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Web-based Peer-Driven Chain Referrals for Smoking Cessation

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Abstract

Background—We are testing web-based respondent-driven sampling (RDS) chain referrals to recruit smokers to the Decide2Quit.org (D2Q) web-assisted tobacco intervention.

Methods—Using an online survey of smokers, we assessed the potential of recruiting 1200 smokers in 9 months using RDS chain referrals. RDS is a complex sample design, and many factors can influence its success. We conducted simulations to determine the design of optimal RDS chains.

Results—Smokers (n=48) were mostly female (72%) and between ages 30–60 (82%). Estimation of smokers in their network: 1–5 (40%), 6–10 (24%), and 10–20 (22%), with mean number of intimate family (2.2, SD=2.1) and close friend smokers (3.7, SD=3.8). Most smokers (82%) were willing to refer to D2Q and thought their friends (mean=5.0, SD=4.4, range=0–20) would be open to referral. Simulations suggested that with a quota of 3 and 10 seeds, 99.9% of the sample would be achieved in 107 days if the acceptance probability was 0.5. Acceptance probability of 25% would necessitate an increased quota.

Conclusions—Our study suggests that it is possible to recruit smokers using RDS.

Keywords

Internet interventions; web-assisted tobacco interventions; Internet recruitment; peer-driven chain referral; respondent-driven sampling

Introduction

Internet interventions have been defined as systematic treatment or prevention programs delivered via the Internet to an end user [1]. Taking advantage of tailored message capabilities, such interventions can be highly structured, interactive, visually rich, and self-guided [1][2]. Effective and often inexpensive, Internet interventions remain an underutilized means of addressing public health problems [1]. Although more than three-

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quarters of American adults now have access to the Internet, recruitment to these interventions is an ongoing challenge [1][3–6].The use of peer-driven chain referrals is an established method for recruiting hard-to-reach persons by means of their social networks [7–9]. Outside healthcare, innovative marketers are successfully using web-based peer-driven chain referrals to recruit their users [10[11]. However, web-based chain referrals as a means of recruiting patients to Internet interventions have yet to be extensively studied.

Within the context of smoking cessation, a major public health challenge and the number one preventable cause of premature death in the United States [12–16], we are building proactive web-based chain-referral tools (e.g., email and Facebook referrals) to recruit a sample of 1200 smokers in 9 months to a web-assisted tobacco intervention. Smoking is a behavior that members of a social network commonly share, and therefore, smoking cessation efforts may be ideally suited for a peer-driven referral recruitment strategy. We are implementing respondent-driven sampling (RDS) [7][17], an advanced chain-referral method designed to remove inherent biases and provide sample weights to estimate the success of the process in the population. Chain referral methods yield a convenience sample that is not necessarily a representative sample of the population of interest. RDS provides a method of quantifying and adjusting for biased samples. Using RDS sample weights we may, for example, be able to say whether a certain demographic or risk-group is underrepresented in our sample. RDS methods also provide a means of insuring that our sample is not overly correlated with the initial sample 'seeds' which are selected non-randomly and are likely to not be representative of the overall population.

We conducted a formative study of smokers using an online survey. Data from this study informed an RDS simulation, the goal of which was to assess the probability of successfully recruiting 1200 smokers via peer referral within 9 months, using varied assumptions about how likely referred smokers would be to accept referrals. In this paper, we describe smokers' prior website referral behavior, their social network characteristics and their willingness to refer to D2Q, and we present our comparison of demographic characteristics of smokers willing to refer with national data on smokers using the 2011 Behavioral Risk Factor Surveillance System (BRFSS) dataset. We also present the results of our RDS simulations.

Materials and Methods

Study Design

In a formative study, we conducted an online survey of smokers. Our study was approved by the University of Massachusetts Medical School Institutional Review Board.

For our survey, current or former adult smokers were recruited online using search engine advertisements between July 1, 2012, and July 30, 2012.

The BRFSS is a yearly, cross-sectional telephone survey conducted by state health departments and the Centers for Disease Control and Prevention to collect prevalence data on risk behaviors and preventive health practices that affect health status [21]. We present data from the 2011 BRFSS dataset because it was closest to our sample. No direct methods

were used to compensate for non-telephone coverage; however, post-stratification weights were used to partially correct for any bias caused by no telephone coverage. These weights also adjusted for differences in probability of selection and non-response. A more complete description of the sampling methodology may be found on the BRFSS website [18]

Respondent-Driven Sampling Chain Referrals

Recruitment to web-assisted tobacco interventions poses unique challenges. Current methods of recruitment mostly attract smokers who are female, white, and ready to quit [19–21]. Recruitment using RDS provides two advantages to a web-assisted tobacco intervention. The use of quotas potentially reduces the number of fake referrals (non-smokers) to the intervention. Additionally, RDS increases the chances of obtaining a representative sample, which would increase the generalizability of the intervention.

Like other chain-referrals, RDS begins with the recruitment of initial participants known as “seeds,” who have a particular characteristic of interest [7][17] . The initial seeds then recruit individuals from their current social or risk-behavior network for research participation. Successive sets of respondents then recruit individuals from their social network for participation. RDS is a complex sample design, and there are many factors that can influence the rate of sample collection and the probability of successful collection of the target sample size. While many aspects of the RDS sample design cannot be controlled (time to recruit and the number recruited by each recruiter), a few aspects can be used to influence the RDS chains. These include the recruitment quota (the maximum number of recruitments allowed for each participant) and the number of initial seeds.

The recruitment quota is the easiest parameter to adjust without altering the cost of sample collection. RDS sample design aims to identify the minimum recruitment quota needed to attain the target sample size within a certain amount of time. Quota adjustments allow those conducting the study to reduce the probability of sample die-out (i.e., the condition of having no eligible recruiters) to acceptable levels.

In the case of sample die-out, it is usually necessary to restart the sample with new seeds, and this entails additional costs as well as a reduction in the effective sample size, since seeds are not used in most analyses. If the goal of sample design is simply to collect the target sample size quickly with low probability of die-out, then it is clearly optimal to put no constraints on recruitment at all (i.e., no recruitment quota). Such a strategy will, however, yield highly correlated samples with large design effects [22][23]; such samples will be much less efficient than simple random samples. RDS samples are also correlated with the initial non-random selection of seeds, which introduces bias into estimates based on RDS samples [24]. Thus, best practices of RDS recommend starting the chains with a lower number of seeds. We conducted our simulations with 10 seeds.

RDS samples may also have high intra-sample correlations, since sampled individuals are connected in a social network, which can reduce the efficiency of RDS. Intra-sample correlations are reduced if a random pair of sample units is distant in the social network (high mean path length). Increasing the number of waves (high mean recruitment tree depth) of the RDS sample also reduces bias due to the non-random selection of seeds.

Data Collection

Data was collected online. Respondents reported on their prior website referral behaviors, estimation of the number of smokers in their social network [overall number and the relationship of each person to the respondent (i.e., immediate family, close friend, etc.)], and their willingness to refer to D2Q. In addition, the survey asked respondents to estimate two key parameters needed for our RDS simulation: (a) time required for recruitment; and (b) number of expected recruits per seed (i.e., how many social contacts the respondent thought would be open to chain-referral recruitment).

The BRFSS questionnaire included a standard set of questions asked by all states about current health-related perceptions, conditions, and behaviors, including smoking, as well as demographic questions. We used the question — Do you now smoke cigarettes every day, some days, or not at all? — to identify smokers in the 2011 BRFSS dataset.

Data Analysis

First, we used descriptive statistics to assess smokers' prior referral/referring behavior, number of smokers in their social networks, and number of smokers willing to refer their friends and family to a web-assisted tobacco intervention.

Second, we compared the demographic characteristics of our smokers willing to refer to a web-assisted tobacco intervention with the national population of smokers in the BRFSS dataset. Since our goal with the RDS was to obtain a representative sample, we used this analysis to assess the differences between our non-random sample of smokers who are willing to refer and the general population of smokers.

Third, we used the RDS Simulator (RDSS) [25] to model the projected recruitment pattern under scenarios that varied the acceptance probability and quota. In all, five scenarios were simulated, each with one thousand simulations. Acceptance probability was defined as the probability of a smoker registering with D2Q following a referral. RDSS predicts the probability of sample completion as a function of time and the probability of sample die-out. RDSS accepts the following parameters: 1. The number of seeds (initial participants); 2. The probability that each recruiter (including seeds and downstream recruiters) successfully recruits k times; 3. The mean time required for each recruitment; and 4. The targeted completion time (i.e., the number of days allotted for recruiting the total sample).

A large number of recruitment trees are simulated using continuous time stochastic branching processes (CTSBP) [26] and we recorded the time required for each recruitment tree to reach completion. In CTSBP models, each unit in the sample produces an independent and identically distributed (iid) number of recruits from the given distribution. The time from when a seed starts participating in the chain-referrals to subsequent recruitments are also iid random variables; we use the exponential distribution. We used Gillespie discrete-event simulations [27] in order to generate the number of sample units over time. We parameterized simulations using the formative surveys described above. These were used to estimate the probability of recruiting k individuals and the mean time to recruitment. Sociometric degree was assessed by the counting method of McCarty et al [28].

According to this method, social contacts are tallied according to membership in different categories, such as whether they are friends, family, or co-workers.

Some samples may die out, and these events are also recorded. The set of simulations provides an asymptotically unbiased estimate of the probability of the following: 1. Sample die-out; 2. Successfully reaching target sample size at or before the targeted completion time; and 3. The time of sample completion conditional on reaching the target sample size. We also estimated mean path length and mean recruitment tree depth. Mean path length is the distance between a random pair of sample units in the social network. Mean recruitment tree depth is the average of the length of each of the chains in the social network.

Results

Overall 48 smokers participated in the online survey. The comparison 2011 BRFSS dataset included 83,144 smokers aged 18 and older.

Prior Referral/Referring Behavior of Online Smokers

The majority of surveyed smokers (54%, n=48) have referred friends or family to a website and 12% state that they frequently make such referrals. Most of those who have made website referrals (97%, n=26) have referred to health-specific websites.

Almost half of those surveyed (46%%, n=48) have been referred by friends or family to a website and 13% describe this as a frequent occurrence. Among those who have been referred, a majority (91%, n=22) reported having been referred to a health-specific website. All but one of these smokers (95%, n=22) also reported visiting that site.

Number of Smokers in the Social Network of a Smoker

Of those surveyed, all but one had smokers in their social network, with 39% reporting network sizes between one and five smokers, 13% reporting a network size over 20 and the remainder tending toward smaller networks (24% with network size of 6–10 smokers and 22% with network size 11–20). Smokers described their relationships to other smokers in their networks (Table 1), reporting a mean of 2.2 immediate family members and 3.7 close friends.

Number of smokers willing to refer to D2Q

Fifty-eight percent of surveyed smokers expressed willingness to refer friends and family to a tobacco cessation website. On average, respondents thought that 5.0 social contacts (range 1–20; SD=2.4) would be open to referral. Twenty-seven percent (n=30) of smokers estimated that they will need only a couple of days to refer their friends and family; the majority (53%) estimated that they will need 1–2 weeks; and 20% estimated that they will need greater than 4 weeks.

Demographic characteristics of smokers willing to refer with national data on demographics of smokers

Compared with the national sample of smokers participating in the BRFSS survey, a higher proportion of smokers in our group willing to refer were female (75% to 45%). They were also more educated. (Table 2)

RDS Simulations

Results of our RDS simulations for the different scenarios are described in Table 3. All simulations are based on targeted time to completion of 270 days. Number of simulations completed for each scenario: 1000.

We can see from Table 3 that with a quota of 3, all of the sample can be achieved in 25 days if the acceptance probability is 1; 99.9% of the sample is achieved in 107 days if the acceptance probability is 0.5. If the acceptance probability is only 0.25 and if the quota remains at 3, the sample will die out in 58 days. With an acceptance probability of 0.25, if the quota is increased to 10 then 83% of the sample will be obtained by the target date. The mean path length (23.56) and recruitment tree depth (15.22) is higher for a quota of 10 and acceptance probability of 0.25 than for a quota of 3.

Discussion

In this paper, we assessed the potential of using web-based RDS chain-referrals to recruit smokers to our Internet intervention (D2Q). Our survey data and RDS simulations demonstrated that it should be possible to recruit 1200 smokers to our web-assisted tobacco intervention using online peer-driven chain referrals. We demonstrated that 1. participation in a chain referral will not be a new experience for smokers; 2. smokers are willing to peer-refer; 3. smokers have close ties to other smokers where their influence may be higher; and 4. Smokers willing to refer were more likely to be female and more highly educated, as compared with the national population of smokers. Simulations suggested that if starting the RDS chains with a quota of 3 and 10 seeds, 99.9% of the sample will be achieved in 107 days with a mean path length of 21.75 and recruitment tree depth of 11.70, if the acceptance probability is 0.5. If the acceptance probability reduces to 0.25, the sample will die out in 58 days.

The use of peer-driven chain referrals and RDS is a well established method to recruit hard to reach subjects, including HIV patients and drug addicts. These “Grassroots” and participatory chain-referrals unfold in line with social network dynamics [29][30]. Hence, peer navigators from the community can facilitate access to high-risk groups within relatively short periods of time. More recently, Web-based chain referrals also are successfully being used by innovative markets as recruitment tools. A recent example is the successful use of Facebook by the Obama campaign to reach unlisted young voters through their friend networks [11]). However, these have not been used to recruit for Internet interventions.

Most smokers surveyed had prior experience participating in a chain referral (54%) and almost all those referred had visited websites following a referral (91%). Most smokers had

family members or close friends who were smokers. Information from close sources tends to be trusted more and responded to more often due to reciprocity [31–33], indicating that family or close friends of smokers may be more accepting of peer recruitment.

Most smokers also expressed willingness to refer to D2Q and indicated that their friends and family would be open to this, indicating a high acceptance probability. With current recruitment methods, only a fraction of those smokers exposed to the intervention actually engage with it. For example, only 7% of those contacted (out of a potential 750,000) responded to access to a web-assisted tobacco intervention in Project Quit [34] 4); while only 2523 participants were recruited using a complex process that included 40,000 mass mailings, search engine advertisements, 1844 mailings to tobacco control advocates, 1120 mailings to previous study participants, newspaper advertisements, and 3000 mailings using a direct mailing list [35]. Thus, recruiting smokers using chain-referrals may be more efficient than current methods.

To understand differences between those smokers willing to refer and the population of smokers, we also compared our data with smokers from the 2011 BRFSS dataset. Smokers willing to refer were more often female (36% more) and had some college education or were a college graduate (44% more) than the smokers in the BRFSS dataset. Typically, smokers participating in Web-assisted tobacco interventions are more often female and more educated than the population of smokers [6], but it is even higher among those willing to refer in our survey. It will be interesting to see if, even if we start with a non-random sample of smokers, following RDS best practices will lead to a final sample that is closer to the population than current recruitment methods.

Based on the simulations and best practices of RDS, we are starting our RDS chain referrals for the main intervention with an initial 10 seeds and a quota of 3. While the mean path length and mean recruitment chains are slightly higher for a quota of 10 and an acceptance ratio of 0.25, our pilot indicates that a smoker can recruit only an average of 5 smokers. Thus, a quota of 3 and an acceptance probability of 0.5 may be closer to reality. While we are starting our initial chain referrals with a quota of 3, we will constantly monitor our recruitment and conduct additional simulations to assess whether we need to modify our quota in the future. If acceptance of referrals is low, quotas may have to be increased in order to avoid having the sample die out prior to reaching target size. By monitoring peer referral rates throughout the intervention, we can compare actual rates to those modeled in the RDS simulation and can adjust accordingly. In this way we can identify and implement optimal quotas as the study progresses, both to minimize intra-sample correlations and bias and to maximize the chances of sample completion.

A limitation of our study is the sample size. The simulations we conducted did not account for errors in estimated recruitment rates or recruitment numbers. Recall that for each scenario we conducted 1000 simulations. A better way to conduct these simulations would be to sample a set of parameters from the confidence intervals estimated from the formative survey. We could then sample a different parameter set for each of 1000 simulations. While such a procedure would give us more accurate estimates of the distribution of time to sample completion, it would be a considerable amount of work for only an incremental

improvement. What is more valuable is to see which scenarios lead to sample die-out versus reaching the target sample size on time. The current round of simulations is sufficient for that purpose. Our sample size was also limited in the comparison with BRFSS. However, in our larger study, we will have additional data on smokers to assess whether we are able to recruit a representative sample.

To our knowledge, our study is the first to assess whether smokers can be recruited to a Web-assisted tobacco intervention using RDS peer referrals. The results of our RDS will provide valuable new knowledge to inform how referrals to informatics interventions can grow through social networks.

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Table 1

Social networks described by online smokers: mean number of smokers per network and relation to respondent

Immediate family	Mean=2.2 (SD=2.1), range =0,8
Extended family / relatives	Mean=3.3 (SD=3.0), range =0,11
Close friends	Mean=3.7 (SD=3.8), range =0,20
Friends	Mean=4.6 (SD=5.0), range =0,20
Acquaintances	Mean=6.4 (SD=10.0), range =0,50
Co-workers	Mean=3.6 (SD=5.6), range =0,22

Table 2

Characteristics of Smokers willing to refer with BRFSS smokers

	Smokers willing to refer (N=28) n (%)	BRFSS N= 83,144 %*
Sex		
Female	21 (75%)	45%
Male	7 (25%)	55%
Age		
19–29	3 (11%)	25%
30–39	7 (26%)	21%
40–49	8 (30%)	20%
50–59	7 (26%)	20%
60+	2 (7%)	14%
Race		
White	23 (85%)	78%
Non-White	4 (15%)	22%
Education		
Less than high school	1 (4%)	22%
High school graduate	3 (11%)	36%
Some college or college graduate	23 (85%)	41%

*Weighted for complex survey design

Table 3

Respondent Driven Sampling Simulations using 10 seeds and target sample size of 1200

Quota (Acceptance Probability)	*Mean Finish Time*	Mean Recruitment Tree Depth	Mean Path Length	*Fraction* of Cases in which sample size was obtained by target date
3 (1)	25.44	6.35	13.01	1.00
3 (0.5)	107.46	11.70	21.75	0.999
3 (0.25)	58.13	1.50	3.48	0.00
10 (0.25)	176.84	15.22	23.56	0.834
10 (0.1)	34.56	0.74	2.23	0.00