog (public or private) and may be a member of an unlimited number of special- and general-interest communities.

We identified 43 NSSI-related communities in LiveJournal. Users are associated with the communities either explicitly (by membership) or implicitly (by posting to the community blogs without becoming formal members, where permitted). Some of these communities promote NSSI activities, while others advocate for NSSI abstinence.

We collected all self-declared interests of the 22,000 LiveJournal users associated with the selected communities (by membership or by posting, as described above). The total number of harvested interests is \( \sim 150,000 \), including misspelled, abbreviated, and hyphenated variants.

Thus, we formed a matrix \( M \) where \( M_{ij} = 1 \) iff the user \( U_i \) has declared the interest \( V_j \), and \( M_{ij} = 0 \), otherwise. In other words, \( M \) is the adjacency matrix of a two-mode network of users and their interests.

SEMANTIC NETWORK GENERATION
We use the matrix \( M \) to generate a semantic network of interests corresponding to the NSSI population. This network is a one-mode projection of the original two-mode network induced by the matrix \( M \). It is undirected, weighted, and signed. The nodes of the network represent interests \( I_i \) and the edges represent the corresponding general similarities \( C_{ij} \in [-1, 1] \).

Thematic (e.g., NSSI-related) communities are more homogeneous than general-interest communities. They consist of people who are similar in a certain sense. In an extreme case, all community members would be uniformly interested in the community subject and use common terminology. This similarity should be taken into consideration while calculating correlations between declared interests. It has been shown by Kovacs and confirmed by our finding that agent agnostic Pearson correlation underestimates the proximity of terms. Kovacs generalized similarity measures take the population structure into account. They are defined recursively:

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Let \( M_i = M_{i,1} - \overline{M}_i \), and \( M_{ij} = M_{j,1} - \overline{M}_j \) be the \( i \)'th row or the \( j \)'th column of the matrix \( M \), respectively, centered by subtracting the mean of the corresponding row or column. Then matrices \( \Theta \) and \( \Phi \) can be calculated recursively by starting with two appropriately sized identity matrices \( I \): \( \Theta_0 = I \), \( \Phi_0 = I \),

\[
\Theta_{i,j,k+1} = M_i \Phi_k M_j^T / \sqrt{(M_i \Phi_k M_i^T) (M_j \Phi_k M_j^T)},
\]

\[
\Phi_{i,j,k+1} = M_i^T \Theta_k M_j / \sqrt{(M_i^T \Theta_k M_i) (M_j^T \Theta_k M_j)}.\]

After a number of iterations the algorithm converges to the “true” values of \( \Phi \approx \Phi_\infty \) and \( \Theta \approx \Theta_\infty \). The similarities between community members \( \Phi \), though calculated, are not used in this study.

As a side note, in the case of totally heterogeneous population, \( \Theta = \Sigma \) and \( \Phi = 1 \) (each person is similar only to herself).

By construction, \( \Theta \) is a dense symmetric signed square matrix with few or no zero terms. The distribution of similarity measures in the matrix is close to uniform. The similarities in the matrix are sustained by the whole body of interests and are robust against random variations of individually declared interests.

Calculating \( \Theta \) for 150,000 interests is computationally infeasible due to time constraints and arithmetic imprecision. We restricted our study to the top 600 most often declared interests shared by \( \sim 14,000 \) NSSI bloggers. That was the largest matrix that could be evaluated on a 64-bit AMD desktop computer with 8GB of RAM.

SEMANTIC NETWORK ANALYSIS
To explore the organization of the semantic network of interests, we extracted some of the strongest generalized similarities between the interests by creating another adjacency matrix \( \Psi \):

\[
\Psi_{ij} = \begin{cases} 
\Theta_{ij} & \text{if } \Theta_{ij} \geq 0.8 \\
0 & \text{else} 
\end{cases}
\]

Matrix \( \Psi \) is square, sparse (its density is 12%), symmetric, undirected, weighted (in a limited range), and unsigned. It has 42,000 non-zero entries that correspond to 21,000 network edges.

We used program Gephi to visualize the network described by matrix \( \Psi \). The sketch of the network is shown in Figure 1. The network has a clear hierarchical structure. It consists of four major clusters: “music” (MUS), “pathology” (PAT), “daily life/emotions” (DLE), and “creativity” (CRE). Some most frequently declared interests from each of the clusters are shown below:
Figure 1. Semantic network of interests in the NSSI-related communities

**MUS**: atreyu, him, incubus, korn, my chemical romance, nirvana, rancid, system of a down, the perfect circle;

**PAT**: alcohol, anorexia, bulimia, burning, cutting, handcuffs, pain, self-injury and self-mutilation (both with and without the dash), spikes, weeds;

**DLE**: cameras, cloths, dvds, flirting, flowers, fun, quotes, smiling, hearts (also as an HTML entity ♥ and as ♥);

**CRE**: astrology, books, languages, philosophy, psychology, shakespeare, sociology, travel, wine.

There is surprisingly little connectivity between the clusters CRE and MUS. The remaining border zones are spanned with few important bridge interests:

**PAT/MUS**: (black) eyeliner, girl interrupted, metal;

**PAT/DLE**: candy, girls, insomnia, red, rock music, sex;

**MUS/DLE**: animals, camping, fashion, games, honesty, humor, travel(l)ing;

All four clusters: bands, bracelets, hoodies, lesbians, making out.

Since, from the point of view of the NSSI users, the bridge terms are similar both to pathological and non-pathological terms, their occurrence in a text may be a signal of a potentially NSSI behavior.

The presence of the tightly interwoven MUS component is equally surprising, given that music is not an explicit topic in any of the NSSI communities.

**SEMANTIC NETWORK COMPARATIVE ASSESSMENT**

While many of the associations shown in the map in Figure 1 may be specific to the NSSI community members, some may be either totally random or specific to the age or cultural group to which these members belong. Thus, some associations that seemingly suggest NSSI behavior, may turn out to be misleading.

To identify NSSI-specific information, we attempted to compare the NSSI communities to a random sample of LiveJournal users whose declared age distribution was similar to that of NSSI users. The members of the chosen sample seem to share very few interests with the NSSI population under study. This is not surprising, given that the ~32 mln LiveJournal users belong to different ethnic and cultural groups and, when chosen at random, are unlikely to share interests expressed by a small number of words form a very limited vocabulary.

Next we tried to find appropriate communities that may share interests with the NSSI population even given a very limited power of expression. After some research we identified two LiveJournal communities that have demographics similar to the NSSI communities and focus on non-pathological topics: “sexy-mood-music” (SMM, 6,700 members, average age 25 years) and “movies-in-fifteen-minutes” (M15M, 13,300 members, average age 28 years). These communities cater to music and video fans, respectively.

We collected the top 450 and 550 most frequently used interests of the SMM and M15M members and used the technique described above to generate their semantic maps $\Psi_{SMM}$ and $\Psi_{M15M}$. We then calculated the intersection between the NSSI semantic network and each of the other semantic networks under consideration. The intersection contains the associations that are significant for both communities and presumably are pathology-free.

We combine semantic network edges using fuzzy set theoretical operations for intersection and difference:

$$A \cap B = \min (\alpha, \beta)$$  \hspace{1cm} (2)

$$A \setminus B = \min (\alpha, 1 - \beta)$$ \hspace{1cm} (3)

Here, $A$ and $B$ are edges, and $\alpha$ and $\beta$ are generalized similarities associated with the edges.

Let $\Psi \cap x$ be the intersection of the original network and a comparison network $x \in \{SMM, M15M\}$. Then for each edge $e_{ij} = (V_i, V_j)$ in $\Psi$, if the corresponding edge also exists in $x$, then this edge is added to the intersection network with the weight calculated using Eq. 2. Otherwise, its weight is taken to be 0 to emphasize the lack of either similarity between the two terms:

$$(\Psi \cap x)_{ij} = \begin{cases} \Psi_{ij} \cap x_{ij} & \text{if } e_{ij} \in (\Psi \cap x) \\ 0 & \text{else} \end{cases}$$ \hspace{1cm} (4)

In other words, if two terms are considered substantially similar both in $\Psi$ and in $x$, then their similarity is universal with respect to $\Psi$ and $x$, that is, neither $\Psi$- nor $x$-specific.
The resulting intersection networks for $x \in \{\text{SMM, M15M}\}$ have fewer nodes (300 and 220) and about the same density (9% and 12%). We analyzed them using Gephi software (Figure 2) and discovered that they have a remarkably common structure: both networks have dense and strongly connected CRE and DLE clusters and smaller and less connected to the “mainland” music/movies clusters. The latter clusters, in turn, consist of easily identifiable “movies” (MOV) and MUS subcomponents.

The intersection networks with their structural similarity exhibit many characteristics observed in the typical adolescent development [7].

Next we adjust the original network with respect to the comparison networks as a way to better distinguish the features of the NSSI semantic network.

Let $\Psi \setminus x$ be the difference between the original network $\Psi$ and a comparison network $x$. If edge $e_{ij}$ exists in $\Psi$ but not in $x$, then it is essential and is inserted in the difference network with its original weight. If the edge exists in both networks, it is inserted with the weight calculated using Eq. 3. Otherwise, the edge exists only in $x$; it is irrelevant and is not inserted:

$$(\Psi \setminus x)_{ij} = \begin{cases} \Psi_{ij} \setminus x_{ij} & \text{if } e_{ij} \in \Psi \\ 0 & \text{else} \end{cases}$$

In other words, if two terms are considered substantially similar in $\Psi$ but not in $x$, then their similarity is $\Psi$-specific but not $x$-specific. These terms may be perceived as similar by the NSSI users because of their NSSI pathologies.

The adjusted NSSI interest network with respect to $x = \text{M15M}$ is shown in Figure 3. The new network has much less dense CRE and DLE clusters; cf. the original network in Figure 1. The PAT and especially MUS clusters are still very dense. From Figure 3 we can identify two groups of possible NSSI beacon interests:

**Non-PAT interests in PAT:** angelina jolie, bdsm, beer, being alone, bisexuality, black, boots, crying, dying, fire, fishnets, goth(ic), graveyards, hair dye, horror, industrial, lust, perfection, porn, serial killers, sex, tattoos, tears, vampires, wicca, witchcraft, etc.

**Bridge interests:** anxiety, bracelets, corsets, edgar allen poe, emotions, (black) eyeliner, girl interrupted, girls, glitter, horror movies, insomnia, leather, lesbians, magick (sic), marylin monroe, (heavy) metal, night, poems, red, safety pins, screaming, spikes, techo, tori amos, etc.

Our findings also appear indicative of the growing global middle-class youth culture revolving around leisure activities (e.g., music, art) reflecting adolescent development in internationally-connected networks [7]. This is further supported by the similarities between the NSSI interested communities and the non-pathological comparison communities. Notably both sets of communities included entertainment, creativity, and daily life clusters.

**CONCLUSION AND FUTURE WORK**

Exposure to NSSI via Internet use (e.g., MOSNS, YouTube) may facilitate the adoption and maintenance of NSSI among vulnerable individuals via social contagion processes [8,14]. With this in mind, we constructed a semantic network of interests declared by non-suicidal self-injury (NSSI) bloggers of LiveJournal. The network consists of four clearly separated interest clusters corresponding to the pathological terms (e.g. “self-injury” and “razor”), daily life, popular music, and creativity. The interests that bridge gaps between the pathology cluster and the other three clusters can be used as beacons signaling the potential presence of an NSSI behavior. These bridge interests appear to be valuable identity...
signals [2] serving as linkages between NSSI group membership and larger youth culture. Future research targeting individuals use of these bridge terms as a means to identify NSSI-oriented social groups would further support this interpretation and could inform prevention efforts aimed at early identification of vulnerable individuals at risk for NSSI.

In related research individuals with a history of NSSI are found to view themselves negatively (e.g., less intelligent and more emotionally unstable) and as having lower social capital (e.g., less attractive, weak social skills [3]). The extent of MOSN NSSI-related communities on LiveJournal could evidence the limited opportunities for social networking among people (e.g., self-harmers) who find themselves excluded from their local communities/local peer networks. Future work is needed examine how members of NSSI-related communities use MOSNs to affirm a sense of meaning and obtain social support and expanding social capital. At the same time, increased time in unstructured peer interactions via NSSI-related MOSNs may lead to further involvement in deviant and antisocial behavior in early adulthood [7].

In this study, we considered only self-declared interests displayed on the bloggers’ profile pages. Some of these interests may have been chosen randomly or based on certain (sub)cultural considerations, and do not necessarily reflect the real user’s attractions. As the next step in this direction, we plan to study keywords in the messages posted to the NSSI communities. We expect that the free-form language of the messages is a better proxy for the pathological involvement in deviant and antisocial behavior in early adulthood [7].

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