Socially Influencing Technologies for Health Promotion: Translating Social Media Analytics into Consumer-facing Health Solutions

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Abstract
Health-related online communities are increasingly popular platforms on which consumers engage in peer-to-peer communication while seeking and providing health-related information. These platforms provide an empirical account of user communications related to health behaviors. Several advanced analytical approaches have been developed to unearth and characterize social influence mechanisms embedded in these platforms. However, translating these insights into design features of consumer-facing health promotion information systems presents very significant challenges. In this paper, we present a design methodology that utilizes persuasive principles and lessons learned from large-scale analysis of an online community for smoking cessation, to harness social influence and implement as technological features of a behavior support intervention. We transformed observed social diffusion patterns underlying user communication events to user-participatory interactions that can potentially lead to superior user engagement through meaningful network affiliations and thence to sustained healthy behavior change. Preliminary evaluation study and future steps are discussed.

1. Introduction

Online social media platforms are being used by hundreds of millions of users worldwide. In conjunction with mobile phones, these platforms capture a rich and real-time account of an individual’s inter- and intra-personal activities as one goes about their daily lives in their natural settings [1]. Driven by the motivation of users to share personal experiences and knowledge, social media platforms (e.g. PatientsLikeMe, MyFitnessPal, specialized Facebook communities) form the crux of participative health communication in the digital era [2-5]. The influence of social relationships and social support on health behaviors has been well documented [6,7]. While associations between social relationships and health are complex and not necessarily causal in nature [8,9], evidence suggests that the positive health enhancing effects of social relationships can be used for the promotion of healthy behaviors [7]. The electronic nature of large scale peer-to-peer user communication in online communities enables granular and comprehensive study of communication patterns underlying health-related behaviors. Recent advances in text analytics [10-12], in conjunction with network simulations have enabled us to gain deeper insights into the social influence and network diffusion mechanisms [13,14] underlying human behavior. However, the ways in which these empirically-derived insights can be translated into technological support solutions are poorly understood [15]. Recent studies on socially influencing systems provide a feasible opportunity for such work [16-18]. In this paper, we describe a study that demonstrates the translation of actionable insights derived from online social media analytics to health promotion technologies that harness and amplify social influence mechanisms inherent in peer-to-peer communication environments. The contributions of this work are, methodological and applications-related in nature, to the fields of health informatics (specifically consumer informatics) and public health (specifically health promotion). The system design methodology outlined in this paper provides a clear illustration and real-time example of data-information-knowledge paradigm, which is the crux of health informatics discipline [19]. In addition, we integrate persuasive design strategies to social informatics applications that are data-driven as opposed to the traditional theory-driven feature design of health-related behavior change application.

The rest of this paper is organized as follows. Section 2 presents relevant background and research objective, section 3 presents methodological framework, section 4 presents the application of our proposed framework to the development of smoking
cessation interventions based on large scale analysis of an online community, section 5 presents the results of preliminary focus group session, and the rest of the paper presents a discussion of study limitations, future studies, and conclusions.

2. Background

According to recent estimates, approximately 80% of internet-using adults in United States go online to seek health information [20]. With the advent of health 2.0 technologies, including online social media resources and blogs, health consumers have been able to share information, ideas, personal messages, images, and other content; and, in some cases, to collaborate with other users in real time. In addition, users challenged by unknowns of health issues faced by self and/or loved ones often turn to peers for emotional and information support [21,22]. Around 1.5 billion people (1/7th of the world’s population) now use a single social networking service, Facebook [23].

To curb the growing health care costs and improve the efficiency of health and wellness programs, it may be possible to exploit the advantage of technologies such as online social networks that can deliver just-in-time support required for a person to adhere to health-related behaviors. In addition, these networks have the capability to deliver interventions to large populations. Today’s social media platforms can be broadly classified as 1) open social networks, or 2) intentionally designed social networks [24]. Open networks such as Twitter and Facebook support social interactions on any topic, while intentionally designed networks such as PatientsLikeMe and QuitNet provide platforms for participants seeking targeted interactions pertinent to health-related goals. A variety of socio-behavioral interventions have been developed to support healthy lifestyle changes by facilitating attitudinal change, behavioral adherence, and the availability of a support network [25-27]. On account of the availability and accessibility of the World Wide Web via mobile phones, online network interventions occur in real-time, and can provide a rich documentation of certain crucial moments in everyday life that can have positive or negative effects on a person’s journey toward healthy behaviors [28,29]. Therefore, online social networks can form the basis for ecological momentary assessments and interventions. These networks form a core component of Health 2.0, which is defined as “user-generated health care promoting patient empowerment and participation” [30]. As the networks mature with scale, their social value increases, and their data can provide valuable insights into fundamental questions of human behavior [24]. To date, scientists have attempted to analyze online social network data to solve a variety of health-related questions.

2.1. Health-related Social Media Analytics

Given the qualitative and quantitative richness, analysis of online social networks demands multidisciplinary approach to deal with its intricacies. Researchers from diverse fields including social science, psychology, behavior science, epidemiology, computer science, and network science have analyzed real world network data yielding valuable insights into social influence, information spread, behavioral diffusion, and structural clues to identify key players and opinion leaders [31-33]. Traditionally, there have been two predominant streams of studies on online social networks. The first category focuses exclusively on content, while the second category concentrates on structural and functional aspects of a network with no consideration of content. As part of our previous work, we have developed a new analytics method that enables content-inclusive analysis of user communication in online social media platforms. We have used automated methods from distributional semantics to merge the qualitative and quantitative threads of network science. The development of such a “structure plus content” network analysis method has enabled us to investigate inter- and intra-individual behavioral intricacies underlying large scale health-related online social media datasets. Detailed description of the method is beyond the scope of this paper, and we refer readers to [34,35]. Application of our method to an online community on smoking cessation revealed interesting patterns that offer potential avenues to improve content delivery, and consequently social engagement and health behavioral adherence. Such insights derived (described in Section 3 in detail), through our work and other network analytics studies, can be fully exploited only when the lessons learned can be translated into user interactive behavior support technologies.

2.2 Socially Influencing Systems and Persuasive Systems Design

The field of Socially Influencing Systems (SIS) [16], which draws from the Persuasive Systems Design (PSD) model [36], Bandura’s Social Cognitive Theory (SCT) [37], sets the stage for understanding the design process of information systems that harness social influence by enabling the study of dynamics among behavior change, user engagement, and social media use. Fogg suggests the use of computers the use of computers to provide people with support environment that enables them achieve and sustain a behavior
change by reducing barriers, changing mental models, and increasing individual’s self-efficacy [38]. In case of online communities, these avenues act as computer-mediated persuasive systems where the sources of persuasion are the messages posted by users through a computer-mediated environment. Through online social media analytics, we should be able to translate the empirically-derived influence patterns to develop a stand-alone persuasive environment, where the system itself would act as the persuader, (or) an add-on system to an existing online community which would amplify the peer influence tactics, resulting in superior computer-mediated persuasion, (or) a hybrid system with both modes of persuasion. The PSD model describes the persuasive characteristics in four categories: Primary task support, Dialogue support, System credibility support, and Social support. Specifically, the social support category outlines seven design principles that can potentially transform traditional information systems into socially influencing systems. These principles are listed as follows [36].

**Social learning:** This principle is related to the observational learning principle in SCT. A person’s beliefs towards a behavior will be reinforced by observing other people performing the same behavior. The PSD model suggests that the proposed system should provide means to observe other users who are performing their target behaviors and to see the outcomes of their behavior.

**Social comparison:** This principle suggests the inclusion of functionality that lets a user compare self-performance with the performance of other users and observe the potential effects of actions.

**Normative influence:** This principle attempts to utilize peer/societal pressure as triggering mechanisms for uptake of a behavior. Such system features would pull together users with similar goals onto a unifying platform and subsequently establish subjective norms.

**Social facilitation:** This principle builds on the notion that users perform an action while being watched by others. Features in technology design that allows users to perceive that other users (peers) are embracing similar behavior along with them will embody this construct.

**Cooperation:** This principle takes into account the users natural inclination towards cooperation to achieve a common goal. System features that allow users to work with one another toward a unified goals will help us draw this influence mechanism to user interactive design.

**Competition:** Systems features that allows users to compete with one another as they venture toward the same target behavior. Gamification, leader board challenges might be helpful in this regard.

**Recognition:** Acknowledging achievement of short term goals and small scale changes provides a sense of social acceptance, social liberation, and self-liberation. Reinforcements and rewards can be used as vehicles to instantiate this principle.

Recent studies have attempted to understand the interplay between these social influence principles and design of behavior change support systems [16,39]. Specifically, this body of work described how social influence principles could be implemented as software features in information systems through utilization of persuasive design framework. Our previous work [40] on content analysis a health-related online community using PSD model has revealed the manifestation of six out of seven social influence principles described above [36]. Through large scale social network analysis, we have found the manifestation of additional behavioral constructs correlated to higher abstinence rates from smoking [34,35]. Those identified constructs can be implemented as part of system features through use of these seven principles outlined in PSD model to effectively harness social influence mechanisms (discussed in Section 4).

Our system design paradigm draws inspirations from related work in the fields of human computer interaction and behavior science, where theory-driven technology design is prevalent [41-43]. Building on contemporary strategies, our work attempts to embody the granular understanding of the organic evolution of peer-to-peer communication in online communities attained through the design of behavior change support systems that are empirically-motivated. Bringing such ecological design philosophy to SIS requires the translation of network diffusion and influence patterns, which are extracted using social media analytics, into interactive functionalities of information systems using the “Social support” design constructs in the PSD model.

**Research objective:** In this paper, we explore the ways in which the empirically-derived network diffusion patterns can be transformed into features of consumer-facing health information systems for behavior change. Such methods might result in technologies that make effective utilization of social support characteristics while minimally disturbing the natural balance of human interactions.

### 3. Proposed Methodological Framework

The proposed framework has two distinct transition curves, ‘data to knowledge’ and ‘knowledge to system design’. As shown in Figure 1, the initial starting point of the proposed framework is an online community
where users interact with one another as they strive to initiate and/or adhere to a new health-related behavior. The peer communication events that define the structure and content of communication in an online platform are then subjected to a detailed analysis in the ‘Social Media Analytics’ engine. This engine can comprise methods that are qualitative, quantitative, and automated in nature. For illustrative purposes, we have outlined a possible analytical structure in Figure 1, where we integrated behavior change theories with text analysis algorithms and network diffusion models. This combination of methods has been adopted in our previous studies [34,35]. Other examples of the methods that can be used in the analytics engine include- cognitive models of reasoning, structural equation modeling, machine learning, and health economic and marketing models. Based on the methods adopted in the analytics engine, one can derive correlation and influence patterns that describe the attributes of social engagement, attitude evolution, and behavioral diffusion, and consequently understand the communication factors underlying human behavior in online platforms. Such an analytics engine is the crux of the ‘data to knowledge’ loop, where we utilize communication events in online communities to derive knowledge underlying, (a) empirically-driven behavioral technologies, which are either standalone or network-embedded in nature, synthesized based on emergent user needs as reflected in one’s online messages, and (b) digital network interventions motivated by theories and models of health behavior change, which are originally proposed in the context of face-to-face communication. Having extracted this knowledge from online social media platforms, the second step involves the transformation of knowledge into user-interactive features of health promotion technologies. The operationalization of social support and influence patterns will lead to socially influencing technologies that may facilitate increased user engagement and consequently sustained healthy behavior changes. Meeting the stakeholder needs is critical for the resulting support systems to reach their desired functionality. An online social community setting would provide the basic environment for involving individuals who have the intention of influencing their peers’ attitudes or behavior. Other critical requirements of behavior change support systems include sustaining users’ long-term interest in adopting and utilizing the system, usability, and transparency [39]. The framework incorporates a design bench that enables the translation of the knowledge derived from our analytics engine to an interactive information system. The method underlying the design bench can adopt any of the existing system design frameworks focusing on persuasive technology, SIS, user engagement, participatory design models, and usability methods. In the context of this paper, we exclusively focus on the second transition, ‘Knowledge to System design’. As part of this process, we implement the PSD model, specifically, social support principles to emulate an interactive component within an online social community. The functionality of the embedded component is to enable meaningful network affiliations that are found to be correlated with healthy behaviors (abstinence from smoking). For illustration purposes, we provide a brief description of some of the knowledge patterns derived from our previous work on smoking cessation (data to knowledge phase) [34,35]. Individuals exchanging messages related to Quit benefits, Quit Obstacles are correlated to higher levels of abstinence from smoking. Similarly, individuals affiliated to successful quitters through exchanging messages related to social support, motivation are found to have higher abstinence rates. Therefore, we chose to implement social recommender systems that expose users to meaningful content and facilitate meaningful network connections that are correlated to higher abstinence rates from smoking.

![Figure 1. Design lifecycle of socially influencing technologies for health promotion utilizing online social media analytics](image-url)
In the next section of the paper, we use social influence principles within PSD to translate these insights into actionable system design features (knowledge to system design phase).

4. Application to Smoking Cessation

In this section, we describe the ‘Knowledge to System design’ transition described in the proposed framework in Section 3. We implement the knowledge patterns outlined previously through utilization of social influence principles in the PSD model. Such integration has resulted in a SIS that facilitated meaningful user-to-user and user-to-content connections, which may presumably lead to higher smoking abstinence rates. As described in Section 2.2, these social factors are based upon the results derived from our analysis of user communications in an online community for smoking cessation [34,35].

The resulting SIS was designed in the context of an online community for smoking cessation. Figure 2 provides an example of the health education module in the resulting consumer-facing information system, ‘SIT2Quit’ (Socially Influencing Technology to Quit Smoking). ‘SIT2Quit’ users are provided with a range of information related to smoking cessation. The users are able to provide feedback on the content delivered using the intervention and refer content to their peers. The level of abstraction of this section, particularly in the description of technological considerations of the proposed system, is intentionally aimed at ‘universal’ applicability irrespective of target operating system and social media platform. Our aim is to identify the system design principles that should form the crux of behavior change support systems that are analytics-driven, theoretically-aligned, and empirically-motivated. The prototypes shown in this paper were created to suit a web-based application (developed using .Net framework) running on Windows environment.

To start with, the users of ‘SIT2Quit’ are introduced to the notion of a new virtual challenge, “Clean Air Initiative”. As part of this challenge, the users are asked to grow and nurture a virtual nursery of flowers. The representation of “flower” used in this strategy was chosen as a universally appealing symbol. Thus, a flourishing garden of flowers, grown essentially from scratch, is very likely to be perceived as personally rewarding activity. Our strategy is to link a thriving flower garden to a behavioral target, i.e. abstinence from smoking, as well as participating in social behaviors that support abstinence. New users start with an empty nursery and progress to a garden well stocked with different types and colors of flowers provided they maintain lengthy periods of abstinence and participate in the supportive social actions. Achieving, and viewing, such a garden curated by self and peers is a satisfying experience that corresponds to the social influence principles described in Section 2.3.

Figure 2. User-facing environment of SIT2Quit health education module
Social learning, comparison, competition are the important principles that ‘SIT2Quit’ corresponds to. The infusion of the aforementioned social influence principles (derived from the PSD model) into the ‘SIT2Quit’ environment is discussed in the following paragraphs of the paper. Implementation of these principles is accomplished by the construction of virtual nurseries that depend upon users’ adherence to their quit. The intent of the “Clean Air Initiative” is to promote socially influencing connections within ‘SIT2Quit.’ A user can grow a flower garden which responds to user’s actions as follows.

Response#1- Users can grow different colored flowers when they make connections with other abstinent users through sending messages related to specific content (e.g. Social support, Progress). Again, this features embodies our earlier finding which revealed that users more exposed to other abstinent users who reported abstinence through sharing the group-centric interpersonal are more likely to stay abstinent. The first column in Figure 3 demonstrates this workflow for promoting meaningful peer affiliations via content, which gives the users capability of nurturing various colored flowers of the same kind.

Response#2- Users achieve the ability to grow different types of flowers when they interact with specific content types (eg. benefits, obstacles). This feature implements the results of our prior work using social media analytics, which indicated that users communicating specific content types, such as obstacles and benefits personally experienced by community members, are more likely to stay abstinent. The second column in Figure 3 represents the ability of users to grown multiple types of flowers by interacting with content that are found to be helpful for smoking cessation. Figure 4 provides comparison of two nurseries distinguishing the users’ affiliation with specific content types. The user associated with the bottom nursery has made more affiliations to suggested content in ‘SIT2Quit’ when compared to the user associated with the top nursery.

Response#3- where the number of flowers links to the progress of one’s abstinence from smoking. The flower count is directly proportional to a user’s achieved length of abstinence. As seen in Figure 4, the bottom image corresponds to the nursery belonging to a user who is abstinent for longer time period when compared to the user corresponding to nursery in the top image. Figure 4 also demonstrates the presence of social influence principles- learning, comparison, facilitation, and normative influence. In addition to the Clean Air Initiative, the proposed ‘SIT2Quit’ system comprises of a recommendation system that eases the users into the Clean Air Initiative module and the use of the intervention as a whole.
As illustrated in Figure 5, users are provided with recommendations to interact with users and content in the ‘SIT2Quit’ platform. Four recommendation components are used for this purpose. The first one exposes users to specific content posts that are found to be correlated with abstinence from smoking. Accessing content furnished in this component will allow users to elicit Response#2, therefore will be able to grow different flower types. The second recommendation component exposes users to their peers, who are successful quitters based on their self-reported smoking status. Users will be able to exchange content with the peers recommended by the system through a pre-selected category of posts curated based on the results derived from our prior analytics work. User interactions facilitated via this component will elicit Response#1, therefore the users will be able to grow same kind of flowers in varying colors. The third and fourth recommendation components let the users browse through the content referred by their peers and watch the nurseries nurtured as part of the Clean Air Initiative. The social influence principles- cooperation, social learning, normative influence, comparison, and social facilitation are imparted using these recommendation entities. Finally, the last component is the “Featured nursery” component, where a user and the corresponding garden are given public recognition in the ‘SIT2Quit’ environment. In addition to the recognition principle, this module also elicits competition and normative influence among ‘SIT2Quit’ users.

5. Preliminary Evaluation

We have conducted a preliminary focus group session with an advisory group of stakeholders comprising of health professionals and health consumers. The focus group participants were shown an interactive web-based and mobile prototype created using C#, Microsoft .Net framework, and JQuery. The participants were asked open-ended questions to understand the levels of user engagement, system usability, and perceived usefulness of the proposed design methodology and ‘SIT2Quit’ design environment. All participants expressed confidence in the proposed design methodology that involves the translation of analytics derived based on social media interactions. All participants preferred (voted favorably for) implementation of analytical insights that consider social network communication frequency and content, to insights derived from communication frequency alone. The ‘SIT2Quit’ design concept was received favorably. Three out of the six participants felt that the proposed intervention would lead to frequent engagement with the online community itself. Four out of six participants indicated that the idea of a virtual nursery is universal, however, the remaining participants indicated that inclusion of gardening...
capabilities beyond flowers (e.g. vegetables, shrubs) would be appealing. All participants in the focus group mentioned that they would prefer a mobile environment, rather than web-based version. When asked about their preference levels for the gaming component (i.e. virtual nurseries) and the recommendation system, the participants preferred to interact with both modules, and did not indicate inclination towards one module over the other. In addition, to the ‘Featured nursery’ feature, the users suggested the implementation of a tangible rewards mechanism to establish a real-world association to the ‘SIT2Quit’ intervention.

6. Discussions, Limitations and Future steps

The proposed methodology described in the paper has utilized the PSD model to feed the knowledge derived through social media analytics into ‘SIT2Quit’ intervention. The PSD model enables the infusion of social influence principles into the user interactions of an empirically-motivated socially influencing system by transforming the knowledge derived from analysis of user interactions in a health-related online social media platform. While this study limits the use of PSD model to social support category in ‘SIT2Quit’ development, other categories (primary task support, credibility, dialogue support) are also equally important and applicable to this context. As part of the future work, we will employ all applicable elements of PSD model to our technology design. ‘SIT2Quit’ design can be further informed through adoption of consumer engagement models [44,45] and usability methods [46,47]. As suggested in the SIS framework [16], we have not made clear distinctions for system interactions between novice and seasoned users. Future design simulations should take into account the demarcation between the intervention functionalities and the intended outcomes at three different levels, attitude, engagement, and behavior. In addition, adaptive modulation of the ‘SIT2Quit’ environment is vital to provide efficacious support infrastructure to its users. Integration of analytics via architecting recommender systems [48] and automated user engagement characterization [49] can help us personalize user exposure to the system. Finally, the intervention features described in the paper have not been fully implemented. Future work should implement and evaluate the effect of multiple components of ‘SIT2Quit’ in terms of technology acceptance, behavioral outcomes, and user engagement.

7. Conclusions

The use of computer-mediated behavioral support has been long standing in public health. In the recent years, online communities have evolved as unique ecological platforms that facilitate a bidirectional feedback loop for health interventionists, system designers/developers, and actual end-users. In this paper, we describe a methodological approach to make a leap from large-scale datasets garnered from online communities to socially influencing health promotion interventions. The method has two distinct constituents- a social media analytics engine and a system design bench. In this paper, we focus on the later component, and describe the use of the PSD model to design a socially influencing technology for smoking cessation. The proposed system uses the social influence principles outlined in the PSD model to build novel computer-mediated user-interactive features that harness the power of social connections. These features aim at harnessing social diffusion mechanisms observed in an online social community to facilitate meaningful network affiliations among users and intervention content, and therefore health-related behaviors. The integration of multi-disciplinary methods from health informatics, public health, and network science to advance user-generated social media analytics, have pushed the research frontiers in the arena of behavior change support systems. Consequently, efforts to translate data-driven actionable insights of health behavior change into user-interactive technologies are imperative to (a) advance the dissemination, uptake, and utility of scalable health promotion programs, and (b) improve health outcomes using scalable and financially feasible population-based initiatives.

8. References


