Measuring Network Size and Recruitment Productivity in Respondent Driven Sampling

by

Ai Rene Ong

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Survey Methodology)
in the University of Michigan
2022

Doctoral Committee:

    Professor Michael Elliott, Co-Chair
    Professor Sunghee Lee, Co-Chair
    Assistant Professor Ceren Budak
    Research Scientist Jake Fisher, Facebook
    Assistant Research Professor Brian Kim, University of Maryland

Ai Rene, Ong

aireneo@umich.edu

ORCID ID: 0000-0002-3118-3458

Dedication

To my *ah ma* and my dad, whom I wish were here with me today

Acknowledgements

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Abstract

Respondent driven sampling (RDS) has been used as a method to sample from populations with sampling frames that are difficult to construct, in particular those that are rare, hidden, and/or marginalized populations. This method leverages the respondents' social networks to reach the target population. Though a popular method touted for being able to overcome the issues of cost and difficulty in reaching these populations, slow or unsuccessful recruitment in RDS studies has been reported. In addition, there is no standardized way respondents are asked for their network size, which is used to developing sampling weights to account for the overrepresentation of highly-networked individuals. This dissertation focuses on the methodological issues in designing RDS research, starting with the construction of the personal network size (PNS) question, followed by an attempt to understand the peer recruitment process, and finally, RDS study characteristics that are associated with successful implementation.

The first study examines how respondents interpret and answer a set of PNS questions commonly asked in RDS studies. This work shows heterogeneity in how respondents interpret PNS questions, and that general PNS questions appear to have more measurement error compared to specific PNS questions (more heaping responses on the general PNS question in the web-RDS, more ranges and estimation given in the in-depth interviews). Therefore, PNS questions need to be more specific and target the network of likely invitees. The second study examines the peer recruitment mechanism in RDS studies. It shows that respondents cooperate with recruitment requests due to altruism, monetary incentive, and interest in the survey topic but that cooperation can be harmed by insensitive survey question-wording. The "top of mind" for

RDS respondents in terms of the alters they prefer to invite are those who are similar to them in age, race, and ethnicity, friends, those perceived to be close, and whom they have known for at least a few years. Younger respondents seem better at recruiting their alters into an RDS study in a web-survey setting than their older counterparts. The third study examines the characteristics of RDS studies in recent years to understand what characteristics, if any, are conducive to a successful RDS study, defined by its overall productivity (how well did the RDS study manage to adhere to the target sample size) and overall seed productivity (the number of recruits each seed generated on average). This chapter indicated that fielding an RDS survey on the web is associated with lower overall productivity, while seed productivity is affected by the location of the RDS study. RDS studies fielded in the U.S. have lower seed productivity compared to studies fielded outside of the U.S.

Chapter 1 Introduction

A significant problem with sampling for public health surveillance is that it can get prohibitively costly for many population subgroups of interest, such as sex workers (SW), people who inject drugs (PWID), and men who have sex with men (MSM). These populations lack proper sampling frames (e.g., a list of addresses for all PWID). In addition, members of marginalized communities may find it hard to trust researchers, which can lead to a high rate of nonresponse. In these settings, traditional probability sampling is either impossible or prohibitively costly to conduct. Thus Heckathorn (1997) introduced Respondent Driven Sampling (RDS). RDS is similar to snowball sampling in that it leverages respondents' networks to sample more respondents. The major difference is RDS restricts the number of invitations to a fixed number. By making several assumptions about the population and recruitment mechanisms, RDS can converge to a probability sample with a probability of selection proportional to the network size of an individual. The other major difference between RDS and traditional snowball sampling is, in RDS, respondents do the recruitment, but in traditional snowball sampling, respondents typically provide researchers with names and contact information. Thus, RDS has been touted as a method that can produce unbiased population estimates (Heckathorn, 1997; Heckathorn, 2007) while offering better anonymity and confidentiality to the respondents.

1.1 What is RDS?

In RDS, initial respondents are usually sampled through convenience sampling. These initial respondents (called "seeds") are asked to invite people they know in the target population

to participate in the study after completing the survey. The invitation usually takes the form of recruitment coupons given to each seed. This process is repeated with the respondents that resulted from the seeds' invitations and continue until the researcher stops the recruitment or when the recruitment no longer produces new respondents. Figure 1.1 illustrates how an ideal RDS recruitment happens using one example recruitment chain. In this figure, A is the seed in this recruitment chain. A knows five people who are in the target population (B through F) and invites three of them to the study (C, D, and E). Ideally, C, D, and E will continue this recruitment. Only C is shown in this example due to space constraints. C continues this process after participating in this study, recruiting G, H, and J into their network. Typically, A will be considered a respondent at wave 0, while C, D, and E are respondents at wave 1, and C's recruits, G, H, and J, are respondents at wave 2. As can be seen, the number of respondents can grow very quickly, providing this method works with all coupon recipients participating.

Figure 1.1 *An illustration of RDS recruitment*
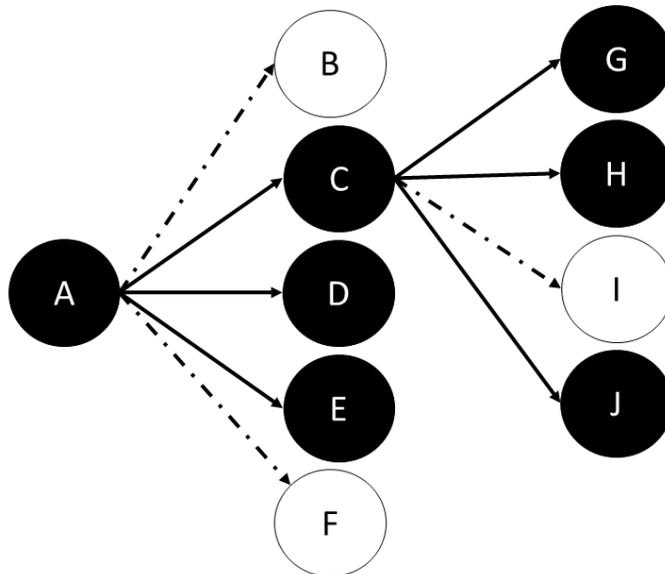
Note: Filled-in circles denote respondents (A, C-E, G, H, J), and non-filled circles denote other alters (B, F, I). The arrows represent ties between respondents and their alters, with dotted arrows representing alters who are not recruited into the study.

The maximum number of people each respondent can invite into the study is fixed through invitation coupons. For example, in National HIV Behavioral Surveillance Injection Drug Use, respondents are limited to five invitees in the fifth cycle of the survey involving PWID. Information about the number of people the respondents know who are in the target population (this is termed as their 'degree' or 'personal network size' in RDS literature) is collected as part of the survey. The respondents are usually given incentives for participation in the study *and* successful recruitment of their network members.

Since its introduction, RDS has grown in its use worldwide as a sampling method for hidden or hard-to-reach populations (Johnston et al., 2016; Ong & Lee, 2020). RDS data was collected by the United States Centers for Disease Control and Prevention, the Joint United

Nations Programme on HIV/AIDSs, and the Global Fund to Fight AIDS, Tuberculosis, and Malaria (White et al., 2015). A recent review has identified over 2000 publications worldwide that have used RDS (Ong & Lee, 2020).

1.2 RDS assumptions

The success of RDS is predicated on several assumptions. Referring to Gile and Salganik (2014), firstly, the target population must know each other as members of the target population. Secondly, the target population must be sufficiently networked so that every member can be reached from any starting point. Thirdly, sampling occurs with replacement, though in reality, this typically is not done, and respondents are only allowed single participation. It is approximated as a small sampling fraction. Fourthly, RDS respondents can accurately report their personal network size, or, in other words, they can accurately report the number of people they know who belong to the target population. Finally, RDS respondents recruit randomly from their network. For example, if a respondent knows 15 alters in the target population, then all 15 alters have an equal probability (m/15, where m is the number of invitation coupons supplied to the respondent) of being invited by the respondent. The final two assumptions are related to analysis using RDS data.

1.3 RDS challenges

Commonly used RDS point estimators (Salganik-Heckathorn (SH), Volz-Heckathorn (VH), Successive Sampling (SS)) use the respondent's reported personal network size (PNS) as an adjustment factor (Salganik and Heckathorn, 2004; Volz and Heckathorn, 2008; Gile, 2011). From the assumption that respondents can accurately report their PNS and that they recruit randomly from their network, respondents with bigger PNS have a greater probability of

selection into an RDS study. However, there has been evidence to the contrary. Respondents have been found to not recruit randomly from their alters, and their reported degree have not been associated with recruitment success (e.g., Lee et al., 2020; Zeng, Li & Crawford, 2019). The use of RDS estimators is a point of contention in the realm of RDS literature (Salganik, 2012). Studies have found that the use of RDS-specific estimators sometimes harms the estimates more than it helps (McCreesh et al., 2012). Salganik (2012) pointed out that RDS estimators must be aligned with the reality of RDS data collection. Given the use of PNS in the estimators, there is a need to examine how PNS is being measured and how to improve PNS measurement.

Much of the RDS literature has been focused on improving RDS estimators and studying the conditions in which the current RDS estimators would be biased (e.g., Sperandei et al., 2018), and more recently, there has been an increased focus on multivariate analyses using RDS data (e.g., Avery et al., 2019; Yauck et al., 2021; Sperandei et al., 2022). However, recommendations for RDS study design best practices are usually made from anecdotal experiences (e.g., Hipp, Kohler & Leumann, 2019). When it comes to conducting RDS studies, despite it being introduced to overcome sampling difficulties due to cost and access to marginalized populations, difficulties in the field, in particular, slow or dead recruitment chains (e.g., Lee et al., 2021), have been reported and resulted in researchers needing to change their strategy on an ad-hoc basis. For example, RDS researchers have added more seeds, increased the number of recruits for each respondent, and increased recruitment incentives (e.g., Martin et al., 2015; Carillo et al., 2020). Therefore, there is also a need to understand the mechanisms behind the RDS peer recruitment process (i.e., who cooperates, who is invited, and who participates)

and examine the current practice when it comes to planning and executing RDS studies whether current recommendations reflect RDS field productivity.

This dissertation addresses the following general questions in three chapters:

1. How to improve asking for PNS in RDS?

2. Who recruits and participates in RDS?

3. What RDS study characteristics (e.g., presence of formative study, number of seeds) are essential for a successful RDS data collection?

The first research question is addressed in Chapter 2. This chapter begins with an overview of RDS assumptions focusing on the assumptions related to PNS, followed by a detailed literature review on PNS and its place in RDS data analysis. In this chapter, I tested the common PNS question and a few modified PNS questions. Eighteen adult LGBT respondents were interviewed about their PNS (their interpretation of the PNS questions and how they came up with their answers) and their hypothetical recruitment patterns (whom they will invite and whom they will not consider inviting, and why). I conducted a thematic analysis of the transcripts, identifying the themes in their responses about their PNS, and noted the variations in definitions and how well they match their hypothetical recruitment patterns. This analysis of the in-depth interview data was complemented by an analysis of data from a web-RDS targeting adult LGBT respondents. This web-RDS study asked respondents several PNS questions of different levels of specificity. It also asked respondents to name and describe up to four alters they know whom they might invite to a hypothetical RDS study. Some respondents were invited to participate in a follow-up survey that asked the same PNS questions as the main survey. The consistency of the responses to the PNS questions was examined using test-retest reliability. The

PNS responses from the main survey were also examined for the degree of estimation from the respondents and for their correlation to the network of likely invitees.

Chapter 3 focuses on RDS recruitment and participation. This chapter uses the same data (in-depth interviews and web-RDS) as Chapter 2. To understand what motivates respondents to engage in peer recruitment, I conducted a thematic analysis of the responses given in the in-depth interviews on the reasons for cooperating in an RDS recruitment request. To understand the profile of likely recruits, I looked at the named alters in terms of their similarity in age and race/ethnicity to the respondents, their relationships to the respondent, their perceived closeness, years known, and perceived likelihood to respond to the respondent in the web-RDS. I also examined the associations between the characteristics of the alters and the characteristics of the respondents with being a successful recruiter in the web-RDS.

Chapter 4 widens the scope and looks at RDS as it is currently implemented. This chapter begins with an overview of the recommendations for planning an RDS study and the current state of reporting for RDS studies. Then, utilizing data from a survey of RDS researchers who have published a manuscript or have a funded grant proposal from 2009 to 2020, I examined some of the recommendations given in past research on the setup and design of an RDS research study in terms of how well they predict RDS field productivity as defined by overall productivity (how well did the RDS study manage to adhere to the target sample size) and overall seed productivity (the number of recruits each seed generated on average).

In the last chapter, I summarize the main findings of each chapter and suggest some directions for future research based on the findings.

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Chapter 2 Measuring Personal Network Size in Respondent Driven Sampling

2.1 Abstract

Respondent driven sampling (RDS) is a sampling method that leverages the respondents' networks to reach more members of the target population. In RDS, the size of the respondents' social network (also known as personal network size (PNS), or respondent's degree) is important in both the study operations and in estimation, and getting a good measure of PNS is something that cannot be overlooked. However, measurement error in the PNS can introduce biased estimates for RDS, especially if the misreporting of the degree is associated with the outcome to be estimated. This current study attempts to understand how respondents report their PNS and what are the best practices for constructing a PNS question by testing the common PNS question wordings from the general (the people they know) to the more specific (e.g., the people they interact with, the people they are close with). This study uses two sets of data; 1. semi-structured in-depth interviews conducted over Zoom with 19 adult respondents of various ages, gender identities (transgender, nonbinary, cisgender), race, and sexual orientations (gay, lesbian, bi), 2) an RDS web survey targeting the adult LGBT population (n = 394). Thematic analysis conducted on the semi-structured interview transcripts showed a large variation in how respondents define "knowing" someone; for some respondents, it covers a larger network than the "recruitable" network (the network of people respondents are likely to think of recruiting to an RDS study). Meanwhile, the web-RDS shows that the more restrictive PNS questions yielded more realistic ranges for a "recruitable" network, with less proportion of rounded responses on the more restrictive PNS questions.

2.2 Introduction

Respondent driven sampling (RDS) offers researchers a way to sample hard-to-reach populations by leveraging the social networks of initial respondents from the target population of interest. RDS is a restricted snowball sampling method that starts with a small pool of respondents who are then asked to invite the people they know who are in the target population of interest to participate in the study. This process continues until the researchers stop the fieldwork, typically when the target sample size is reached. It is a feature of RDS studies to restrict the number of people a single respondent can invite into a study in order to prevent the sample from representing only one network. RDS is widely used as a sampling method for hidden or hard-to-reach populations (Johnston et al., 2016; Ong & Lee, 2020), and data from RDS studies have been used by the United States Centers for Disease Control and Prevention, the Joint United Nations Programme on HIV/AIDSs and the Global Fund to Fight AIDS, Tuberculosis, and Malaria (White et al., 2015).

A key measure in studies using this method is the size of the respondents' social network (also known as personal network size (PNS), or respondent's degree). Personal network size is an important variable outside of RDS and has been studied within research on social support (e.g., Wagner et al., 2017; Cheyne, Smith & Pollet, 2021), public health (e.g., Marquez et al., 2018), and more. Many of these studies directly asked respondents to self-report their egocentric network, though this task varied in the burden on the respondents. Some studies asked for additional information on all the network members named across multiple types of relationships with the aid of a visual network mapping software (e.g., Wagner et al., 2017) or just a subset of the network members named without the aid of a visual network mapping software (e.g., Marquez et al., 2018). Some asked respondents to name and describe a specific number of alters

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(e.g., up to 25 people respondents were in contact with in Cheyne, Smith & Pollet, 2021). In all the studies described, respondents were asked to name people from specific relationships, e.g., people they can count on (Wagner et al., 2017), people they have been in contact with in the past month (Cheyne, Smith & Pollet, 2021), people they have discussed important matters with (Marquez et al., 2018).

In RDS, the PNS is important to both the study operations (i.e., the number of people a respondent can invite into the study) and in estimation (i.e., adjustment to estimates from an RDS study). It is typically directly measured by asking respondents to self-report the number of people they *know* who are in the target population and is not as elaborate as the studies mentioned above (i.e., Wagner et al., 2017; Marquez et al., 2018; Cheyne, Smith & Pollet, 2021). This measurement of respondents' PNS is predicated on the assumption that respondents interpret the PNS question similarly and can report the numbers with very little to no error. However, these are strong assumptions. Firstly, the wording for the PNS questions is not standardized. Secondly, respondents might interpret "knowing" someone in their network differently from one another, and "knowing someone" is commonly used to ask for respondents' network size (refer to Appendix A for examples of PNS questions), unlike non-RDS studies, which may define the boundaries of the network better. Due to the difference in interpretation, some respondents might include people they are only mildly acquainted with, while others only include those they regularly meet.

2.2.1 The use of PNS in RDS estimation

As mentioned above, PNS is commonly used as part of RDS estimators, as it can be used to adjust for the probability of being invited into an RDS study under certain conditions (e.g., Salganik and Heckathorn, 2004; Volz and Heckathorn, 2008). The earliest proposed RDS point

estimator is the Salganik-Heckathorn estimator, also known as the RDS-I estimator. The

Salganik-Heckathorn estimator assumes that seeds are selected with a probability proportional to

their PNS, respondents recruit one person from their personal network, this selection is random,

and the ties between the respondent and their alters are reciprocal (i.e., if person A is connected

to person B, then person B is connected to person A). Given these assumptions, the equation for

the Salganik-Heckathorn estimator is as follows:

$$PP_A = \frac{\widehat{D_B}\ \widehat{C_{BA}}}{\widehat{D_A}.\widehat{C_{AB}} + \widehat{D_B}.\widehat{C_{BA}}}$$

In the equation above, PP_A is the population proportion of group A, D_B is the average

PNS in group B, C_{BA} is the probability of cross-group connections from group B to group A

estimated by calculating the proportion of actual cross-group recruitment from group B to group

A from all group B recruitments, and C_{AB} is similar to C_{BA} but is from group A to group B

instead. The use of PNS is within the calculation for D_A and D_B. Here, n_A is the number of

people in group A, and d_i is the reported PNS of person i:

$$\widehat{D_A} = \frac{n_A}{\sum_{i=1}^{n_A}\frac{1}{d_i}}$$

Similar to the Salganik-Heckathorn estimator, the Volz-Heckathorn estimator (also

known as the RDS-II estimator) also makes use of the reported PNS in its equation, but the

difference between these two estimators is that the Volz-Heckathorn estimator uses it to create

weights for the respondents similar to survey weights and does not rely on the cross-group

relationships (Volz and Heckathorn, 2008):

$$PP_A = \frac{\sum_{i \in N}(d_i^{-1}y_i)}{\sum_{i \in N} d_i^{-1}}$$

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In the equation above, N denotes the sample, PP_A is the proportion of group A, d_i is the PNS of individual i, and y_i is an indicator variable where it is 1 if the individual is part of group A and 0 otherwise. The PNS is used in this case as an individual weight. It is assumed that the larger the degree, the higher the selection probability, and therefore the smaller the weight given to the individual. Both the Salganik-Heckathorn and Volz-Heckathorn estimators assume sampling with replacement. Given many waves of sampling, this is likely a fair assumption, but in practice, the number of waves is usually small.

There have been other estimators proposed and used (e.g., Gile, 2011), but the Salganik-Heckathorn and Volz-Heckathorn estimators are the most used RDS estimators, and both use the PNS measure in their calculation. Since degrees are self-reported by the respondents, variations in the way respondents interpret the degree question will cause a violation of this assumption of reciprocity of both RDS-I and RDS-II estimators. If Person A considers Person B as part of their network, but Person B does not due to a difference in how they interpret the degree question, then Person A and Person B will be thinking of different networks. This is on top of assuming that respondents are reporting their degrees accurately.

Measurement error in the PNS can introduce biased estimates for RDS, especially if the misreporting of the degree is associated with the outcome to be estimated. For example, men have been known to report a higher number of sexual partners than women due to social desirability bias (Smith, 1992; Tourangeau and Smith, 1996). In an RDS study about sexually transmitted diseases, women, in general, might be weighted more and men less, which would lead to a possibly erroneous conclusion about the prevalence of sexually transmitted diseases among men and among women.

Mills et al. (2014) had shown in a simulation study that the error associated with degree misreporting is worse when respondents with lower degrees misreport. The authors manipulated the extent of misreporting by generating degree distributions and applying different rounding schemes to the degrees, as rounding is often seen in the reported degrees in RDS data (e.g., heaping of degrees reported at multiples of 5 such as 5, 10, 15). "Misreporting" degrees had led to an overestimation of the prevalence of Hepatitis C in their study when the Volz-Heckathorn estimator was used.

Meanwhile, Gile et al. (2015) asked their respondents to report their degrees twice, once during the main survey and another time during the follow-up survey. Though the median difference between the main survey degree and follow-up survey degree is 0, they found that there were substantial differences between the degrees reported at both times for many respondents. When they compared the estimates obtained using the Volz-Heckathorn estimator using both of these degrees reported, they found that absolute difference in the estimates for the diseases with very low prevalence is more than 50% of the original estimate. In summary, accurately measuring PNS is important to obtain reliable estimates from RDS data, and there is evidence of both misreporting of PNS in RDS and how it biases estimates.

The second way PNS is used is to estimate the population size for these hard-to-reach populations. An example of this is by using the network scale-up method (NSUM) (e.g., Maltiel, Raftery, McCormick, & Baraff, 2015). Using this method, the respondents are asked for their PNS for different subpopulations, including the population for this population size estimation. Some of the subpopulations will have known prevalence (e.g., number of people they know who own a car) in order to calculate the total number of people the respondents know, which is then used to calculate the population size of the subpopulation of interest. This method does not

require the assumption of reciprocity, though it does still assume that respondents define

"knowing" the same way across all the subpopulations asked.

2.2.2 The issues with measuring PNS in RDS

From the perspective of using PNS in estimation, it is important to reduce the variation in

the interpretation of the PNS question and measure the number of people the respondent knows

who might invite the respondent into an RDS study. Due to the assumption of reciprocity, this

means that the PNS measure should measure the number of people the respondents know whom

the respondents might invite to an RDS study. Meanwhile, from the perspective of RDS

fieldwork, the PNS question serves as a measure of how many people a respondent can invite, as

a respondent who only knows one person will not be given more than one invitation coupon.

Therefore, the ideal PNS measure should be reliable, be interpreted the same way across all

respondents, and is reflective of the network of people respondents will invite to an RDS study

(network of likely recruits).

To date, there have been many versions of the RDS PNS question. An example of a single-

item PNS question in RDS is, "Think about the people you know and met in the last six months,

who also know you. How many of these people use injection drugs?". However, this may be

asked using a series of questions instead of a single question, and the question's wording differs

across RDS studies. For example, in two RDS studies on targeting men who have sex with men

(MSM), the PNS question used were:

> "How many transgender and MSM do you know, who knows you and who live in this
> city? Of these, how many are 18 years of age or older? Of those, how many have you seen
> or spoken to in the past 30 days? (Paz-Bailey et al., 2013)

> "Approximately how many men who have sex with men do you know personally who live
> in greater Beirut and are age 18 or above? These should be men whom you know by name

and that you have contact with either by phone, email or face-to-face" (Wagner et al., 2014)

The first prompt was broken into a series of questions that get increasingly specific and emphasized that the people in the respondent's network (also called "alters") should know the respondents too, while the latter is just one question but specified that the respondent should know the names and be in contact with their alters. These two types of PNS questions may lead respondents to use very different recall strategies. In the first example, respondents who know many people in the city may give a rough estimate, while in the second example, respondents are explicitly told at the start to think about people they know by name and have contact with, possibly leading respondents to explicitly count the number instead of estimating.

Though there is no consensus on what the question for PNS should be, there are recommendations on how to construct PNS questions. According to Johnston (2014), a PNS question must have four elements: 1) a definition of the target population, 2) a shared understanding of the meaning of "knowing" someone, 3) a geographical boundary for the survey, and 4) a reference period. The importance of defining the target population that is also salient to the respondents when answering the question is demonstrated in McCreesh and colleagues' (2012) RDS study on the head of households in Uganda. In that study, they found that many of their respondents did not think of younger men as the "head of household," which led to the underrepresentation of younger men in their sample.

These guidelines also addressed the issues with the lack of specificity in PNS questions that Johnston et al. (2008) had pointed out in an earlier review of RDS studies. Even with this set of guidelines, PNS questions are still not standardized. Appendix A has more examples of PNS questions. Given the lack of standardization in the PNS question, how can a researcher using RDS choose which PNS question to use? And what are the best practices for writing a PNS

question for RDS to reduce measurement error, help with recall and target the network of likely recruits?

Even if the target population is well defined and is salient to the respondents, measurement errors in PNS responses persist. For surveys that are interviewer-administered, the interviewers have been found to influence the size of the networks reported (Van Tilburg, 1998). In Van Tilburg (1998)'s study, more educated interviewers who have little interviewing experience seemed to collect larger network size estimates from their respondents than less educated interviewers with more interviewing experience.

Aside from interviewer effects, recalling personal network size is an error-prone activity in itself. For one, respondents could forget about some relationships. Bell et al. (2007) reported that people tend to forget fewer behaviorally specific relationships. "Friends" has fuzzier boundaries than "drug use partners" as friendship is a more imprecise concept. "Sexual partners" who represent more salient ties were also better recalled than less salient ties such as "drug use partners". Finally, forgetting happens more with longer reference periods.

The strength of the relationship affects recall. Brewer and Webster (2000) found that recalled friends have a closer relationship than forgotten friends in a complete network study of a university dormitory. Though they found that their respondents forgot 20% of their friends, they did not find sociodemographic patterns in the types of friends that were forgotten. Marin (2004) also found that closer relationships tend to be more likely to be recalled compared to less close relationships. Brewer and Webster (2000) also found that recalled ties are more likely to be reciprocated. This indicates that the PNS question ideally should ask about specific, close relationships with a reasonably short reference period. The relationship's saliency in a PNS question depends on the RDS study's target population. By the nature of the target population,

some networks will be more salient compared to others (e.g., sexual partners compared to drug use partners as mentioned in Bell et al., 2007), but one could keep in mind that the chances of misreporting are higher with a less salient relationship.

In another study using a series of name generators where respondents were randomized into either the web survey or telephone survey, Kogosek (2006) found that respondents gave more reliable PNS estimates for the name generator question that appears after the first name generator question regardless of the mode. Kogosek (2006) posited that respondents in that study might have needed time to adjust to the name generator questions. This suggests that having multiple PNS questions is preferable to just one.

Fu (2005) found that it was difficult for respondents to come up with the exact number of contacts when asked directly but were able to give a range (e.g., "from 20 to 30") through a series of cognitive interviews. This led them to use a categorical PNS question with six ranges of PNS as response options. Larger PNS leads to greater reporting errors (Iguchi, Ober & Berry, 2009). RDS studies typically ask PNS using an open-ended question, but it is possible that providing specific ranges as response options might be preferable. However, this measurement cannot be used for weighting, which defeats the purpose of asking for PNS in RDS studies.

In Li et al. (2017), a direct PNS question that follows Johnston's (2014) recommendations, which the researchers call the "typical RDS degree," was compared against the sociometric degree. The sociometric degree was from the sociometric network constructed by comparing the ego network data (i.e., the network data where the respondent is central) they collected, including the respondent's network members' names/nicknames and some demographic information. They also compared the sociometric degree against the self-reported degree of more specific networks, e.g., the people they feel close to and receive support from.

The typical RDS degree had the largest range, from 0 to 500. It was not associated with the total degree from the sociometric network. The self-reported degree had a much smaller range and was associated with the total degree from the sociometric network. This is in line with Brewer and Webster (2000)'s findings.

Besides comparing RDS PNS to a different measure of PNS, several studies tested the reliability of these RDS PNS measures. For example, Gile, Johnston & Salganik (2015) measured the PNS for female sex workers (SW), people who inject drugs (PWID), and men who have sex with men (MSM) using a series of four increasingly specific questions administered twice. The fourth question, "How many of them have you seen in the past week?" was used as the respondent's PNS. The correlations were low, ranging from 0.17 to 0.47. This was very different from another study of SW in China (Yamanis et al., 2013), which yielded a high test-retest reliability, a correlation of .98, though their PNS question used a different reference period and asked in a single question (i.e., "How many sex workers do you know in Shanghai? By knowing, I mean that you know their names and they know yours, and you have met or contacted them in the past month."). Therefore, it is unclear if the differences in the reliability of the PNS in these two studies are due to the reference period, the target population, or something else.

The issue in using PNS in RDS could also be due to the mismatch of the PNS with the probability of inclusion, as alluded to earlier in this paper. Li et al. (2017) did not find any association between the alter's total degree to being recruited, but the total degree may not be the measure that is most useful to RDS researchers even if it is accurately reported. Assuming the relationships are reciprocal, this still needs to be a measurement of the network of people who will invite them and not the people they know, which is what the total degree was measuring. Thus, there is an additional layer of complication when asking for PNS in RDS: How do we get a

PNS that most closely resembles the in-degree of the respondents (the number of people who includes the respondents in their network)?

In sum, although there are guidelines for asking for a respondent's PNS, there is no consistency in how this is done in RDS studies. It seems that being more restrictive and specific in the PNS question (e.g., specifying close relationships only) might be better than a more general PNS question, but this has not been examined extensively, and there are different ways to define a close relationship. In the following section, I will further discuss the PNS by sexual orientation and gender identity (SOGI), status, and race, with these dimensions selected to illustrate the possible differences in PNS self-reporting by different types and sizes networks.

2.2.3 PNS by race and Sexual Orientation and Gender Identity (SOGI) status

Different subpopulations may require different questions as the type of relationships that are more amenable to recruitment might be different, and the average PNS for the specific subpopulation might be larger, requiring more specific questions to allow for easier recall. PNS questions that are less specific may elicit large network sizes from some subpopulations, and large network sizes tend to have more measurement errors (Brewer and Webster, 2000). "Knowing," "closeness," "friends," and other subjective relationship modifiers in PNS questions may be interpreted differently across different populations (e.g., Hruschka, 2010).

Several studies have shown that PNS is associated with individual characteristics and tends to decrease with age (Cornwell, Laumann, & Schumm, 2008). Studies have found some ethnic/racial disparities, where older African Americans and Hispanics reported a smaller network size than Whites (Cornwell et al., 2008). Among the MSM population, there have been differences found in the network characteristics between Black and non-Black MSM. For

example, Black MSM reported a smaller number of people they would discuss their health with than white MSM (Zarwell & Robinson, 2019).

When comparing gender and sexual minorities, there are no PNS differences between lesbian, gay, and bisexual older adults (Grossman et al., 2000), though there have been some mixed findings comparing the network size of LGBT individuals against non-LGBT individuals (Cornwell et al., 2008). Specifically, older transgender adults have larger networks than nontransgender LGB older adults, though the size of the PNS of transgender older adults is comparable to cisgender heterosexual adults (Fredriksen-Goldsen et al., 2014). Little is known regarding the diversity of social networks in older LGBT adults. It is also unclear if these network size differences are due to the actual networks being smaller or if the people considered as being in their networks are different.

Due to time and budget limitations, I chose to focus on differences between race/ethnicity groups and gender/sexual minority groups. Among the LGBT population, there are differences between the lesbian and gay community and the bisexual and transgender community. The latter two communities may not feel wholly comfortable within the cisgender gay and lesbian community spaces (Nash & Gorman-Murray, 2014) and may report smaller network sizes or have a more restrictive interpretation of PNS questions.

Specifically, this paper aims to answer the following research questions:

1. What do different PNS questions mean to the respondents?

    a. What does "knowing someone" mean to the respondents?

    b. What does "being close with someone" mean to the respondents?

    c. Is there a common definition for these terms across the respondents?

2. What strategies do respondents use to answer PNS questions (specifically the PNS questions that ask about "knowing someone" and "being close to someone")?

3. Are there differences in race/ethnicity and sexual orientation/gender identity in interpreting "knowing," "closeness," and their general strategy for answering these questions?

4. Which PNS questions are the most useful for RDS?

"Usefulness" in this case means having a reasonable range of values (i.e., fewer outliers), stable, having less estimation, and reflecting how respondents report they will invite their network members into an RDS study (i.e., do they match the social network that RDS studies actually care about?). This study will assess the stability of the responses as defined as test-retest reliability and the degree of estimation as measured by heaping responses (responses in multiples of 5), assuming that questions that produce more reliable responses and less heaping are more salient to respondents and have less error.

Weighted estimates for several sociodemographic variables (e.g., age, income) using the different PNS questions will also be compared against a benchmark estimate using the Behavioral Risk Factor Surveillance System 2020 (BRFSS) data, assuming that the PNS that provides the closest weighted estimate will be the most useful for RDS. Due to the respondents of the web-RDS data used in this study being from Michigan only and the nature of qualitative data being more exploratory and descriptive, the findings from this study may not be generalizable to the whole of the United States. It may also be limited to only the LGBT population. However, the findings can serve as a good starting point for further research on the best practices for asking PNS questions in RDS.

2.3 Methods

2.3.1 Data

This research draws from two sets of data (1. semi-structured in-depth interviews conducted over Zoom with 19 sexual and gender minority adult respondents of various ages and races, 2) an RDS web survey targeting the adult LGBT population). As much possible, I had aimed to interview two respondents from each intersection of race (Black, white), sexual orientation (gay/lesbian, bisexual) and gender identity (cisgender, transgender) (n=18), but recruitment for white transgender gay/lesbian respondents and, Black bisexual respondents was challenging and some respondents who screened in identified themselves differently during the interview. Only one category was not interviewed (white, transgender/nonbinary, gay/lesbian). Table 2.1 below shows the demographic breakdown of the respondents interviewed. The ages of the respondents interviewed ranged from 19 to 65, with an average age of 34. The average length of the interviews was 44 minutes.

The interviews were conducted to understand how people think about RDS recruitment and network sizes. As network size may be interpreted and reported differently for different populations, respondents were interviewed with questions structured to understand possible differences in interpreting and reporting of network sizes by race and by sexual orientation/gender minority status. The respondents have been recruited through the Michigan Institute for Clinical & Health Research participants portal and the University of Michigan LGBT groups. Sixteen interviews were conducted from February to March 2021, and three interviews in April 2022. The three respondents interviewed in 2022 had participated in the web-RDS study prior to the interview. Respondents who completed the hour-long interview were

compensated $50 for their time. The interviews were audio-recorded with consent for transcription and analysis.

Table 2.1 *Respondents interviewed in the in-depth interviews*

	Gender identity	Sexual orientation	n
Race: White	Transgender/Nonbinary	Gay/lesbian	0
		Bisexual	3
		Something else	1
	Cisgender	Gay/lesbian	4
		Bisexual	2
Race: Black	Transgender/Nonbinary	Gay/lesbian	5
		Bisexual	1
	Cisgender	Gay/lesbian	2
		Bisexual	1

The web RDS survey had 394 respondents, with 68 of them as seed respondents (further information is provided in page 50. This web survey targeted the adult LGBT population residing in the United States. In the web survey, respondents were asked several different PNS questions, followed by questions about the people they are inclined to invite to a hypothetical RDS study. At the end of the survey, respondents were asked to invite two of the people they knew to participate in this survey. Two weeks later, respondents who were asked to invite people to participate in the survey were invited to participate in a follow-up survey about their experiences with inviting people into the study. Respondents were compensated $10 for completing the main survey, $5 for each person they successfully invited into the study, for a maximum of $10, and $5 for completing the follow-up survey. The average time taken to complete the main survey was 8 minutes while the follow-up survey was 5 minutes. All of the web-RDS respondents were Michigan residents.

BRFSS 2020, which is used as a benchmark for comparing the RDS-II weighted

estimates using the different PNS asked in the web-RDS, is a probability survey administered by

each state. The BRFSS covers various topics related to health and risky behavior. The target

population was the non-institutionalized adult population aged 18 and older residing in the

United States. The total sample size in the Michigan BRFSS 2020 is 7268, with 118 of them

identifying as LGBT.

2.3.2 Measures

In the semi-structured interviews, respondents were asked about their definition of

"knowing," "interact," "feel close to," and "ask for help and advice" for different subpopulations

(by race and by sexual orientation/gender identity). They were also probed about their recall

strategy for the PNS questions and the people they would invite to a hypothetical RDS study.

The discussion guide is in Appendix B.

For the web-RDS survey, respondents were asked the following PNS questions twice

(main survey and follow-up survey):

1. PNS (all): How many [TARGET POPULATION] do you know, who knows you and who live in the United States?

2. PNS (18): Of these [PNS (all)], how many are 18 years of age or older? If you are not sure, just count them as adults.

3. PNS (close): Now I am going to ask you questions about the [PNS (18)] people you know that are [TARGET POPULATION]. How many do you feel close to (that is, you feel at ease with, can talk to about what is on your mind, or call on for help)?

4. PNS (interact): Of those [PNS (18)] people you know who are [TARGET POPULATION], how many do you interact with (including talking to, visiting with, calling, emailing, texting, Facebook, etc.) personally more than once week?

5. One of the main difficulties in research is reaching sexual and gender minorities. We would like to understand how we can leverage your social network to reach people in the LGBT community.

   The next few questions will be referring to a **hypothetical study** described below.

   "LGBT Health Study is an online survey which is 15-20 minutes long. This survey asks questions about various topics such as physical and mental health and healthcare access. Participants are compensated a $10 gift card for their time upon completing the survey."

   PNS (interest): Of those [PNS (18)] people you know who are [TARGET POPULATION], how many how many do you think will be interested in participating in this study?

6. Now, imagine that you have participated in that hypothetical study. At the end of that study, you are asked to invite a few people you know to participate in that study.

   PNS (invite): Of those [PNS (18)] people you know who are [TARGET POPULATION], how many do you think you can invite individually to participate in this study?

Respondents were also asked to report the age, race, and ethnicity, years known, closeness (rated from 1 to 7 where 1 is "not at all close" and 7 is "very close"), and their relationships (family, romantic partner, friend or other) with up to four people they think will be interested in the hypothetical study, and assess the likelihood of these people to respond to an invitation from the respondents. Finally, in the follow-up survey, respondents were asked their reasons for not inviting anyone into the study if they responded that they did not invite anyone.

2.3.3 Analysis plan

Thematic analysis was used to analyze the data from the qualitative interviews. Responses to the questions asking about the definition of knowing people and being close to people were closely examined to elicit the different ways if any, these terms are interpreted. Furthermore, they were also examined in terms of how well they match the respondents' considerations about inviting their network members to an RDS study.

The consistency and the extent of respondents estimating their responses to PNS questions in the web-RDS were examined. Consistency was assessed using test-retest reliability by using Spearman's rho rank correlation between the network size reported in the main survey and the follow-up survey, while the extent to which respondents estimated their PNS was examined by looking at the proportion of responses in multiples of five that is 10 and above. They will also be examined on how well they correlate with the size of the social network of interest to RDS peer recruitment, which is the social network of the people the respondents think they can invite (PNS (invite)). The correlation with the PNS (invite) will only be using data from the main survey.

To determine the impact of the different types of PNS responses on point estimates, RDS-II weighted (Volz-Heckathorn) estimates using all the different PNS questions for sociodemographic variables (age, race/ethnicity, annual household income, work status, education attainment, sexual orientation, gender identity) were compared against each other. The BRFSS 2020 was used as a benchmark for variables common to both surveys. Weighted estimates of the LGBT subpopulation in Michigan were obtained from BRFSS 2020 and compared against the estimates from the RDS survey; the PNS that yields the closest estimates to the BRFSS 2020 benchmark were considered to be better.

In addition to these analyses, this paper explored the relationship between the respondents and the four people they named as people they were likely to invite to the hypothetical study. This analysis is on the level of the named alters and further sheds light on the match between how the PNS questions are interpreted and the types of people respondents are likely to invite to an RDS study. Possible recruiter race differences in the type of relationships

named, the number of years known, closeness and race of alters are tested using chi-square tests and independent t-tests where appropriate.

2.4 Results

2.4.1 Thematic analysis: Strategies for responding and defining "know" and "close"

When the respondents were asked how many people they know in the city for the various subpopulations they were a part of, there was a big variation in the responses and the amount of time taken to think through their answers. Many gave responses that were in a range (e.g., "20-30", "15-20"), though those who do not know anyone else either because they just moved or the people they know have moved, were very quick to respond with "zero". For respondents who gave large numbers, they reported either roughly estimating based on feeling or counting up based on specific locations/occasions. An illustrative quote is provided below for those who counted up by location/occasion:

> *"I was thinking about who has the most recent parties. Like usually it's about like 20... 20-ish people, but like a rotating cast."* – Age 28, White, Bisexual Transgender man

The variation in the intimacy involved in their definition of knowing seems to correspond very loosely to the number of people they report knowing. Those who report knowing more people, such as 20-30 people or 250 people, tend to define "knowing" more loosely, though some who responded with lower numbers also defined it this way. Meanwhile, there were some who responded with 15-20 people they know who define "knowing" more intimately.

On the least intimate end of the definition of "knowing," to these respondents, to know someone and be known is to be able to recognize them. Below are a few quotes that illustrate this.

"Oh yeah like people who like could recognize me or like I would say 'Hi' like I would say 'Hi' and greet." – Age 28, White, Bisexual, Transgender man

"Okay, knowing me doesn't necessarily mean friends with, I think it means more like you are aware of my existence like if I ran into them at the grocery store, they would be like oh that's [NAME]" – Age 24, Black, Bisexual, Nonbinary

Some defined knowing as having interactions, which is a little more intimate than mere recognition.

"That we have interacted in one way or another, like as part of the university..." – Age 24, Black, Gay, Cisgender man

"These are people that I really like communicating with or they're also people that I might work with so not necessarily friends." – Age 25, Black, Gay, Cisgender man

And for some, knowing someone has a more intimate meaning. They would think of people whom they have a closer relationship with and people they trust.

"I would say that a person would know another person if they were able to infer certain moods depending on actions" – Age 34, White, Bisexual, Cisgender woman

"Knowing definitely implies a greater sense of who I am. They know the mannerisms I have as a bisexual man." – Age 46, Black, Bisexual, Cisgender man

"They know how I think, they know what I like and what I dislike." – Age 50, Black, Gay, Transgender woman

There does not seem to be any clear differences age or race in the way respondents think of the definition of knowing. This degree of intimacy changes for some respondents when asked about the people they know in the city they live in compared to the people they know in the United States in general. For some, it shifts to a less intimate definition of knowing when the location changed to "the United States" rather than just the city. This is especially apparent with

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respondents who are more active on social media, as shown by one respondent who, when asked about the people he knows in the city, responded with the number of people whom he has shared similar struggles with as part of his identity. However, when asked about the whole of the United States, offline and online included, he struggled to conceptualize the question.

> *"[...] so I tend to be really vocal about my sexuality on Twitter, so I have like a lot of followers from academia, who follows me and they're also, like, persons who are 'out' in there in the community so I don't even know if I would consider those to be part of the list, but if I did, then it would be even bigger."* – Age 24, Black, Gay, Cisgender man

However, there is a more consistent interpretation of "being close to someone", with most respondents mentioning being able to confide in the people they are close to, being able to call in favors, and lean on for support. The number of people the respondents reported being close to were generally smaller than the number of people the respondents reported knowing, and no respondents gave a range as an answer.

> *"It's people who, like, I care about their feelings they care about mine like, I could call them for a favor and like I would do a favor for them."* – Age 26, Black, Lesbian, Transgender woman

> *"Like I can talk to you, and tell my problems, explain my problems on all levels, like our body problems."* – Age 23, Black, Lesbian, Transgender woman

> *"I guess it mostly boils down to a transaction of information between each people and the specificity of that information let's say."* – Age 34, White, Bisexual, Cisgender woman

2.4.2 Who will they invite and how well does that map onto the definition of knowing/close/interact?

Generally, from the qualitative interviews, when asked about who they will invite, respondents tend to mention the people they are close to either explicitly (e.g., "*It would*

definitely be close friends…") or implicitly (e.g., *"my wife"*), have interactions with, and those who will feel receptive to the study which implies a level of knowledge that is more than just a casual acquaintance. A few have also mentioned that they will not invite people they do not feel close to or the people they do not regularly interact with. The people they have fewer regular interactions with do not come up in their minds when thinking of whom to invite, according to one respondent.

> *"It would definitely be close friends from the research group and then my close friends from high school. Those would be my three, I think that would definitely do it." –* Age 24, Black, Gay Cisgender man

> *"Maybe going back to like the four or five that I talked to like on a regular basis, I don't know if I feel comfortable sending a survey specifically to, like, people I don't interact with much." –* Age 23, White, Bisexual Transgender woman

> *"Ones that I would be comfortable inviting or ones I think would be receptive to the idea." –* Age 33, White, Bisexual, Nonbinary

There were a few who mentioned altruistic reasons such as knowing that the people they plan to invite have need for money, which again implies that these are people they are more than just casually acquainted with.

> *"A friend of mine is non-binary and they aren't super close to me, like, they're not somebody that I would talk about my feelings with, but they always need money and I'm, like, when I've given them little job opportunities before they've done [them], so I would give them." –* Age 28, White, Bisexual Transgender man

When asked if these people they think of inviting are likely to invite them into a study, respondents did indicate that these relationships are reciprocal, unless the people they intend to invite do not usually participate in survey studies to begin with.

A total of 394 respondents completed the web-RDS and named a total of 1012 alters. Referring to Table 2.2, the people named by the respondents as people they can invite to a hypothetical RDS study are rated to be close to the respondents. Almost all the people named are either family, romantic/queerplatonic partners or friends to the respondent. On average, these are people the respondents have known for about 4 years. There are race differences in the type of relationship the respondents have with the alters named ($X^2 = 9.80$, df = 3, p < .05), but no differences in the years known (t(908.92) = 1.41, p = .16). Non-Hispanic White respondents (mean = 5.15, std. err.= .05) tend to name alters they are closer to compared to non-white respondents (mean = 4.86, std err. = .05) (t(976.95) = 4.02, p < .001).

Table 2.2 *Descriptive statistics of alters named in web-RDS*

	Est (SE)			Difference
	Overall n = 1012	Respondent's race/ethnicity: Non-Hispanic White n = 566	Respondent's race/ethnicity: Black/others n = 446	
Relationship: Family	1.3% (0.4%)	1.4% (0.5%)	1.1% (0.5%)	0.3%
Relationship: Partner	18.2% (1.2%)	14.8% (1.5%)	22.4% (2.0%)	-7.5%
Relationship: Friend	80.1% (1.3%)	83.4% (1.6%)	76.0% (2.0%)	7.4%
Relationship: Other	0.4% (0.2%)	0.4% (0.2%)	0.4% (0.3%)	<-0.1%
Closeness (1: Not at all close, 7: Very Close)	5.02 (0.04)	5.15 (0.05)	4.86 (0.05)	0.29***
No. of years respondents have known the alter	4.27 (0.16)	4.46 (0.20)	4.01 (0.25)	0.45

*p < 0.05, **p < 0.01. *** p < .001

2.4.3 Consistency and the extent of estimation of the PNS questions

Answers to the most general PNS questions (PNS (all) and PNS (18)) had a maximum of 318 (refer to Table 2.3). Though this is not an unthinkable number, it is unlikely that the boundaries of recruitable network members are this large for most people. The more restrictive PNS questions yielded more conservative responses, with the maximum being 20. Restricting the

analysis to only the respondents who completed the follow-up survey (n= 166), the Spearman's

rank correlation between the PNS reported in the main survey and the PNS reported in the

follow-up survey indicated that the test-retest reliability of all the PNS measures do not differ

very much from each other, with the highest being PNS (all) and PNS (18+). When we look at

the correlations with PNS (invite), all of the PNS questions seem to be highly correlated with

PNS (invite) with the highest being PNS (interest) followed by PNS (close).

As for the degree of estimation, defined as the proportion of heaping responses, involved

in answering these questions, the worst performing question seems to be the PNS (all) and PNS

(18+) questions. About 10% of the responses to these two questions were in multiples of 5.

Meanwhile, the best performing questions using this metric are PNS (close) and PNS (invite).

Table 2.3 *Quality indicators of PNS questions*

Personal network size type	Mean (Range)	Reliability	Correlation with PNS (invite)	Proportion of heaping*
PNS (all)	6.29 (1-318)	0.74	0.84	10.3%
PNS (18+)	6.08 (1-318)	0.71	0.85	9.2%
PNS (close)	3.58 (1-36)	0.66	0.90	3.8%
PNS (interact)	3.54 (0-50)	0.64	0.88	4.3%
PNS (interest)	3.36 (0-20)	0.67	0.96	4.9%
PNS (invite)	3.24 (0-20)	0.68	-	3.8%

*Multiples of 5 was coded starting from the value 10, as 5 is likely to be a valid response and not an estimation

2.4.4 Comparison with BRFSS 2020

In Figure 2.1, RDS-II weighted estimates for age (18-24), household income (more than

$50k), education attainment (more than high school), work status, race/ethnicity (Non-Hispanic

Black, Non-Hispanic White), and sexual orientation and gender identity (bisexual, gay/lesbian

and transgender) using the different PNS measures were compared against the BRFSS 2020

estimates. The web-RDS was not meant to be representative of the adult population in Michigan

and was not expected to be, but this comparison serves as a measure of the impact of using

different PNS questions in the construction of RDS II estimates.

Figure 2.1 *RDS-II weighted estimates vs. BRFSS 2020 weighted estimates*
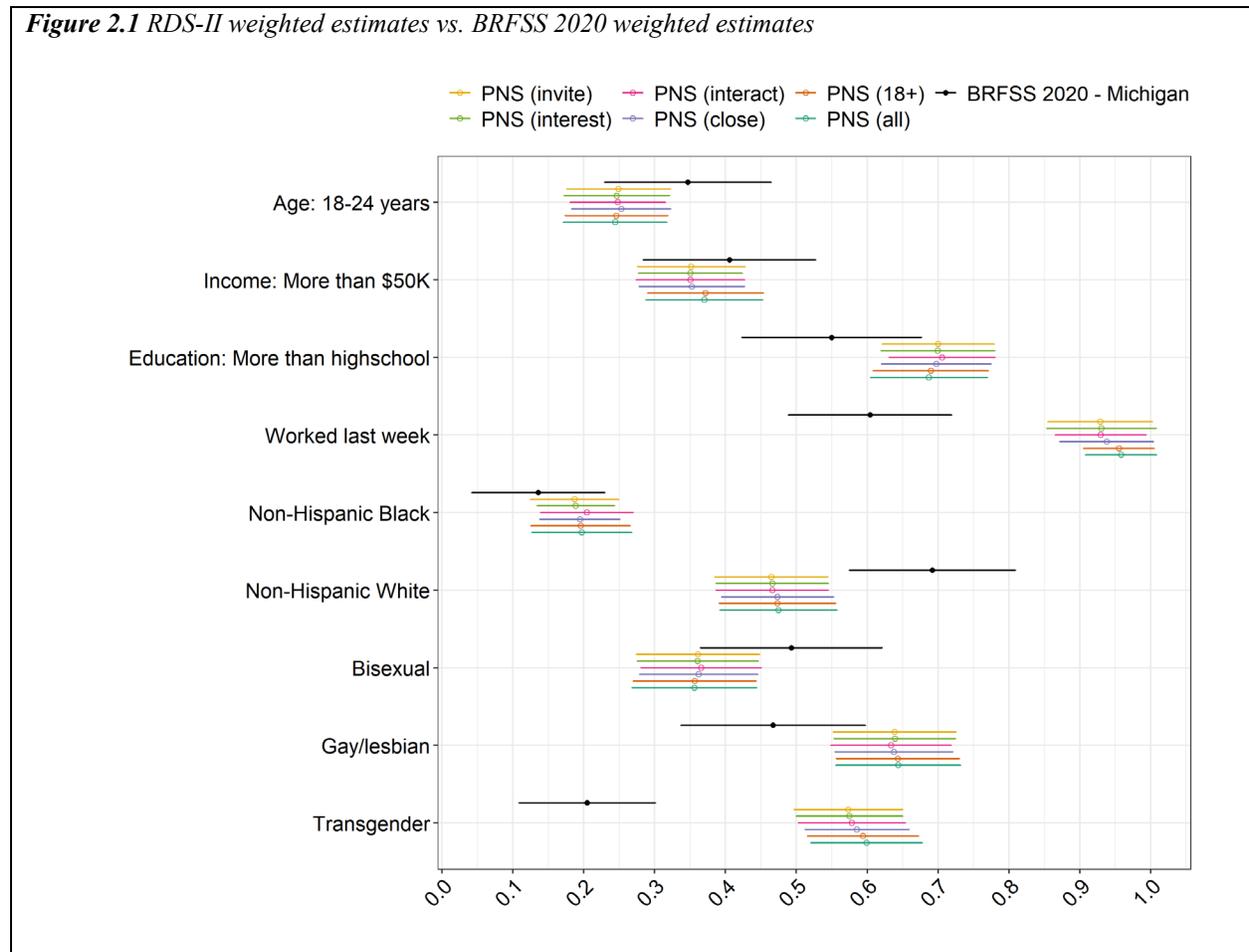
Overall, it seemed that the respondents in the web-RDS was quite different from the

respondents in BRFSS 2020 (e.g., older, higher educational attainment) and it did not seem that

the different PNS measures made much of a difference in the estimates. None of the different

PNS measures brought the estimates for people who worked last week, Non-Hispanic White, and

transgender much closer to the benchmark estimate from BRFSS 2020. Looking at minute

differences though, for different variables, different PNS performed slightly better — PNS (all)

and PNS (18+) bringing the estimate of those with an income of more than $50k slightly closer

to the BRFSS 2020 estimate, while PNS (invite), PNS (interest) and PNS (interact) was closer to BRFSS 2020 for the "worked last week."

2.5 Discussion

PNS is used in the construction of RDS point estimators and to determine the number of invitation coupons to distribute to the respondents. It has the potential to be a predictor of recruitment productivity, which can help RDS researchers plan their RDS fieldwork better. A PNS measure that fulfills these roles should measure the network of possible invitees, should be reciprocal, and be asked in a way that reduces measurement error. This current paper attempts to understand how adult LGBT respondents report their PNS and what are the best practices for constructing a PNS question by testing the common PNS question wording, which asks respondents to report the number of people they "know."

Though the PNS question used in many RDS studies uses the term "knowing", there is a large variation in how respondents define knowing someone, from just being able to recognize each other to having a more intimate relationship with each other. Meanwhile, the respondents' definition of "closeness" appears to be more stable. This poses a problem to using the network size reported in the general "know" question as it very likely violates the assumption of reciprocity in the network when used as part of RDS estimators. If one person defines "knowing" as mere recognition but this person's network member defines "knowing" as being close friends, there is a mismatch that makes it unidirectional. There is also some indication that changing the context of the question changes the way some respondents define "knowing" someone, which may be problematic for its use in population size estimation using NSUM.

The way the respondents in the interviews reported their PNS for the people they "know" also reflects Fu (2005)'s findings. Many respondents were unable to give a single number and

reported in a range unless they knew very few people or none at all. This indicates that being forced to respond with a single number, as they usually have to in RDS surveys, may be a difficult task subject to many errors. Respondents are motivated to give an accurate response in an in-depth interview but are a lot less likely to give the same amount of effort in a self-administered survey. This finding is likely not limited to the LGBT population as it is due to the question wording itself.

Furthermore, just asking for people respondents know does not get at the network of people that is likely to be invited to participate in the RDS studies. From the interviews, the people respondents think of inviting tend to have a closer relationship than just knowing their names. The respondents are at least somewhat aware of how receptive their network members will be to their invitation. It remains to be seen if this is truly a reciprocal relationship though many have reported that the people they think of inviting are likely to invite them into a study as well. This is corroborated through the web-RDS, as very few respondents named alters who are neither family, partner, nor friends, and generally are people they have known for a while and feel at least somewhat close to.

Finally, it does look like the more restrictive the PNS questions are, the more realistic the ranges are if one is trying to get a measure of the recruitable network. The PNS for the more restrictive questions has fewer heaping values, which points to less shaky estimates from respondents. According to Mill et al. (2014), rounded PNS responses can lead to biases in RDS estimates, so a PNS measure with fewer rounded responses is also better when used the way they are in RDS — as weights. Even though all the PNS questions tested were highly correlated with the PNS for the people respondents think they can invite; the highest was for the more restrictive questions. However, it was gratifying to see that there is a degree of consistency in the way

respondents respond to the PNS questions, lying somewhere in between what Gile, Johnston & Salganik (2015) found and Yamanis et al. (2013) found with a similar follow-up period (the former's follow-up study was two weeks after while the latter was one to three weeks later). As Giles, Johnston and Salganik (2015) had noted, further research needs to be done to understand the differences in the consistency of the responses.

However, the similarity in the RDS-II weighted point estimates for age, income, education, work status, SOGI status, and race/ethnicity using the different PNS questions implies it may not matter as much what PNS questions are used, at least for these variables and among this population. Weighting has less of an impact if there is no association between the variables the estimates are obtained for and the weighting variable. For target populations such as commercial sex workers (CSW), the different PNS might have more impact when used as weights for estimates of the prevalence of sexually transmitted diseases. Further research will need to be done to compare estimates using different PNS for other variables and for other populations.

Besides that, further research needs to be conducted in order to test the assumption of reciprocity using more specific PNS questions. This study only has the respondents' perception on whether the alters they named would also invite them, but this is not tested in practice. Besides that, the order of presentation of PNS questions for the semi-structured interviews might have also led the respondents to think from general to specific, making the more specific questions more aligned with the recruitable network compared to the general question. This limitation is also relevant to the web-RDS, as the questions were ordered the same way for all respondents. The respondent burden associated with answering the different PNS questions could

be better measured with response time data which was unavailable in the web-RDS data, thus future research should include a measure of response time.

Furthermore, this study is restricted to mostly the LGBT population. The way the respondents in this study thought about the people they would hypothetically invite to a study may be different from how other populations think about it. This type of interview needs to be done for other populations that are differently sensitive and hard to reach for other reasons, such as PWID, commercial sex workers (CSW), and recent immigrants. My expectations would be that recent immigrants will be more likely to be similar to the findings in this study, while PWID might be more likely to invite people they are not necessarily close to.

In summary, this study has shown that PNS questions have to be more specific, at least with the LGBT population. The general PNS question ("how many people do you know") has too many different interpretations, does not truly capture the network of possible invitees and is burdensome for respondents to answer. More specific PNS question targeting respondents' close network is more reflective of the network of possible invitees and is less burdensome for respondents to answer. The general PNS question can serve as an opener to a sequence of PNS questions, but it is not recommended to be used as is. It may be possible even to ask how many people respondents think they can invite. Though this study may not be completely generalizable to RDS studies involving non-LGBT populations, I expect that the finding from the qualitative interview component of this study on the different ways "knowing" may be understood by respondents is still relevant to other RDS studies involving other populations. Therefore, I would still recommend using a more restrictive PNS question for other populations.

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Chapter 3 Who Recruits, Who is Recruited, and Who Participates?

3.1 Abstract

The efficacy of the RDS method in reaching the population of interest depends heavily on the existing respondents' peer recruitment cooperation and peer recruitment success. This can break down in two different ways: 1) when respondents do not invite their alters, and 2) when the invited alters do not participate. This study aims to explore the motivation to cooperate in recruitment, the characteristics of the recruiters, and the characteristics of the alters they consider recruiting with an eye to examining the correlates of success in recruitment. This study uses the same two sets of data from Chapter 2 — 1. semi-structured in-depth interviews conducted over Zoom with 19 adult respondents of various ages, gender identities (transgender, nonbinary, cisgender), race, and sexual orientations (gay, lesbian, bisexual), 2) an RDS web survey targeting the adult LGBT population (n = 394). Thematic analysis of the semi-structured in-depth interviews indicated that cooperation could be motivated by altruism, interest in the study topic, and monetary incentives. Meanwhile, analysis using the web-RDS data indicated that recruiters prefer to recruit alters who are similar to them in race and ethnicity, friends they have influence over, and those who they feel close to and are likely to respond positively to their recruitment. However, when it comes to recruiter characteristics, only the age of the recruiter was associated with recruitment success, with younger recruiters being more successful.

3.2 Introduction

RDS studies rely on their existing respondents to cooperate with the recruitment process. Even if the target population forms a single system of networks, RDS studies rely on the respondents to propagate the chain of recruitment. Difficulties in the field have been reported and resulted in researchers needing to change their strategy on an ad-hoc basis, such as adding more seeds, increasing the number of recruits allowed for each respondent, or increasing recruitment incentives (e.g., Martin et al., 2015; Carillo et al., 2020) due to slow or dead recruitment progress. A recent systematic review indicated that only 20% of the articles reviewed reported their sample successfully achieved the targeted sample size (Ong & Lee, 2020).

There are two steps to the recruitment of new respondents into RDS. Firstly, the respondent must cooperate with the recruitment request and invite their alters to the study. This usually involves respondents giving their alters a coupon that has details about the study and a unique ID that will tie the alters back to their recruiter. The second step requires their alters, after receiving the invitation, to participate in the study. This process can break down in two ways — RDS respondents may not cooperate with recruitment, which means they do not invite their alters; or the alters they invited decide not to participate in the study at all. Respondents may not know whether the alters participate in the study after accepting the coupon. Which respondent ends up being a successful recruiter is likely an interaction between the characteristics of the respondent, the characteristics of the alter they choose to approach, and their relationship with each other.

A burgeoning body of research has emerged examining the components of productive RDS recruitment (e.g., Cornwell & Schneider, 2017; Forrest et al., 2016; Lachowsky et al., 2016;

Carillo et al., 2020; Lee et al., 2020). Getting a better understanding of how these recruitment processes can break down (i.e., recruiters' non-cooperation, recruitees non-participation) will help researchers target likely recruiters in initial seed selection while knowing the types of respondents who will be less productive in recruitment will help researchers plan for it and mitigate data collection challenges upfront.

3.2.1 Characteristics of a productive recruiter

Given the diversity of the type of populations recruited through RDS, it is important to understand the correlates of RDS recruitment in different types of populations, but the focus has largely been on the PWID and MSM populations (e.g., Abramovitz et al., 2009; Cornwell & Schneider, 2017; Forrest et al., 2016; Lachowsky et al., 2016). Some characteristics of productive recruiters may transcend different types of populations (e.g., sociodemographic characteristics, self-reported degree). Still, some are also population-specific (e.g., recruitment effectiveness is similar between HIV positive and HIV negative respondents in Abramovitz et al., 2009).

There have been some mixed findings with the relationship between recruitment productivity and sociodemographic variables (age, race/ethnicity, income, marital status). For some populations, older MSM respondents (Reisner et al., 2010) and older PWID respondents (Lee et al., 2020) are more productive though Lee et al. (2020) found that the strength and direction of that association to be different for Korean immigrants. A few studies have found race to be associated with recruitment productivity (e.g., Black respondents were more productive than White respondents in Martin, Johnson & Hughes, 2015; Aboriginal respondents were more productive than White respondents in Forrest et al., 2016) but others did not find such

association (e.g., Reisner et al., 2010). In terms of income, respondents with lower income have higher productivity (Reisner et al., 2010; Martin, Johnson & Hughes, 2015). Being married was associated with better recruitment productivity for Korean immigrants but not for PWID (Lee et al., 2020).

One common variable that has been studied as a correlate of recruitment productivity is the recruiter's personal network size (PNS) (Reisner et al., 2010; Kuhns et al., 2015; Forrest et al., 2016; Cornwell & Schneider, 2017; Li et al., 2018; Lee et al., 2020; Carillo et al., 2020). From the assumption that RDS ties are assumed to be reciprocal, respondents who report a larger PNS have more choices in alters and opportunities to recruit their alters into the study. Between two equally motivated respondents, one with only three alters (Respondent A) and the other with six (Respondent B), there is a higher likelihood that the respondent with six alters can recruit someone into the study. Respondent B, as they know more people, is more likely to know someone who would participate compared to Respondent A, who only knows three alters. Respondent B also has more choices if the people they invited declined the invitation. However, this has not been consistently found to be true. Rudolph et al. (2013) found that the PNS of PWID was not associated with their recruitment productivity. It was also not found to be associated with recruitment success among lesbians and bisexuals in one study (Martin, Johnson & Hughes, 2016). Still, it was positively associated with recruitment success among MSM (Kuhns et al., 2015; Forrest et al., 2016). Lee et al. (2020) found that PNS for close relationships was associated with recruitment productivity for Korean immigrants but not for PWID. The general RDS degree question (i.e., "How many people do you know, who know you who are [target population]?") was not associated with recruitment productivity (Lee et al., 2020).

The measurement issues with PNS described in Chapter 2 may be the reason for the mixed findings regarding PNS and recruitment productivity. Drawing from Chapter 2, it may be that the PNS for close relationships is more reflective of the network of recruitable alters. These findings are also complicated by the fact that recruitment productivity is also reliant on whom the respondents chose to recruit and who responded positively to the invitation.

3.2.2 Who ends up participating?

In the social network literature, tie strength is related to cooperation between the ego and the alter, though tie strength itself is defined in a myriad of ways (e.g., duration of the relationship, frequency of contact, type of relationship, closeness, the degree of supportiveness of the tie) (Melamed & Simpson, 2016). The relationship's closeness and duration have been indicated to be good proxies for tie strength (Marsden & Campbell, 2012). People are willing to go to greater lengths for those they are tied strongly with (Harrison et al., 2011). In the context of RDS recruitment, this may mean that alters who are approached by RDS respondents are likelier to cooperate if they have stronger ties with them.

In a study on RDS recruitment dynamics, Phillips II et al. (2014) asked MSM respondents to describe their relationship with their alters, the frequency of their communication, and their relationship strength. They found that respondents are more likely to attempt to recruit alters they communicate with at least daily. They are also more likely to recruit friends than acquaintances. Respondents are likelier to recruit alters who are very close to them. This pattern emerges in terms of who ended up enrolling in the study as well. It was the alters who were very close to the respondent, communicated on a more regular basis, and thought they had the same type of relationship with the respondents who ended up participating in the study.

Li and colleagues (2017) had examined the recruitment intention and actual recruitment for alters with different relationships with the respondents in a study of PWID. A higher level of trust was associated with actual recruitment and subsequent participation of the alter in the study, although trust was not associated with the intent to recruit. Living together reduced the recruitment intention but increased actual participation of the alter in the study. Being able to depend on the alter (i.e., "ego can go to alter for a place to stay") increased recruitment intention but was not associated with actual enrolment. Echoing Phillips II et al. (2014)'s findings with the MSM population, respondents are more likely to expend more effort to recruit the alters who are close to them or they have leaned on for support. However, unlike Phillips II et al. (2014), this did not translate into more close alters' actual enrolment. Meanwhile, alters who spent time together in the past six months were less likely to be considered as recruits and were less likely to end up participating in the study. One could argue that perhaps six months was too long a reference period for this. Li and colleagues (2017) examined factors specific to the PWID population as well (e.g., injecting together), but as this study is interested in recruitment dynamics more generally, these factors are not described here. From this study, it seems that the people respondents say they will recruit are not exactly related to who they end up recruiting.

Lee et al. (2020) utilized data from follow-up surveys of two RDS studies involving two different populations (i.e., PWID and Korean immigrants) to examine recruitment dynamics. With the caveat that participation in the follow-up surveys was associated with recruiting at least one other person into the studies, they found that respondents are knowledgeable about the status of coupons distributed. This study compared recruitment intention and actual enrollment. Though the gender profile of the alters respondents intended to recruit and those they successfully recruited were similar, the age of the recruits for the successful recruiters in the

PWID study was older than the intended recruits. PWID and Korean immigrants ended up recruiting friends and those they felt close to. Korean immigrants ended up recruiting more of their own families than they intended to. Most alters who enrolled in both studies were in contact with their recruiter within the past week.

From these three studies, close relationships and regular contact seem to be important factors in both the decision to recruit and the alter's decision to participate. Intuitively, this makes sense as more regular contact translates to more opportunities for the respondents to invite their alters into the study. However, Li and colleagues (2014) have also shown that recruitment intention and who ultimately participates are not always in the same direction. Perhaps some respondents are better at making decisions on which alter to approach, or there are differences for different target populations.

Overall, we still do not have a firm understanding of the characteristics of a productive recruiter. Findings with regards to age, race/ethnicity, income, marital status, and personal network size have been mixed. On top of that, these studies were conducted with different target populations. Though there have been a few studies on the types of relationship that matters in successful recruitment attempts in RDS, recruiters were free to recruit anyone in their network to the study, which hampers the ability of these studies to disentangle the recruitment mechanism. In this study, I attempt to add to the current literature on the characteristics of a productive recruiter by studying both the characteristics of the recruiters and the intended recruits. However, in this study, recruiters were not given complete freedom of choice of recruit, which may result in a cleaner interpretation of the findings with regards to both the characteristics of a successful recruiter.

Due to budgetary constraints, this study is limited to studying the recruitment dynamics for the adult LGBT population residing in the U.S., specifically Michigan as most respondents from the web-RDS data used in this study is from Michigan.

The research questions this chapter hopes to answer are as follows:

1. What are the considerations in deciding whether to cooperate in recruitment?

2. What are the characteristics of the alters respondents would consider recruiting?

    2.1 Are the alter characteristics associated with being successful recruiters?

3. What are the characteristics of a respondent who is successful at RDS recruitment?

    3.1 Do PNS question predicts recruitment productivity?

Based on past literature, I expect respondents to consider recruiting alters they consider friends more often than other types of relationships, and alters they would consider as close to them though this may not necessarily translate to an association with successful recruitment. I do not have an expectation for the characteristics of a successful recruiter due to the mixed findings for various sociodemographic variables and the nature of some of those studies compared to the current study (in-person vs. web mode). As for PNS, I expect close PNS to be associated with recruitment productivity given the way it seems to align more with the recruitable network compared to the general PNS.

3.3 Methods

3.3.1 Data

Semi-structured in-depth interviews

Similar to Chapter 2, this chapter uses the same two sets of data, 1. semi-structured in-depth interviews conducted over Zoom with 18 adult respondents of various ages, gender

identities (transgender, nonbinary, cisgender), race, and sexual orientations (gay, lesbian, bi), 2)

an RDS web survey targeting the adult LGBT population. Characteristics of the respondents

interviewed can be found in Table 2.1 in Chapter 2.

The respondents for the in-depth interviews were recruited from the Michigan Institute

for Clinical and Health Research participant portal (MICHR), the University of Michigan's

LGBT groups' listservs, and word-of-mouth referrals. Respondents were eligible to participate in

the interview if they were older than 18 years old, currently reside in the United States and

identify as either transgender and/or gay or bisexual, and are either racially Black or White.

Respondents were compensated with a $50 Amazon gift card for their time.

Web-RDS

The web RDS study is a 10-15-minute-long survey targeting the adult LGBT population

residing in the United States. It is a restricted RDS study where most of the recruitment was

stopped at the second wave. Three wave 2 respondents were randomly selected at the end of the

field period to recruit two randomly selected alters from the people they named to account for the

unanticipated interest in the survey, which led to many successful RDS recruitment.

Figure 3.1 *Number of recruits and recruiters by wave (Web-RDS survey)*
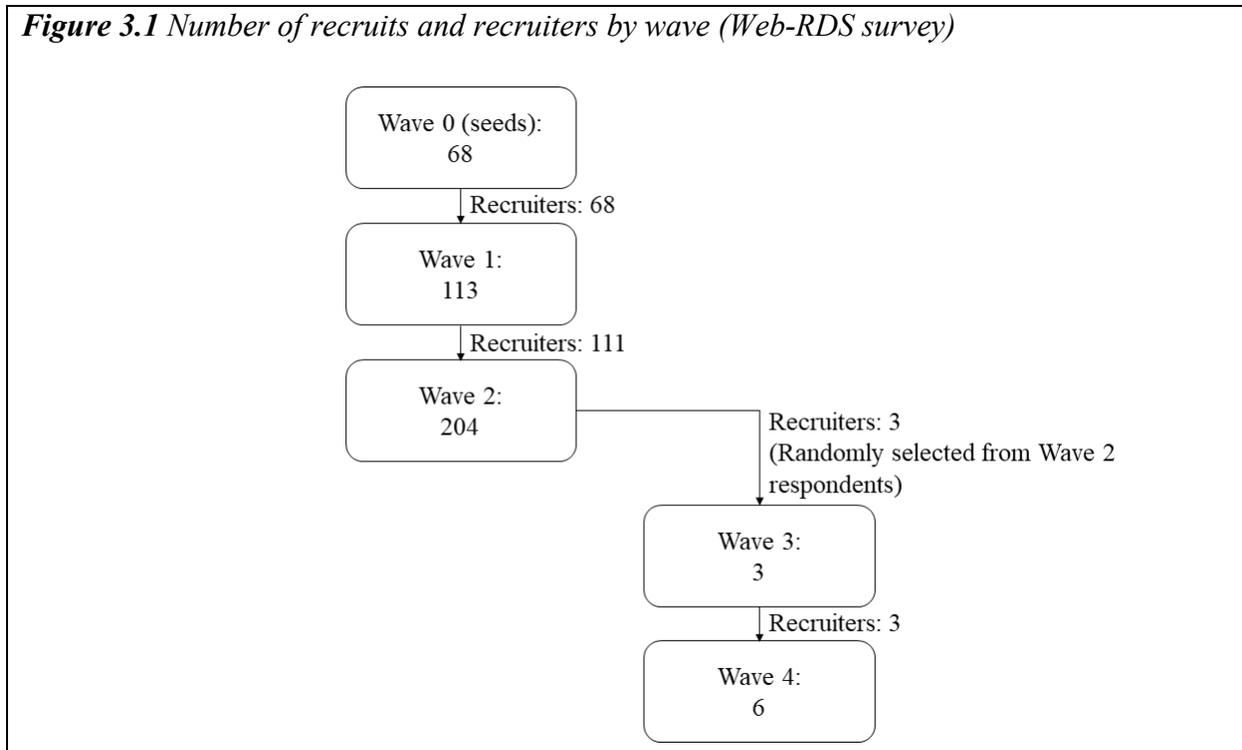
Seed respondents were recruited from the Michigan Institute for Clinical and Health Research participant portal (MICHR). Respondents were eligible if they were older than 18 years old, identified as transgender and/or gay, lesbian, or bisexual, and are either white or Black. The race inclusion criteria were to have a balanced racial demographic to examine the peer recruitment productivity of Black respondents, to account for the intersectionality of race and sexual orientation and gender identity. A total of 77 seed respondents were invited to participate, out of which 68 responded to the survey. These seeds then recruited a total of 326 respondents in four waves (excluding 11 respondents who attempted to be interviewed twice, presumably to recollect the incentive payment and their recruits). Figure 3.1 above illustrates this restricted RDS methodology and the total number of recruits and recruiters at each wave. Note that respondents who reported their network size is 0 were not asked to invite anyone.

Respondents who were asked to invite their alters in the web-RDS were invited to participate in a follow-up survey two weeks later. The follow-up survey asked the respondents about their recruitment behavior (e.g., did they invite the people they were asked to invite, how many people did they approach, and reasons for non-recruitment if they did not invite anyone). Respondents were compensated with Amazon gift cards for completing the surveys and for recruitment ($10 for the main survey, $5 for each successful recruitment up to $10, and $5 for completing the follow-up survey).

3.3.2 Measures

Semi-structured in-depth interviews

In the interviews, adult LGBT respondents were asked if they would be willing to invite people to participate in an RDS study, the number of people they think they can invite to an RDS study, the characteristics of these people and the characteristics of the people they would not invite. They were also be asked to consider if they will cooperate if their alters invite them into an RDS study, and to explain the reasons. The discussion guide is in Appendix B.

Web-RDS

To understand the characteristics of the alters named in the web-RDS and how that might differ between respondents who are successful at recruiting, as defined in this study as having all the unique invitation codes given to them redeemed, variables related to how the respondents described their alters, such as their relationship (family, romantic or queerplatonic partner, friend, other), closeness (rated on a 1 to 7 scale where 7 is very close), number of years they have known each other, perceived likelihood to respond (rated on a 1 to 5 scale where 5 is most likely)

if the alters are invited to a hypothetical survey, the similarity of the alters' age, race, and ethnicity to the respondent, are examined.

The age similarity variable is not precise as the data has the respondents' age, but only the age category of their named alters. Respondents' ages were categorized the using the same cut-offs as the response categories for the alter's age (the response categories were: 18-29, 30-39, 40-49, 50-59, 60-69, 70 and older) and if both the respondent and the alter are in the same age category, the alter will be coded as being similar in age to the respondent.

Alters were coded as racially and ethnically similar to the respondents if the alters were reported to be in the same race category and were either both non-Hispanic or both non-Hispanic.

As for the relationship with the alter, if the respondents had reported that the alter was a friend or other relationships, they were asked a follow-up question about their perceived influence on their alter ("Are you in a position of influence over [ALTER] (e.g., work supervisor, church leader, someone they respect)?"), with a binary response option of either "yes" or "no". The responses to this follow-up question were collapsed with the relationship question, creating a new relationship variable with four levels (family/partner vs. friends/others recruiters have influence over vs. friends/others recruiters have no influence over).

Respondent characteristics (respondents' age, race, ethnicity, educational attainment, annual household income, work status, gender identity, general personal network size, degree of disclosure of their sexual orientation or gender identity to the people they know, close personal network size and general network size) and the target population they were asked to recruit from are also taken into account to control for their effects when examining the differences in the

types of alters they think about. Transgender respondents were asked to invite other transgender people in their network even though they may also identify as lesbian, gay, or bisexual, therefore it was necessary to account for the target population.

As for the third research question, only the respondents' characteristics were used. The variables used in the analyses using the web-RDS data are further explained in Table 3.1. Refer to Appendix C for the specific question wording where these variables were derived from.

Table 3.1 *Variables used, by recruiter or recruit status*

Type	Variable
Respondents' characteristics	1. Race/ethnicity (Non-Hispanic white vs. Others)
	2. Age (continuous variable)
	3. Gender identity (cisgender male vs. female/others)
	4. Education attainment (high school and less vs. more than high school)
	5. Annual household income (less than 20k vs. 20k to 50k vs. more than 50k)
	6. Worked last week
	7. Perceived closeness with alter (1: Not at all close, 7: Very close)
	8. Personal network size, close (continuous variable) ("Of these [PNS (all)], how many are 18 years of age or older? If you are not sure, just count them as adults")
	9. Personal network size, general (continuous variable) ("How many do you feel close to (that is, you feel at ease with, can talk to about what is on your mind, or call on for help)").
	10. Disclosure of sexual orientation or gender identity to the people known (continuous variable)
	11. Successful recruiter (Used all the unique invitation codes vs. did not use all the unique invitation codes)
Alters' characteristics	1. Race/ethnicity similar to recruiter (Yes/No)
	2. Age similarity to recruiter (Yes/No)
	3. Respondents' reported relationship with the alter (family/partner vs. friends/others recruiters have influence over vs. friends/others recruiters have no influence over)
	4. Years known (continuous)
	5. Closeness (1: Not at all close, 7: Very close)

	6. Perceived likelihood of alter responding (1: Least likely, 5: Most likely
Others	1. Target population asked to invite (Gay/lesbian vs. Bisexual vs. Transgender)

3.3.3 Analysis plan

Semi-structured in-depth interviews

To address the first research question, thematic analysis was used to analyze the data from the qualitative interviews. Responses to the questions about their reasons for cooperation with RDS recruitment were closely examined for common themes.

Web-RDS

The web-RDS data is used to answer the second and third research questions regarding the characteristics of alters recruiters consider inviting and the correlates of a successful recruiter. I first present the unweighted characteristics of the recruiters and non-recruiters. Though most of this chapter will be focused on recruiters only, it is possible that the recruiters who responded at the first two waves are different from the non-recruiters who responded at the later waves, which would make conclusions made using only the recruiters to be less generalizable. If there are differences between the unweighted estimates with the RDS-II (Volz-Heckathorn) weighted estimates, it will be noted. Then, the descriptive statistics of who the recruiters say they will recruit by potential recruit's age, race/ethnicity, closeness, years known, relationship with recruiter and perceived likelihood to respond to the invitation will be presented. I then fit a generalized linear model with a logit link on successful recruiters examining the associations of the recruit's characteristics, recruiters' characteristics and the target population they were asked to recruit for with recruitment success (less successful vs. successful recruiter). The close network size and general network size are included in separate models which will be compared.

The third research question is addressed with the data from the web survey. Recruitment success is defined similarly as above. This analysis is at the respondent-level. For this research question, I fitted a generalized linear model with a logit link on recruitment success as the outcome (predicting being a successful recruiter), with the respondent characteristics and target population as predictors (refer to Table 3.1). This is an exploratory analysis to establish what are the correlates of a successful recruiter. Both the general PNS and the close PNS were tested in this model separately.

3.4 Results

3.4.1 Semi-structured in-depth interviews

What are the considerations in deciding whether to cooperate in recruitment?

In the interviews with LGBT respondents, some have mentioned wanting to ensure their communities are represented in surveys due to the historical underrepresentation of their communities. A few mentioned the personal importance of the survey topic as a motivator. One respondent also mentioned that if their experience with the survey was uncomfortable due to the perceived non-inclusivity in the language used, they would not cooperate with the recruitment request. This respondent mentioned specifically being uncomfortable with language that assumes romantic relationships to be the norm.

> *"I think so [that I would be motivated to reach out to people]. Especially if I believed in the merits of the survey, I'd be that much more proactive about it, because you know I want people to have good data to operate on and try to understand LGBT people better."* – Age 33, White, Bisexual, Transgender man

> *"You know, like I wouldn't want to call in a favor from everybody unless I thought that it was important to […] yeah, so like if I feel like the survey isn't amatonormative, so like it doesn't assume that about people because, like, I guess, I should have said this in my*

identity like one of my identity is like I'm a political aromantic so I'm against romantic relationships." – Age 26, Black, Lesbian, Transgender woman

Monetary compensation for inviting their network members into a study is helpful to some, but not a strong motivator for everyone. Interest in the survey topic does help with the motivation to cooperate.

"I mean if I finished the survey and I thought it was interesting and I thought that the results might be helpful to my friends." – Age 65, White, Lesbian, Cisgender woman

Though there does not seem to be a difference between white respondents and Black respondents in what motivates them to cooperate in recruitment, respondents who are younger or are currently in an education institution tend to mention reasons such as interest and importance of research.

3.4.2 Web-RDS

Description of the web-RDS sample

The characteristics of the respondents in the web-RDS are presented in Table 3.2. Comparisons with weighted estimates are provided in Appendix D. The differences between the weighted estimates for recruiters (respondents who were asked to invite their alters) and non-recruiters (respondents who were not asked to invite their alters) are similar with the unweighted estimates. From the table, recruiters were slightly older than non-recruiters (recruiters' mean age = 27.93 compared to non-recruiters' mean age = 26.22, t (247.44) = 2.32, p = .021), have significantly bigger general network size (recruiter's mean general network size = 8.59 compared to non-recruiters mean general network size = 3.85, t(190) = 2.11, p = .036) and close network size (recruiters average close network size = 3.92 vs. non-recruiters average close network size = 3.26, t (307.8) = 1,99, p = .048). Recruiters and non-recruiters do not significantly differ on any

other characteristic such as gender identity, sexual orientation, disclosure of their sexual

orientation and gender identity, work status, education attainment, household income and

race/ethnicity.

Table 3.2 *Descriptive characteristics of web-RDS respondents (unweighted)*

	Est (Std. Err.)		Differences
	Recruiters (n=185)	Non-recruiters (n=208)	
Age[2]	27.93 (0.68)	26.22 (0.28)	1.71*
Race/ethnicity:[1]			
Nonhispanic White	50.8% (3.7%)	52.4% (3.4%)	-3.5%
Black	31.9% (3.4%)	27.9% (3.1%)	4.0%
Others/Biracial	17.3% (2.8%)	19.7% (2.8%)	-2.4%
More than high school education	71.3% (3.3%)	69.9% (3.2%)	1.5%
Transgender/nonbinary[1]	44.3% (3.7%)	54.3% (3.5%)	-10.0%
Sexual orientation:[1]			
Gay/lesbian	62.7% (3.6%)	63.9% (3.3%)	-1.2%
Bisexual	37.3% (3.6%)	36.1% (3.3%)	1.2%
Disclosure of sexual orientation or gender identity to the people they know (%)[2]	51.65 (1.84)	52.80 (1.57)	-1.16
Worked last week[1]	92.4% (1.9%)	96.7% (1.2%)	-4.2%
Annual household income[2]	51929.95 (2174.08)	49687.94 (1850.11)	2242.00
Network size (general)[2]	8.59 (2.23)	3.85 (0.27)	4.75*
Network size (close)[2]	3.92 (0.28)	3.26 (0.17)	0.66*

*p < .05, ** p < .01; ***p < .001 [1]Fisher's exact test/Chi-square test; [2]T-test for independent samples

What are the characteristics of the alters respondents would consider recruiting? Are the characteristics associated with being successful recruiters?

Restricting the sample to only recruiters, Table 3.3 presents who the recruiters think of

when they were asked about the people they will invite to a hypothetical study. Altogether,

recruiters in the web-RDS described 1012 alters. They tend to name alters who are similar to

them in age and race/ethnicity. In terms of the quality of the relationships, they tend to name

alters whom they have known for 4.65 years on average, and these alters are perceived to be

close (average closeness: 4.87). Most of the named alters are friends of the recruiters and are

perceived to be very likely to respond to the recruiters' invitation.

Table 3.3 *Characteristics of alters named by recruiters*

	Est. (Std. Err.) n = 1012
Same age category	87.9% (1.0%)
Same race/ethnicity	83.3% (1.18%)
Closeness (rated 1-7)	4.87 (0.06)
Years known	4.65 (0.27)
Relationship	
Family/partner	19.5% (1.2%)
Friends respondents have influence over	46.3% (1.6%)
Friends respondents have no influence over	34.2% (1.5%)
Likelihood of responding (rated 1-5)	4.64 (0.03)

These measures were then fitted in a generalized linear model with the binary outcome of

being a successful recruiter (refer to Table 3.4). In this multivariate model using the close

network size, controlling for respondents' characteristics, naming alters of the same age category

as the respondent (OR = 3.46, 95% CI [1.26, 9.52]) and naming friends respondents have

influence over compared to naming family members and romantic/queerplatonic partners (OR =

3.06, 95% CI [1.02, 9.23]) are associated with being a successful recruiter. Meanwhile,

respondents who named alters with the same race/ethnicity was associated with a decreased odds

in being a successful recruiter (OR = 0.17, 95% CI [0.05, 0.58]).

The results are generally similar when the model is fitted using the general network size

instead of the close network size, though naming friends respondents have influence over

compared to naming family members or romantic/queerplatonic partners is no longer

significantly associated with being a successful recruiter. The general network size was not

significantly associated with being a successful recruiter either.

Table 3.4 Odds ratio of being a successful recruiter by characteristics of named alters

	OR (95% CI)	
	Close network size	General network size
Same age category as respondent	**3.46 (1.26, 9.52)***	**3.49 (1.28, 9.52)***
Same race/ethnicity as respondent	**0.17 (0.05, 0.58)****	**0.24 (0.07, 0.80)***
Closeness	1.40 (0.98, 2.00)	**1.44 (1.02, 2.03)***
Years known	0.99 (0.93, 1.06)	0.99 (0.93, 1.06)
Relationship to respondent (Ref: family/partner)		
Friends respondents have influence over	**3.06 (1.02, 9.23)***	2.95 (1.00, 8.69)
Friends respondents have no influence over	0.89 (0.33, 2.44)	0.84 (0.31, 2.27)
Perceived likelihood of alter to respond to invitation	0.90 (0.54, 1.50)	0.88 (0.52, 1.48)
Age of respondent (centered)	**0.89 (0.84, 0.94)****	**0.90 (0.85, 0.96)****
Race/ethnicity: non-Hispanic White	0.87 (.34, 2.22)	0.90 (0.37, 2.23)
Gender identity of respondent: Cisgender man	**0.17 (0.05, 0.64)****	**0.14 (0.04, 0.51)****
More than high school education	1.21 (0.53, 2.74)	1.18 (0.52, 2.65)
Household income of respondent (ref: More than $50k)		
Less than or equal $20k	2.11 (0.47, 9.53)	2.37 (0.56, 9.98)
$20k to $50k	0.72 (0.22, 2.38)	0.83 (0.26, 2.64)
Target population (Ref: bisexual)		
Gay/lesbian	1.07 (0.41, 2.80)	1.06 (0.40, 2.80)
Transgender	0.30 (0.06, 1.41)	0.25 (0.05, 1.19)
Network size (close)	0.93 (0.83, 1.04)	-
Network size (general)	-	0.97 (0.93, 1.02)
McFadden Pseudo R^2	0.40	0.40

* $p < .05$, ** $p < .01$, *** $p < .001$

What are the characteristics of a respondent who are successful at RDS recruitment? Which PNS question best predicts recruitment productivity?

The analysis for this section differs from the previous as it is at the respondent level. The analysis sample size are all the respondents asked to recruit someone (n= 185) out of which there were 88% (n=162) who were categorized as successful recruiters as the unique codes given to them were all used. As the alters named were randomly selected to be the persons the recruiter was instructed to invite unless the recruiters named less than three alters, it should balance the differences in the characteristics of the alters named by the recruiters. The analysis in this section

was repeated using general network size. Neither the close network size nor the general network size was associated with being a successful recruiter. As the model fit and the strength and direction of the associations were similar, only the model with close network size is reported in this section.

Referring to Table 3.5, only age was significantly associated with being a successful recruiter, where being older is associated with decreased odds of being a successful recruiter (OR = 0.90, [95% CI: 0.84, 0.96]).

Table 3.5 *Odds ratio of being a successful recruiter by recruiter characteristics*

	OR (95% CI)	
	Close network size	General network size
Age (centered)	**0.90 (0.84, 0.96)****	**0.90 (0.84, 0.98)***
Race/ethnicity: non-Hispanic White	0.85 (0.24, 3.03)	0.83 (0.23, 2.99)
Gender identity: Cisgender man	0.22 (0.03, 1.82)	0.20 (0.02, 1.63)
More than high school education	1.90 (0.48,7.50)	2.09 (0.53, 8.28)
Household income (ref: more than $50k)		
Less than or equal $20k	0.36 (0.04, 3.41)	0.45 (0.05, 3.99)
$20k to $50k	1.15 (0.24, 5.51)	1.25 (0.27, 5.68)
Target population (Ref: bisexual)		
Gay/lesbian	1.12 (0.26, 4.81)	1.20 (0.28, 5.16)
Transgender	0.40 (0.04,3.75)	0.44 (0.05, 4.29)
Disclosure of SOGI	0.98 (0.96, 1.01)	0.99 (0.96, 1.01)
Network size (close)	0.88 (0.72, 1.06)	-
Network size (general)	-	0.97 (0.90, 1.04)
McFadden Pseudo R^2	0.32	0.32

* p < .05, ** p < .01, *** p < .001; 92% of the respondents reported having worked last week, therefore the variable is dropped from analysis

3.5 Discussion

This chapter explores motivations for adult LGBT respondents in RDS to recruit their alters, the type of people in their network that they first think of for recruitment into an RDS study, and finally if there are differences between the types of respondents who have better

success in recruitment versus those who are less successful. From the interviews with the respondents, cooperation in RDS recruitment can be motivated by altruism, interest in the topic and monetary incentive. Though only one respondent mentioned that they may not cooperate with recruitment if the RDS study is perceived to be not reflective of the experiences of the target population, this is still an important finding as this respondent had reported large networks and seemed to be influential in her community. This was corroborated by a nonrespondent in the web-RDS who did not finish the survey due to discomfort with the questions though the respondent did not elaborate further. From a practical perspective, it is important for RDS studies to gain the buy-in of their target population by pretesting the study instruments. It is also important for researchers of minority communities to be aware of the linguistic changes in accepted terminology.

As for the alters who are "top of mind" for recruiters, recruiters do seem to consider alters who are of the same race and ethnicity as them, have a close relationship with them and are perceived to be likely to respond to their invitation, which aligns with what the respondents have said in the in-depth interviews as presented in Chapter 1 and aligns with Phillips II et al. (2014)'s findings. They also tend to name more friends who they perceive to have an influence over compared to any other relationship. Recruiters who named alters who are of the same race and ethnicity are less likely to be successful at their recruitment, which seems somewhat counterintuitive. Given that most alters named were of the same race/ethnicity, it may be that cross-race relationships have a higher barrier to be considered close ties; therefore, if cross-race alters were invited, they are more likely to participate.

Some RDS researchers do aim to recruit different types of seed respondents in hopes that the recruitment will reach different networks as respondents are likely to share closer ties with

alters who are similar to them. For this population, race and ethnic similarity may not be the most influential. Respondents who named friends they have influence over are more likely to be successful in their recruitment. This suggests that RDS researchers ideally should start with seeds who are influential in their community. On the other hand, this also means that respondents who do not have as much influence in their networks will be less likely to successfully recruit their alters. Respondents identified to have a lower influence, perhaps through an additional question in the RDS survey, can be incentivized more or to be given more materials to help them persuade their network.

Finally, when it comes to respondents who are likely to be successful, younger LGBT respondents were more likely to be successful recruiters, which is slightly different from what Reisner et al. (2010) had found with MSM population and Lee et al. (2020) had found with PWID population, though it aligns with Lee et al.'s (2020) finding with the Korean immigrant population. No other characteristic was significantly associated with being a successful recruiter. This difference in finding may be due to the mode in which the survey is administered. Both the MSM study in Reisner et al. (2010) and the PWID study in Lee et al. (2020) were interviewer-administered and in person. Meanwhile, the Korean immigrant study and this current study were administered on the web.

Overall, the general network size was not associated with success in recruitment, which aligns with the findings from Rudolph et al. (2013), Martin, Johnson, & Hughes (2016), and Lee et al. (2020). The close network size was associated with recruitment success for Korean immigrants in Lee et al. (2020), but the current study did not find this association. This finding could be attributed to the structure of the survey. In this survey, respondents were led through a series of questions that made them think deeply about the people they would invite to a survey.

Due to this prompt, the way the respondents think about the alters they will approach may be different than if they had not been asked about the people they will invite. This is a major limitation to the web-RDS study as the design of this web-RDS does not completely reflect how an RDS study is commonly done. One way to mitigate this issue in future studies extending this current research is to ask respondents to name a few alters they know before asking about the people they will invite, and randomizing the selection of alters respondents are asked to invite to be either someone they named before the prompt about inviting people, or after the prompt.

There are a few other limitations to this study and the way it was implemented. Due to the budget constraints, this web-RDS was limited to two waves of recruitment with an exception to the three randomly selected respondents who were asked to continue the recruitment chain for two more waves. The recruited respondents for both the in-depth interview and the web-RDS may be different from the type of respondents who are in later waves of RDS. The in-depth interview respondents were open to an hour-long Zoom interview, and a few of them are part of large LGBT-focused organizations or workgroups. Most of the in-depth interview respondents are unlikely to be an RDS nonrespondent or a non-cooperative recruiter if the RDS survey is perceived to be legitimate. As for the web-RDS, the recruitment rate was extremely high. Given that seed respondents were recruited from a participant portal, they are likely to be motivated to help with recruitment to begin with. Some of their recruits were also part of this participant portal. It is likely that this web-RDS managed to reach out to a population that is more motivated to be a part of research compared to the general LGBT population.

Besides the sample possibly being different from the general adult LGBT population, there have been some likely cases of respondent fraud. In order to provide maximum anonymity to the respondents, respondents were only asked to provide an email address. The same IP is

blocked from taking the survey again, but this was an easy restriction to get around. Although 11 cases were removed due to suspicious activity (e.g., both recruitees of the same respondent took the survey and finished it at the same time, and the same email address for the recruiter and recruitee was used to redeem the Amazon gift card), it is unclear if there are more cases than that that should be removed.

In summary, this study showed that pretesting with the target population is important to ensure inclusivity in the language, respondents who intend to invite alters they have influence over tend to have better recruitment success, and older respondents are less likely to be successful recruiters when it comes to an RDS study targeting adult LGBT administered on the web. Inclusivity of the language in the survey is likely important to other target populations as well, though it is unclear if the other conclusions can be generalizable outside of the adult LGBT population in Michigan. The unique contribution of this study is the differentiation of the "friends" relationship and understanding the patterns of people respondents are likely to consider if asked to invite alters to an RDS study.

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Chapter 4 What is Important to RDS Data Collection?

4.1 Abstract

Although RDS is a popular method of sampling hidden populations, slow or stopped recruitment have been reported by researchers using it. This has resulted in ad-hoc changes to the data collection protocols, such as adding a number of seeds or increasing the number of recruits. the lack of clear reporting of current RDS methodology in published papers creates a challenge in understanding what helps or hinders data collection efficiency. This current study overcomes this limitation by analyzing data from a survey of RDS researchers. A total of 121 RDS researchers responded to this survey, answering questions about their RDS research (e.g., the target population, use of formative research, incentive amount, sample size, number of seeds, mode of administration). These study characteristics were examined for their associations with productivity in data collection, defined as overall productivity (the ratio of an achieved sample size to the target sample size) and overall seed productivity (the ratio of an achieved sample size to the final seed size. Of the examined RDS study characteristics, the target population of the RDS research and formative research and the mode of administration (web vs. non-web) are associated with overall productivity. The target population of the research and formative research was also associated with overall seed productivity. Besides that, the study location was also associated with seed productivity, with studies done in the U.S. being less productive than those done outside of the U.S.

4.2 Introduction

Respondent driven sampling (RDS) is a popular method of sampling hidden populations that are rare or marginalized, such as people who inject drugs (PWID) or commercial sex workers (CSW). A recent review has identified over 2000 publications worldwide that have used RDS (Ong & Lee, 2020) for various hidden populations.

In RDS, initial respondents (called "seeds") are sampled, typically through some type of non-probability sampling. After completing the survey, the seeds are asked to invite a fixed number (typically, one to five) of people they know in the target population. The recruits participate and then are asked to invite the people they know as well. This chain referral process is repeated and continues until the researcher stops the recruitment or when the recruitment no longer produces new respondents. The respondents are usually given incentives for participation in the study and successful recruitment of their network members.

Although RDS is a popular method of sampling hidden populations, difficulties in the field, such as poor RDS field productivity (e.g., extended field periods to reach target sample size due to slow or stopped recruitment), have been reported and resulted in researchers needing to change their protocols during data collection on an ad-hoc basis. For example, RDS researchers have added more seeds, increased the number of people respondents can recruit, and increased recruitment incentives (e.g., Martin et al., 2015; Carillo et al., 2020). Given the popularity of this method in collecting data on hidden and hard-to-sample populations, this unpredictability can be a cost liability to researchers using RDS. Moreover, as the quality of RDS data is reliant on the assumptions of random recruitment and the propagation of recruitment chains, the productivity of RDS studies also directly impacts the point estimates from such

studies. Therefore, it may be useful to understand what decisions can impact RDS productivity when planning an RDS data collection.

However, the biggest roadblock to doing an in-depth review study on the mechanisms behind RDS study productivity is the lack of clear reporting of current RDS methodology in published papers. The first reporting guideline for RDS studies, called Strengthening the Reporting of Observational Studies in Epidemiology for Respondent-Driven Sampling Studies: 'STROBE-RDS' Statement, was published in 2015 (White et al., 2015), but researchers have not consistently adhered to the reporting guidelines (Avery & Rotondi, 2020). The lack of adherence to the STROBE-RDS guidelines would mean an attempt at a systematic review will likely have missing data problems, which would make it difficult to present recommendations as the current practice is poorly reported. Secondly, any recommendations presented from an analysis of incomplete reports may not reflect actual practice. The current study uses survey data from a survey of RDS researchers on their RDS studies to examine RDS design features that are associated with RDS productivity.

4.2.1 RDS design features

Though there has been less focus on the methodological side of RDS research compared to the statistical side of RDS research, some recommendations have been made for RDS best practices. Formative studies, which are studies conducted prior to data collection to ascertain the suitability of RDS and to plan the RDS data collection, are among the recommendations for RDS (Simic et al., 2006; Johnston et al., 2010; Gile, Johnston & Salganik, 2015), although some regarded it unnecessary due to the sampling being driven by the target population (Semaan et al., 2002). Formative research is an exploratory study of the target population and usually involves in-depth qualitative interviews and focus groups with key informants or members of the target

population. It may also involve an observational study where the researcher visits the locations where the target population is known to be present (e.g., in Wang et al., 2005, ethnographers observed dance clubs where users of 3,4-Methylenedioxymethamphetamine, commonly known as ecstasy, were known to frequent). Information gathered from formative research can shed light on whether RDS is appropriate to use given the network of the population and the average degree size of the target population, how much to offer as an incentive to the target population, and the locations of appropriate interview sites. It can be an early indication of whether the RDS fieldwork may encounter difficulties.

However, there is little guidance on how formative research should be conducted. Researchers could conduct multiple types of formative studies; researchers could choose to interview only the community leaders, or they could interview the target group members. The use of formative research is also inconsistently reported by RDS researchers, and some had reported poor RDS recruitment despite having conducted formative studies that indicated that the use of RDS was appropriate (e.g., Truong et al., 2013). In a review study by Johnston et al. (2008), they did not find an association between whether formative research is done and RDS field productivity. The authors pointed out that specific information about the formative research methods was lacking in the studies they reviewed.

Besides conducting formative studies, the target population might be an important factor in understanding RDS productivity. Intuitively, different populations would be networked differently and, therefore, would be different in the way peer recruitment works. Some populations might be hard to reach (e.g., recent migrants) but not necessarily a sensitive population to survey (e.g., undocumented immigrants). Malekinejad et al. (2008)'s review paper

found that RDS was more successfully used to sample PWID compared to other populations, such as sex workers.

Given that RDS relies heavily on respondents' recruitment cooperation, the type of instructions given to the respondents might also be an important factor in propagating the chains. Though there has not been much focus in the literature on the instructions and possible training given to respondents to recruit their network members, there have been some indications that having more precise instructions help. In Hequembourg and Panagakis (2019), respondents have reported that the in-depth recruitment instructions given in those studies helped ease them to the idea of recruiting their peers. Meanwhile, Truong and colleagues (2013), who had also included in-depth recruitment instructions to their respondents along with an instruction email, reported that respondents commonly forward the instruction email to their peers to recruit them into the study when given the option to do so and had found that it was more convenient and enabled them to reach more of their social networks. It is clear that the methods of instruction can vary greatly with respect to how much information is provided and in what form the instructions take.

However, RDS studies do not always report what instructions were given to the respondents to aid them in recruiting. It is unclear if it is simply not reported or if there really is none provided to the respondents. Training respondents with recruitment instructions is an easier task when the survey is interviewer-administered rather than self-administered (e.g., web survey). In an interviewer-administered survey, interviewers are able to instruct respondents about whom to recruit (e.g., only people they know and not strangers) (e.g., Abdul-Quader et al., 2006; Okal et al., 2016) and to instruct respondents to try to recruit people who are likely to participate (e.g., Abdul-Quader et al., 2006). This becomes especially challenging without interviewers.

Much has been said about the value of incentives in increasing survey participation and survey data quality (e.g., Debell et al., 2020), but respondents in RDS studies are incentived to both participate in the study and recruit their network members. Intuitively, incentives should be an important factor in RDS productivity. However, the incentive amount is not often reported in published RDS papers, preventing a proper review of the impact of incentive amount on participation. In some RDS studies, the incentives may not even be monetary; instead, sometimes respondents may be given gifts (e.g., Platt et al., 2006). In Johnston et al. (2008)'s review, a third of the papers included did not provide incentive information. With the remaining papers reviewed, the authors reported that incentives were not associated with RDS productivity. However, in Helms and colleagues' (2021) review of web-RDS, monetary incentives were associated with more successful peer recruitment.

As web-RDS and in-person RDS might function differently due the difference in the way alters can be contacted, the mode of administration of the RDS study may also be an important factor in RDS productivity. Helms and colleagues (2021) examined 18 web-based RDS studies on a number of metrics. The authors reported that an effort with seed selection (e.g., the researchers personally contacted the seeds rather than the seeds responding to a survey request online) and monetary incentives were associated with more successful peer recruitment. However, the small number of studies reviewed makes it difficult to make strong conclusions about productivity.

In the three review studies on RDS described above (Johnston et al., 2008, Malekinajad et al., 2008; Helm et al., 2021), the authors have mentioned a common key limitation being lack of RDS reporting clarity, and in Helm et al. (2021)'s case, a lack of web-RDS studies available to be reviewed at the time of their analysis.

Given the incomplete nature of the RDS datasets used in prior review studies, the current paper examines the use of formative research, incentives, and the training of respondents, and mode and their associations with RDS productivity using data from a survey of RDS researchers. As the target population has emerged as a factor that affects RDS productivity (Malekinejad et al., 2008), this paper also examines the interactions of these RDS design decisions with the target populations on RDS productivity.

Therefore, the aims of this study are to answer the following:

1. Does conducting a formative study improve RDS productivity?

2. What is the relationship between the incentive amount and RDS productivity?

3. Does training respondents on peer recruitment improves RDS productivity?

4. Does the mode of administration (web vs. not web) for RDS affect RDS productivity?

4.3 Methods

4.3.1 Data

The data comes from a survey of 121 RDS researchers who have published an article using RDS or have applied for grants for research using RDS from 2009 to 2020.

The sampling frame for this web survey was built from a census of RDS studies published in English between 2009 and 2020. This census of RDS studies was built through a systematic database search for articles and grant applications relating to RDS by using the keywords "respondent driven sampling" and "respondent-driven sampling" in Google Scholar, Web of Science, JSTOR and PubMed for articles, and the same terms in the National Institutes of Health (NIH) and National Science Foundation (NSF) databases. (The search in the NIH and NSF awards databases was limited to the fiscal year from 2010 to 2020.) The list of RDS researchers was created by extracting the name and contact information of the first author,

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second author and last author of the articles, and the name of the primary investigator on the grants. Due to data privacy requirements of the General Data Protection Regulation in the European Union, researchers residing in the European Union as identified by their current affiliation were excluded. After deduplication of the names, a total of 344 researchers were invited to participate in this RDS survey.

The survey was a five-minutes long on average and asked questions regarding the respondents' use of RDS in their research. Respondents associated with more than one project were randomly assigned to answer the survey based on one of the projects they were associated with. The questions in the survey included how they had planned their RDS data collection (e.g., the mode of the interview, the target sample size, seed recruitment, whether they considered conducting formative research, how long was the planned field period) and how the data collection panned out (e.g., actual sample size, final number of seeds, actual length of data collection). The questionnaire is provided in Appendix E. Respondents were compensated with a $10 Amazon gift code for their time.

4.3.2 Nonresponse Bias

Out of the 344 unique RDS researchers on the frame, 121 completed the survey, yielding a response rate of 35.8%.

To check for possible nonresponse bias, respondents and nonrespondents were compared based on the studies they were assigned to respond about using the frame data. Table 4.1 contains an estimate of how the RDS studies conducted by the respondents compare to those conducted by the nonrespondents on the properties that are most likely to be reported in the published papers or grant applications. For both RDS studies from journal articles and grant applications, the type of target population, target sample size, target seed size was compared.

These types of information are expected and likely to be included in both journal articles and grant applications. However, for the RDS studies from journal articles, additional properties such as the achieved sample size, the achieved seed size, whether the type of incentive is reported, whether the incentive is monetary, whether the mode of administration is reported, and if the RDS study is administered on the web were also compared between respondents and nonrespondents. These types of information are unlikely (and for some, such as achieved sample size, impossible) to be included in grant applications.

The coding for the target population was done based on mentions of the eligibility criteria in the manuscripts or abstracts when the manuscript cannot be obtained or if it is a grant application (e.g., if the eligibility criteria for the study was 'adults who injected drugs in the past six months,' then only PWID will be coded). As the eligibility criteria for these documents can include multiple descriptions, such as "young Black MSM aged 15-21", they were coded to be as inclusive as possible. In the example given, it will be coded as "MSM", "racial/ethnic minority" and "other" ("other" is included to account for the fact that it targets minors). The types of target population reported do not sum up to 100% as a single study may target more than one population. Further explanation on the methodology for coding the articles and grant applications is included in Appendix F.

The differences between respondents and nonrespondents were tested with chi-square test of independence, t-test of independence means and Fisher's exact test when appropriate. The reporting of the target sample size, planned seed size, and achieved seed size were poor. Less than half the studies included in the frame reported this information. The mode and incentive structure were better reported, with more than half of the studies including this information in their publication.

Table 4.1 *Comparison of the studies in the frame to those in RDS researcher survey*

	Respondents	Nonrespondents	Difference
Journal articles and grants applications	**n=121**	**n=223**	
Source: Journals[1]	80.2%	78.5%	1.7%
Target population[1]			
PWID	28.1%	23.8%	4.3%
Other substance use	14.1%	12.1%	1.9%
Sex workers	12.4%	14.4%	-2.0%
MSM	27.3%	26.5%	0.8%
LBGQ	8.26%	7.62%	0.6%
Transgender	7.44%	7.62%	-0.2%
Racial/ethnic minority	8.26%	6.73%	1.5%
Immigrants	7.44%	8.07%	-0.6%
Other	20.7%	26.5%	-5.8%
Target sample size reported[1]	37.2%	28.7%	8.5%
Average target sample size (among those reporting a target sample size)[2]	807	785	22
Planned seed size reported[1]	48.8%	32.7%	16.0%**
Average target seed size (among those reporting a planned seed size)[2]	25.0	22.0	3.0
Journal articles only	**n=97**	**n=175**	
Source: Public health journals[1]	86.6%	85.7%	0.9%
Mode reported[3]	99.0%	98.9%	0.1%
Web mode for main interview[3]	8.3%	7.0%	1.4%
Type of incentive reported[3]	74.2%	64.0%	10.2%
Monetary incentive offered[3]	91.8%	94.5%	-2.7%
Achieved sample size reported	96.9%	94.6%	2.1%
Average achieved sample size[2]	845	810	35
Ratio of achieved sample to target sample size	1.01	1.15	-0.1
Achieved seed size reported	43.3%	41.1%	2.2%
Average achieved seed size[2]	28.6	30.4	-1.8

* $p < .01$, ** $p < .001$; [1] independent t-test; [2] chi-square test; [3] fisher's exact test; Some articles are on the formative research conducted for the subsequent RDS studies which is why sample size for the RDS study is not reported. These were included in the total analysis sample as they are a very small proportion (n=2).

Overall, respondents and nonrespondents only differed on whether they reported the

planned number of seeds ($X^2 = 8.70$, df=1, p = .003). Though there is a difference between

respondents and nonrespondents on the reporting of planned seed size, it is unlikely this is associated with measures of productivity.

4.3.3 Measures

RDS productivity was measured using two measures of productivity. The first is a measure of overall productivity, which is a ratio of achieved sample size to the planned sample size, following Johnson et al. (2008) method. Ideally, this value should be one which means that the achieved sample size is the same as the target sample size. If this ratio is lower than 1, it is an indication that the study did not go as planned.

$$Overall\ productivity = \frac{Achieved\ sample\ size}{Target\ sample\ size}$$

The second measure is an indication of the overall seed productivity, defined as the ratio of the achieved sample size to the final seed size. The overall seed productivity is a crude measure of how productive the seeds are in these studies.

$$Overall\ seed\ productivity = \frac{Achieved\ sample\ size}{Final\ seed\ size}$$

Other variables that describe the RDS research design examined in this study are as follows:

i. Target population: As a given RDS study may target multiple populations as shown in Table 2 (e.g., PWID and sex workers in an HIV surveillance study), we used latent class analysis (LCA) with the poLCA package v1.4.1 in R to identify population grouping patterns. The latent class models were fitted successively, starting with a two-class model, then adding another class and refitting up till six classes. The two-class solution yielded the best fit. The first latent class (LC) comprised of studies that targeted non-drug use related populations (mostly sexual and gender minority), and

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the second LC comprised of populations with substance use disorder. Therefore, the first LC will be referred to as "SOGI focused" populations, and the second LC as "substance-use focused" populations. See Appendix G for details of this LCA analysis.

ii. Web mode vs. other modes: This indicates the mode the RDS study was conducted in where 1 is on the web and 0 is otherwise.

iii. Formative research conducted: This is a binary variable where 1 indicates that formative research was done and 0 indicates that formative research was not done.

iv. Formative research type: This is a four-level categorical variable that indicates the combination of formative research conducted. The categories are "focus group, in-depth interviews and field observation", "focus groups and in-depth interviews only", "field observation only", and "did not conduct focus groups, in-depth interviews and field observation".

v. Formative research target groups: Formative research can be conducted with members from the target population, other knowledgeable people, or other informants. This variable is a 3-level categorical variable indicating whether it was done with the target population, target population and other informants, or neither.

vi. Recruitment instruction: Recruitment instruction captures whether respondents were coached or given any instruction about how to recruit before they were sent on their way. As nearly all (96.7%; n=117) of the respondents reported some form of training given to their respondents, this two-level variable is defined as having more than one method of instruction or not.

vii.   Incentive: This will be a continuous variable indicating the monetary incentive given

to respondents for completing the RDS studies reported in this RDS researcher

survey. Those that did not offer monetary incentives were coded as 0.

viii. Seed difference: This is a continuous variable calculated from taking the difference

between the final number of seeds and the planned number of seeds.

ix.   Data collection location: – within the U.S. only vs. others: different locations will

have different local contexts for the degree of target population sensitivity, among

other differences. The location served as a control variable in this study.

x.   Data collection duration: This variable is measured in months, rescaled to years.

xi.   Study size: This is a continuous variable based on the planned sample size of the

study. Larger studies might encounter more difficulties in achieving their target

sample size; therefore this is included as a control variable.

Appendix E contains the question wordings for the questions used in this study.

4.3.4 Data cleaning

Due to some missing or unlikely data on this dataset, some responses were manually

recoded by referring to the published articles the respondents reported on when possible, or

removed from analysis when not possible.[1] This section documents the decisions made during

this process. The variables that had the most recoding are the mode and number of seeds.

For mode, the documents where the research was reported in were checked for mentions

of "interviewers", "telephone" or respondents needing to go to a specific location. These are

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[1] Of the studies that had a reported target sample size in their publications or grant applications (n=38), 61% was different than what was reported in the survey, while studies that reported final sample size (n=97), 60% of them were different than what was reported in the survey. The same was observed for seed size. Further details of the discrepancies are in Appendix H.

coded as "other modes". Those that had mentions of "web-survey" or "online" were coded as "web mode". Those that did not have any mentions of any mode were left as missing.

For the number of seeds, entries that had a smaller achieved seed size than planned seed size were checked. For example, one of the respondents reported that they had recruited 495 less seeds than planned. When referring to the number of seeds reported in the article, the final number of seeds was also inconsistent. Therefore, for this specific study, the planned and final number of seeds were recoded as missing. In general, if the achieved seed size was within 90% of the planned sample size, the difference is considered to be reasonable. Two studies failed this criterion and had their number of seeds recoded as missing.

4.3.5 Analysis

Data were analyzed using the survey package version 4.1.1 in R. As the sampling frame represents a census of RDS researchers and a substantial number of them responded to the survey, a finite population correction factor of $\sqrt{(1-121/344)} = 0.805$ has been applied to the standard errors during analysis.

The associations of the different variables mentioned above with the outcomes overall productivity and overall seed productivity were examined using linear model, treating the outcome as a continuous variable. The outcome measures that are skewed were log-transformed. Higher-order associations and interactions were also explored where sensible, such as interactions with the target population.

4.4 Results

Descriptive statistics of the RDS studies reported in the survey are presented in Table 4.2. Of the 121 studies, the majority were on drug use related populations. RDS productivity, on

average seems to be only a little worse than planned, though when it is bad, it can be quite bad

(min = 0.20). As seen in Table 4.2, very few RDS studies in this survey were fielded on the web.

Most RDS studies did conduct formative studies prior to data collection, with the combination of

focus groups and in-depth interviews being the most popular type of formative studies done. If

the formative study was conducted, researchers tend to study both the target population and other

informants. It was rare for researchers to only seek information from other informants. Almost a

third of the studies provided more than one type of recruitment guidance for their respondents.

Seed productivity has been log-transformed due to the skewness of the data. Figure

4.1shows the distributions of each linear outcome and the log-transformed seed productivity.

Table 4.2 *Estimates of the reported RDS design features*

	Mean (SE)
Average overall RDS productivity	0.97 (0.021)
Average overall seed productivity	65.84 (6.38)
Average target sample size	1127.3 (223.2)
Average achieved sample size	1069.7 (215.3)
Average target no. of seeds	33.8 (7.5)
Average final no. of seeds	36.0 (6.6)
Average amount for monetary incentive for the main interview ($)	18.29 (1.67)
Average field time (years)	0.82 (0.059)
Seed difference (Final number of seeds – target number of seeds)	9.60 (2.73)
	Proportion (SE)
Target population:	
Drug use focused	62.0% (3.6%)
SOGI focused	38.0% (3.6%)
Web mode for the main interview	13.2% (2.5%)
Formative study conducted	60.3% (3.6%)
Type of formative research conducted:*	
Focus groups, in-depth interviews, and field observation	39.7% (4.6%)
Focus groups and in-depth interviews only	53.4% (4.7%)
Field observation only	4.1% (1.9%)
Did not conduct focus groups, in-depth interviews and field observation	2.7% (1.5%)
Target for the formative research:*	
Target population and other informants	53.4% (4.7%)
Target population only	38.4% (4.6%)

Did not include target population	8.2% (2.6%)
Recruitment instruction provided	97.5% (1.1%)
More than one type of recruitment instruction	28.1% (3.3%)

*Proportions are based on the studies that had conducted formative research

Figure 4.1 *Distributions of the outcome measures*
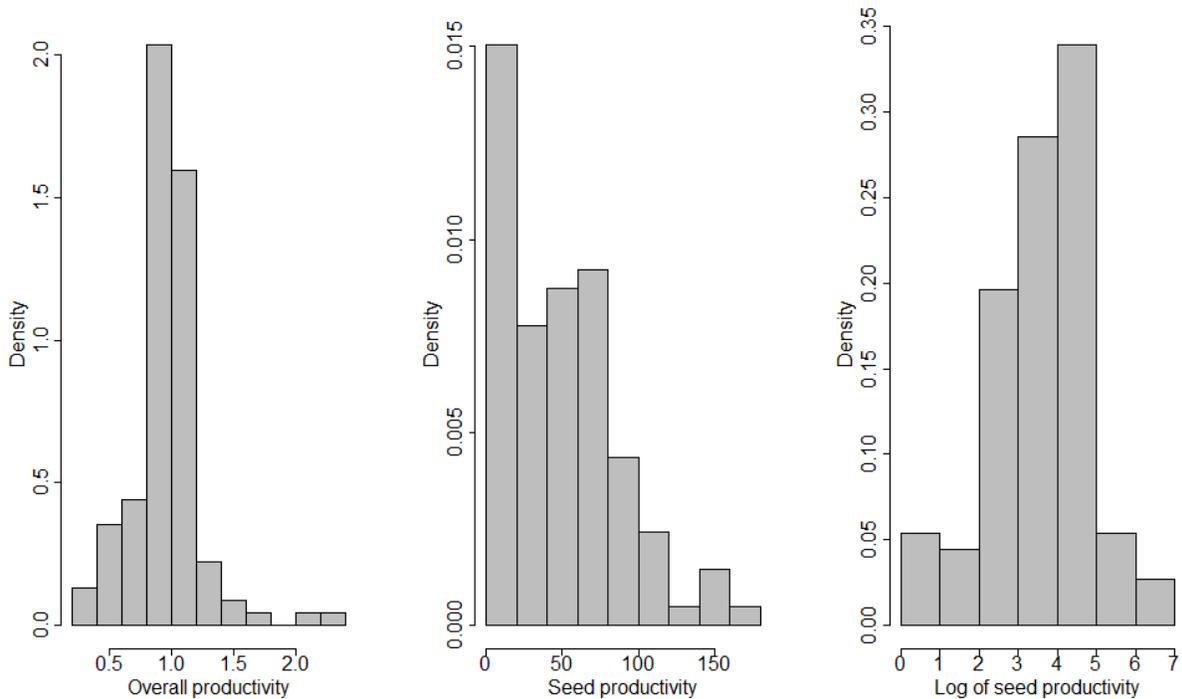
Table 4.3 reports the associations between the RDS design variables of interest with overall productivity, and log of seed productivity using the base model where no interactions are included. The model fit, as described by the adjusted R^2 ranged was 0.11 for overall productivity and 0.32 for seed productivity. Study size was significantly positively associated with seed productivity (an increase of .122 [95% CI: .082, .161] on the log scale for a one thousandth increase in study size) but not for overall productivity. In the base model without interactions for overall productivity, after dropping study size as a predictor, fielding the RDS survey on the web, and including other informants in the formative research compared to only studying the

target population decreases the overall productivity (a decrease of -.202 [95% CI: -.365, -.039] and -.214 [95% CI:-.351, -.078] respectively). Meanwhile, the drug use focused target populations have a statistically significant relationship with better overall productivity (increase in overall productivity of .109 [95% CI:.018, .200]). Target population is also significantly associated with seed productivity in the same direction (studies with drug use focused target populations have better seed productivity than SOGI focused target populations, with an increase of .381 [95% CI: .050, .713] in productivity on the log scale).

Besides that, the location of the RDS study (a decrease of -.614 [95% CI: -.1.032, -.196] on the log scale for US only versus sites including non-US locations), and seed difference (a decrease of -1.128 [95% CI: -1.521, -.734] for each one-hundredth unit increase on seed difference) also have a significant association with seed productivity.

Table 4.3 *Associations with overall productivity and seed productivity*

	Coefficients [95% CI]		
	Overall productivity	Overall productivity (Drug use x Type of formative research)	Log of seed productivity
Intercept	.450 [.687, 1.209]	.785 [.539, 1.031]	3.255 [2.032, 4.477]
Target pop. – Drug use focused	**.109*** **[.018, .200]**	**.392**** **[.162, .621]**	**.381*** **[.050, .713]**
Location (Within U.S. only)	-.035 [-.138, .068]	-.025 [-.121, .072]	**-.614**** **[-1.032, -.196]**
Web mode	**-.202*** **[-.365, -.039]**	**-.204*** **[-.359, .048]**	-.158 [-.816, .500]
Formative research conducted	.131 [-.112, .374]	.152 [.089, .394]	.257 [-0.946, 1.460]
Type of formative research (Ref: Interview and focus group only)			

Focus group, in-depth interview and field observation	-.020 [-.147, .107]	-.027 [-.089, .394]	.252 [-.066, .569]
Field observation only	-.498* [-.945, -.051]	-.482* [-.954, .010]	-2.018 [-4.064, .028]
Other	-.216 [-.449, .016]	-.180 [-.416, .055]	-1.113 [-2.313, .086]
Formative research sample (Ref: target population only)			
Target population and other informants	**-.214**** **[-.351, -.078]**	.016 [-.128, .160]	.113 [-.245, .471]
Did not include target population	.203 [-.086, .492]	**.364* [.087, .642]**	**1.513* [.205, 2.822]**
Incentive amount for interview/10 (USD)	-.011 [-.040, .018]	-.008 [-.033, .017]	.030 [-.083, .143]
More than one form of recruitment instruction	.044 [-.071, .159]	-.029 [.080, .138]	-.103 [-.396, .190]
Length of data collection (years)	.017 [-.044, .079]	-.012 [-.048, .072]	-.163 [-.398, .071]
Seed difference/100	-.040 [-.137, .057]	-.019 [.103, .064]	**-1.128** [-1.521, -.734]**
Target pop. – formative research sample (Ref: target population only)	-		-
Target population and other informants	-	**-.424** [-.663, -.184]**	-
Did not include target population	-	**-.344* [-.600, -.087]**	-
Study size/1000	-	-	**0.122** [.082, .161]**
Adjusted R^2	.11	.19	.32

* p < .05, ** < p < .01

To test whether these variables with significant effects have different associations with the outcomes depending on the target population, interactions with the target population were examined. The only significant interaction effect was found in the model for overall productivity, with the interaction of target population with the formative research sample. The interaction effect is depicted in Figure 4.2 and results in Table 4.3. A nonlinear association between the amount of incentive and RDS productivity, assuming that at the effect of incentives is quadratic,

was also tested by including a squared term for incentive but this nonlinear association was not statistically significant and was dropped from the model.

In this second model, target population had a significant interaction with formative research sample on the RDS productivity. When this interaction is examined in Figure 4.2, not including the target population of the RDS study in the formative research study seems to lead to better overall productivity for SOGI-focused target populations. However, the pattern is a little different for drug use-focused target populations, where including the target population and other informants seem to be associated with worse productivity compared to only studying the target population.

Figure 4.2 *Interaction between formative research sample x target population*
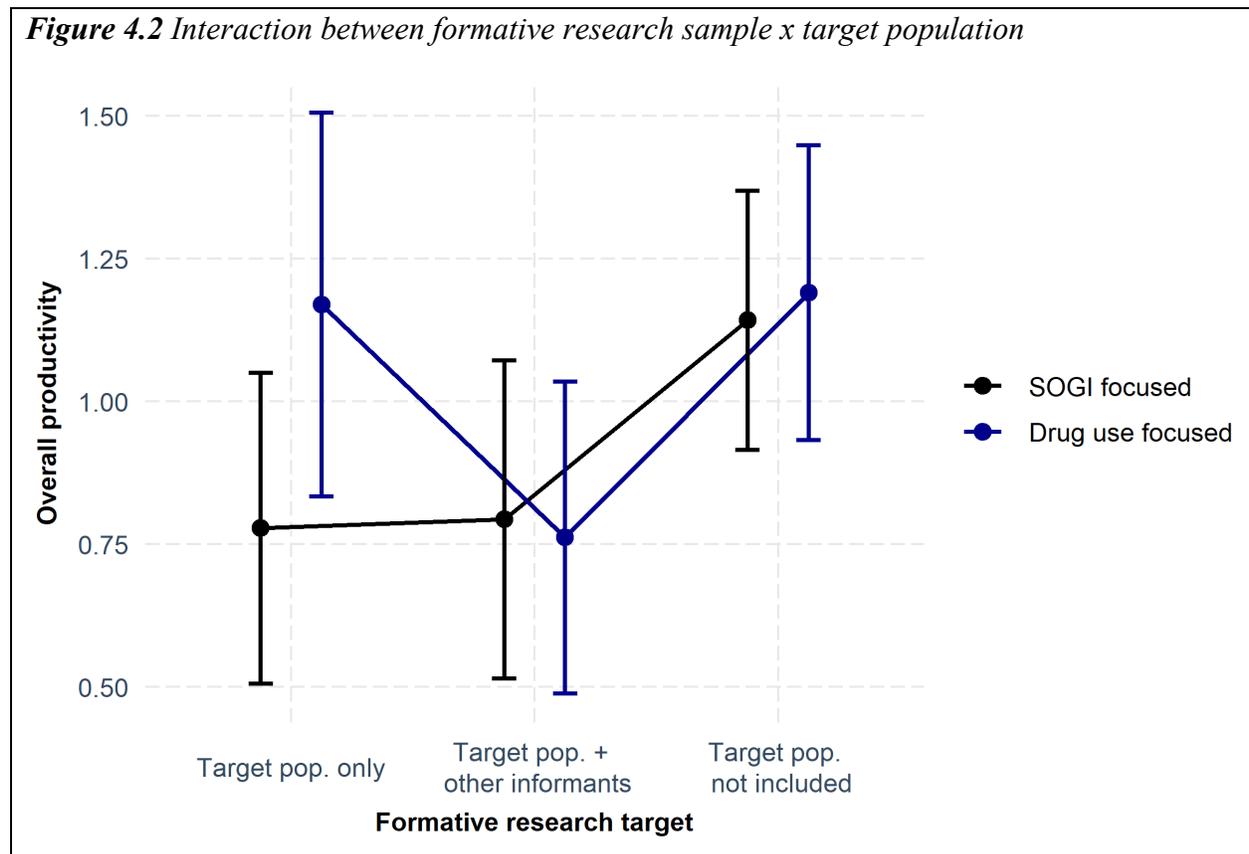
4.5 Discussion

The current study explores the aspects of RDS methodology that may help RDS fieldwork. Given that researchers will adapt the research design to account for more challenging circumstances, and the predictors in the models are not randomly assigned, findings from this current study must be interpreted cautiously. This study also only includes studies outside of Europe that were published or had grants funded, which may leave out many more RDS studies either because they are done in Europe or were less successful. With these caveats in mind, this current study points to some possible recommendations for better RDS field productivity and provides a framework for a more in-depth investigation of the best practices for RDS design.

Overall, formative research, which is part of the general recommendation for RDS studies (Simic et al., 2006; Johnston et al., 2010; Gile, Johnston & Salganik, 2015), does matter, but we will need to do more to understand the nuances behind conducting useful formative research. Who is included in the formative research seems to be more important than what was done as part of the formative research for both overall productivity and seed productivity. Rather counterintuitively, having the target population as part of the formative research sample might not always result in better overall productivity or seed productivity. Web-RDS also seemed to decrease overall productivity, which suggests that greater care needs to be taken when designing web-RDS studies to account for possible slow recruitment. However, due to the small number of Web-RDS studies available for analyses in this study, that result should be taken with some caution. Incentive amount was not associated with either overall productivity or seed productivity.

Giving more recruitment instructions to respondents was not associated with overall productivity or seed productivity despite anecdotal reports on how such instructions have helped

respondents with recruiting their network members (Hequembourg & Panagakis, 2019). However, details about how peer recruitment instructions were given or how recruitment training (if any) was conducted were not collected in this survey, so it is unclear if the quality of the instructions or training, if any, varied a lot across the studies. As most of the RDS studies reported in this survey likely were on-site and had an interviewer or a staff member to assist, instructions on RDS recruitment might be delivered very differently across the studies. Further research will have to be done to understand what makes an effective peer recruitment instruction, and how much it matters to RDS field productivity.

Though higher incentive was expected to be associated with greater survey participation rates (e.g., Debell et al., 2020) and had led to more successful peer recruitment in web-RDS (Helms et al., 2021), the current study did not find any relationship with either overall productivity or seed productivity. Only the incentive for participating in the RDS studies was accounted for in this research as details about the recruitment incentive were not captured. It is possible that the recruitment incentive might play a bigger role in increasing RDS productivity.

The target population and location were associated with seed productivity. Studies with drug use-focused target populations tend to have better seed productivity than studies with SOGI-focused target populations. Studies within the United States only had lower seed productivity than studies outside of the United States. The practical takeaway from this is RDS researchers who are conducting their RDS studies within the United States only and are targeting SOGI minority populations should consider starting with a greater number of seed respondents. However, it has to be stressed that this is only an exploratory study, and though it is an important first step in trying to get to a more scientific way of planning for the number of seeds to start an

RDS study with, this could potentially be re-examined for stronger recommendations using a much larger dataset with more specific information on the RDS study designs.

Even though the survey asked the RDS researchers specifically about their research, some reported details (e.g., number of seeds, sample size) were different from what was published. In those cases, what was reported in the survey was considered true over what was published, assuming that there may be details that could not be included in the publications. This does indicate that the data from the RDS researcher survey possibly suffers from recall error, as some researchers were asked to recall details about their research from almost ten years ago.

Besides recall error, there were also information unavailable that may be a better predictor of RDS productivity. The reported incentive was not differentiated between the participation incentive and recruitment incentive. It is possible that the two different types of incentives in RDS studies are weighted differently in terms of how much they can motivate respondents to recruit their network members into the RDS studies.

The other main limitation of this study is publication bias. As the sample frame is from a database comprising of published articles and successful grant applications, studies that failed to get funded or did not get published would not be included. Ultimately, the population of interest is RDS researchers, and it is likely that most of them would have had at least one publication on their research, but this still leaves out practitioners who may not be as concerned about publishing or those that did not get published because of data collection challenges.

To account for this limitation, it would be better if there is an online database where RDS researchers can record their RDS data collection plan prior to data collection, and deviations from the plan due to data collection difficulties once data collection is over. This will account for research that did not result in publications, and also provide information to other RDS

researchers on what works and what does not in a specific location for a specific population. On top of that, this can provide a platform for researchers to discuss strategies to overcome their field challenges with others who are familiar with RDS.

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Chapter 5 Conclusion

This dissertation focuses on the methodological issues in planning an RDS research. More specifically, this dissertation attempts to shed light on the following three questions:

1. How to improve asking for PNS in RDS?

2. Who recruits and participates in RDS?

3. What RDS study characteristics (e.g., presence of formative study, number of seeds) are essential for a successful RDS data collection?

Chapter 2 addressed the first question using qualitative (in-depth interviews with adult LGBT respondents) and quantitative data (web-RDS with adult LGBT respondents). In this chapter, I found a large variation in respondents' definition of "knowing someone." This general PNS question also has the highest proportion of rounded responses, which indicates that general PNS questions may have more measurement error than other alternatives (e.g., PNS question for close relationships or regular interactions). As the phrase "someone you know, who knows you" is commonly used in PNS questions used in RDS, and PNS measures are used in RDS estimators to create weights, this variation in how respondents define "knowing" has several negative ramifications for its use in RDS. The main issue here is it will likely lead to the violation of the RDS assumption of reciprocity (e.g., if A knows B, B knows A as well) as two respondents may have very different definitions of "knowing someone" and one person might exclude the other from that network. Conversely, the PNS question restricted to only the people respondents are close to is defined more consistently by the respondents and aligns more with the network that is important to RDS, i.e., the network of likely invitees. The practical implication here is that PNS

questions need to be more specific and target the network of likely invitees, and we should stop using PNS questions that use the phrasing "someone you know, who knows you" to measure the PNS used to construct RDS weights.

Chapter 3 studied the peer recruitment process of RDS. The main findings were that respondents were motivated to cooperate with recruitment requests through altruism (e.g., wanting their communities represented in research), interest in the topic, and monetary incentives. The profile of the people respondents think of recruiting is people who are of similar age, race/ethnicity as them, perceived to be close, and they tend to think of friends more than family or their partners. Generally, the people they think of inviting are perceived to be likely to respond to their invitation. However, only thinking of alters of similar age was more likely to lead to successful recruitments. Meanwhile, those who named alters of similar race/ethnicity were less likely to lead to successful recruitment. As for the profile of a successful recruiter, only age was associated with being a successful recruiter, with younger respondents being more successful than older respondents. These findings on age's relationship to peer recruitment productivity have been mixed thus far (e.g., Reisner et al., 2010, Lee et al., 2020), and it may be because of the mode these RDS studies were administered in. Neither the general PNS nor the close relationship PNS was associated with success in peer recruitment. In summary, this study shows that respondents do have preferences in alters to invite, in line with past research on this (Phillips II et al., 2014; Li et al., 2017).

This means that the assumption of random selection of recruits generally held in RDS as one of the foundations upon which the RDS estimators were built is violated. Inversely weighing respondents by their network size is inappropriate when every alter does not have an equal chance of being invited, and success in recruitment is related to age, with those of similar age

being more likely to be recruited. Though this has been acknowledged to be an issue that can cause bias in the estimates (e.g., Gile and Handcock, 2010; Gile and Handcock, 2015; McCreesh et al., 2013), RDS estimators have largely not accounted for this assumption violation. Beaudry and Gile (2020) introduced a modification to the current RDS estimators attempting to correct for differential recruitment, but their method requires RDS researchers to collect data on respondents' personal networks on the variables they think will be associated with differential recruitment. This is not usually done in RDS studies and would pose a burden on respondents.

Chapter 4 examined RDS study design decisions as they are currently implemented in a sample of RDS researchers. I used two indicators of RDS field productivity here — overall productivity as defined by the ratio of an achieved sample size to the target sample size and overall seed productivity as defined by the ratio of an achieved sample size to the final seed size. I examined the associations of the target population, location of the study, the mode, the type of formative research conducted, incentive amount, number of added seeds throughout the field period, the length of data collection and size of the RDS study with the outcomes and found that who was included in the formative research matters more than what was done for the formative research. For target populations related to sexual orientation and gender identity minority, including the target population in the formative research might decrease overall productivity. Web-RDS decreases the overall productivity of RDS studies compared to non-web modes. As for overall seed productivity, the target population, location of the RDS research site and the target population in the formative research matter. Overall seed productivity is lower for RDS studies conducted within the U.S. only, and RDS studies targeting sexual orientation and gender minority (compared to drug-use focused target populations). This means RDS researchers who

are doing RDS data collection in the U.S. or are studying LGBTQ+ populations should consider increasing the number of seeds.

5.1 Future directions

The high recruitment rate in the web-RDS data used for Chapter 2 and 3 requires further investigation. Web-RDS has been seeing more use in recent years (see Helms et al., 2021), and there need to be further investigations on the mode effects on peer recruitment. There were only 16 studies reported in the RDS researcher study data used in Chapter 3, which is not enough to examine how the mode may moderate the relationships between RDS design features and RDS productivity. The best practice for web-RDS is likely different from an in-person RDS study.

Secondly, further research is needed on the RDS peer recruitment by improving on the method in Chapter 3 to decompose respondents' preferential recruitment and their alter's participation in a study. In Chapter 3, respondents were asked to name and describe alters after being asked about the number of people they think they can invite to a hypothetical survey. This order of survey questions had likely primed the respondents to name alters likely to respond to respond to their recruitment request. This might not be how respondents would naturally think about this task in other RDS studies. To account for that, respondents should be asked to describe a few alters before answering the series of PNS questions and being informed of the hypothetical RDS recruitment request. Only then should they be asked about whom they think will respond to their hypothetical recruitment request.

Finally, Chapters 2 and 3 were entirely based on the adult LGBT population and likely skewed towards the adult LGBT population who are active online and lives in Michigan. The web-RDS study used in Chapters 2 and 3 were not meant to get a representative sample of the adult LGBT population in the United States. The primary function of the study was to explore

the recruitment mechanism in RDS. Therefore, this type of research should be replicated with LGBT populations in different settings and other target populations to examine the generalizability of the findings. Ideally, these other target populations should be different from each other in terms of the way they are considered marginalized or minoritized. For example, sex workers and recent immigrants are two target populations that are different on these axes, as sex work itself is a crime in many states while the latter population is not defined by engaging in illegal activities.

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Appendix A   Examples of Personal Network Size Questions

Table A.1 *Examples of Personal Network Size Questions*

Citation	PNS question
Aung et al. (2013)	How many MSM do you know personally by name and how many MSM know you personally by name?
Evans et al. (2011)	Do you know any other Central or East European gay men in London? [IF YES] How many of these men do you know well enough to talk about this survey with?
McCreesh et al. (2011)	How many men do you know who (i) were head of a house- hold in the last 12 months in any of the MRC villages, and (ii) you know them and they know you, and (iii) you have seen them in the past week"
Johnston et al. (2017)	How many women have you seen in the past week who you know and who know you, are ages 15 years and above, live and/or work in this province, and engaged in intercourse in exchange for money in the past 6 months?
Jonsson et al. (2019)	How many people whom are also precarious workers (working but without a fixed, full time employment), older than 18 years, could you invite to this study via internet if the invitations were not limited to four?
Paz-Bailey et al. (2013)	How many transgender and MSM do you know, who know you and who live in this city? Of these, how many are 18 years of age or older? Of those, how many have you seen or spoken to in the past 30 days?
Cárdenas et al. (2018)	How many gay men/lesbian women do you know who know you and live in this city?
Wagner et al. (2014)	Approximately how many men who have sex with men do you know personally who live in greater Beirut and are age 18 or above? These should be men who you know by name and that you have contact with either by phone, e-mail or face to- face

Raymond et al. (2019)	How many other transwomen to do you know?
	How many of these transwomen have your seen in person in the past six months?
	How many of these transwomen have you seen in the past one month?
	Of these transwomen how many would you be willing to give a recruitment coupon to?

Appendix B   Semi-structured In-depth Interview Guide

Notes:

In blue are additional probes]

Terms in square brackets are matched to participant's racial identity/sexual orientation/gender identity

Thank you for agreeing to participate in this interview. The purpose of this interview is to understand how your community relate to each other, and how we can better reach people like you in our surveys.

1. Can you tell me a little bit about yourself? What do you do, how old are you and what are your identities?

2. How many [L/G/B/T] people do you know, who know you and who live in the city you live in?

       Can you walk me through how you came up with that answer?

       In your words, how would you define [L/G/B/T] people?

       What does "knowing you" mean to you?

4. Of these, how many are 18 years of age or older?

5. Now, thinking about all the people you know both offline and online, how many [L/G/B/T] people do you know, who know you and who live in United States?

       Can you walk me through how you came up with that answer?

6. Of these, how many are 18 years of age or older?

7. Of those, how many do you interact with (including talking to, visiting with, calling, emailing, texting, facebook, etc) personally more than once week?

       And how do you normally interact with them?

       How did you come up with that answer?

8. Of those, how many how many do you feel close to (that is, you feel at ease with, can talk to about what is on your mind, or call on for help)?

       How would you personally define "feel close to"?

       What are some examples of things you talk about?

       How did you come up with that answer?

9. Of those, how many had called on you for help or advice in the past 2 weeks?

       What type of advice do they ask from you?

Are these the same people you will seek advice from?

How did you come up with that answer?

10. Hypothetically, if you are asked to help invite your [L/G/B/T] friends into a survey, how many of those do you think you can invite to participate in a survey you have just completed?

How did you come up with that answer?

How many of those do you think will end up participating?

What method do you to use prefer to invite them?

Now thinking of those people you plan to invite, do they generally fall under the category of "people you interact with more than once a week", "people you feel close to", "people who called on you for help" or something else?

If it's something else, how would you describe your relationship with them?

11. Imagine if you are the one being invited to complete a survey by your friend. How many [L/G/B/T] friends would invite you?

Are these the same people as those you thought to invite?

12. How about [Black/White] people do you know, who know you and who live in United States?

13. Of these, how many are 18 years of age or older?

14. Of those, how many do you interact with (including talking to, visiting with, calling, emailing, texting, facebook, etc) personally more than once week?

15. Of those, how many how many do you feel close to (that is, you feel at ease with, can talk to about what is on your mind, or call on for help)?

16. Of those, how many had called on you for help or advice in the past 2 weeks?

17. Hypothetically, if you are asked to help invite your friends into a survey, how many of those do you think you can invite to participate in a survey you have just completed?

18. Imagine if you are the one being invited to complete a survey by your friend. How many [Black/White] friends would invite you?

19. Was it different when you were thinking about [Black/White] compared to when you were thinking about [L/G/B/T] people you know?

What was different? Consider the different qualities you might have been thinking about.

Was one harder than the other?

19. Alright, now I would like you to think of a [L/G/B/T] person you know who you think you might invite into a survey on LGBT related concerns. Can you describe to me what type of person they are?

What made you think of them first?

How close are you to them?

Do you think they will participate if you invite them?

Do you think they will ask you to participate?

20. How about a [Black/White] person you know who you think you might invite into a survey. Can you describe to me what type of person they are?

What made you think of them first?

How close are you to them?

Do you think they will participate if you invite them?

Do you think they will ask you to participate?

21. How about someone you will not think of inviting at all? Can you describe to me what type of person they are?

What made of think of them?

How close are you to them?

Do you think they will participate if you invite them?

Do you think they will ask you to participate?

22. If you have just completed a survey, and you are asked to help invite more people into the survey, would you do it? Why/why not?

What would help convince you to invite the people you know?

What if you will receive additional incentive as a token of appreciation for your help?

What do you think about $5 for a respondent?

[START SCREENER]

INTRO Thank you for your interest in Community Connections Study. This study aims to understand what motivates people in your community to participate in research.
Before we start, we will first ask you to answer some questions to see if you are eligible to participate in the study. This will take 1-2 minutes.
RESIDENCY Are you currently living in United States?

◯ Yes (1)

◯ No (2)

AGE How old are you?

_____

[IF AGE is EMPTY]
AGE_1 We do not need to know your exact age, but what is your age group?

◯ Below 18 (1)

◯ 18 to 30 (2)

◯ 31 to 40 (3)

◯ 41 to 50 (4)

◯ 51 to 60 (5)

◯ 61 to 70 (6)

◯ Above 70 (7)

ETHNICITY Are you of Hispanic, Latino, or Spanish origin or descent?

○ Yes (1)

○ No (2)

RACE What is your race?

☐ Black or African American (91)

☐ White or Caucasian (92)

☐ American Indian or Alaskan Native (93)

☐ Asian (94)

☐ Native Hawaiian or Pacific Islander (95)

☐ Other (96)

SEX What sex were you assigned at birth, on your original birth certificate?

○ Male (1)

○ Female (2)

○ Prefer not to say (3)

GENDER How would you describe yourself today?

○ Male (1)

○ Female (2)

○ Transgender (3)

○ I do not identify as male, female or transgender (4)

[IF SEX = 1 AND GENDER = 2 OR SEX = 2 AND GENDER = 1]
CONFIRM_GENDER Earlier, you said that you are assigned {SEX} at birth and described yourself as {GENDER}. Would you consider "transgender" to be an identity that describes you?

○ Yes (1)

○ No (2)

ORIENTATION Do you think of yourself as gay/lesbian; straight, that is, not gay/lesbian; bisexual; something else; or you don't know the answer?

○ Straight (1)

○ Gay/lesbian (2)

○ Bisexual (3)

○ Something else (4)

○ Don't know the answer (5)

[END SCREENER]

<u>Recruiter's information</u>

<u>**Note: Only displayed for non-seed respondents**</u>

REC1 First, we would like to ask some questions about the person who invited you into this study.

Do you know the person who invited you?

○ Yes (1)

○ No (0)

[IF REC1=1]
REC2 What is your relationship to them?

○ Family (parents, spouse, siblings, children, other family/relative) (1)

○ Romantic partner or queerplatonic partner (2)

○ Friends (close friend/casual friend) (3)

○ Others (acquaintance, something else) (4)

[IF REC1=1]
REC3 How long have you known them?

_____

[IF REC1=1]
REC4 How close do you feel to them?

○ 1 - Not at all close (1)

○ 2 (2)

○ 3 (3)

○ 4 (4)

○ 5 (5)

○ 6 (6)

○ 7 - Very close (7)

[IF REC1=1]
REC5 How often do you personally interact with that person? Please include time that you talk to, visit with, call, email, text, whatsapp, facebook, etc. with that person.

○ Daily (1)

○ 3-6 times a week (2)

○ 1-2 times a week (3)

○ 1-3 times a month (4)

○ Less than once a month (5)

[IF REC1=1]
REC6 Have you ever talked the person who invited you to this study about Covid-19?

○ Yes (1)

○ No (2)

[IF REC1=1]
REC7 What did they tell you about the study?

☐ $10 payment (1)

☐   Web survey (2)

☐   Survey length (3)

☐   Study objective (4)

☐   Other, specify: (9) _____

[IF REC1=1, CARRY FORWARD ALL CHOICES IN REC7]
REC8 Why did you decide to participate in this study?

☐ $10 payment (1)

☐   Web survey (2)

☐   Survey length (3)

☐   Study objective (4)

☐   Other, specify: (9) _____

[IF REC8 IS EMPTY]
REC9 Why did you decide to participate in this study?

_____

Network size

NET_ALL For the first few questions, we would like to understand how connected you are with your community. Previously you mentioned that you are transgender. How many {TARGET POPULATION} people do you know, who know you and who live in United States?

_____

[IF NET_ALL = 0]
NET_ALL_CHECK You said you do not know any transgender people who live in United States. Is that correct?

○ Yes (1)

○ No, the number of people I know is: (2)

_____

[IF NET_ALL > 1]
NET_18 Of these {NET_ALL}, how many are 18 years of age or older? If you are not sure, just count them as adults.

_____

[IF NET_18 = 0]
NET_18_CHECK You said you do not know any {TARGET POPULATION} adults who live in United States. Is that correct?

○ Yes (1)

○ No, the number of adults I know is: (2)

_____

[IF NET_ALL = 1]
NET_18_1 Is this person at least 18 years old? If you are not sure, answer with your best guess.

○ Yes (1)

○ No (0)

○ Don't know (99)

[IF NET_18 > 1]
NET_CLOSE Now I am going to ask you questions about the {NET_18} people that you know who are {TARGET POPULATION} and 18 years or older…

How many do you feel close to (that is, you feel at ease with, can talk to about what is on your mind, or call on for help)?

_____

[IF NET_18_1 = 1]
NET_CLOSE_1 Do you feel close to this person (that is, you feel at ease with, can talk to about what is on your mind, or call on for help with this person)?

○ Yes (1)

○ No (0)

[IF NET_18>1]
NET_INTERACT Of the {NET_18} {TARGET POPULATION} adult people that you know, how many have you interacted with (including talking to, visiting with, calling, emailing, texting, facebook, etc) personally in the past 2 weeks?

_____

[IF NET_18=1]
NET_INTERACT_1 Have you interacted with that person personally in the past 2 weeks? This includes talking, visiting, calling, emailing, texting, facebook, etc.

○ Yes (1)

○ No (0)

[IF NET_18 > 0]
SCENARIO
One of the main difficulties in research is reaching sexual and gender minorities. We would like to understand how we can leverage your social network to reach people in the LGBT community.   The next few questions will be referring to a **hypothetical study** described below.

 "LGBT Health Study an online survey which is 15-20 minutes long. This survey asks questions about various topics such as physical and mental health, and healthcare access. Participants are compensated $10 giftcard for their time upon completing the survey."   (You will be able to refer back to this description in some of the questions later by hovering over the blue text.)
[IF NET_18 > 1]
NET_INTEREST Of the {NET_18} {TARGET POPULATION} adult people that you know, how many do you think will be interested in participating in this study?

_____

[IF NET_18 = 1]
NET_INTEREST_1 Do you think the person you know will be interested in participating in this hypothetical study?

○ Yes (1)

○ No (0)

○ Don't know (99)

The next few questions will be about who you can invite into this <u>hypothetical study</u>. Please note that you will not be able to go back to the previous questions in this section after you click "Next".
[IF NET_18 = 1]
NET_INVITE_1 Now, imagine that you have participated in that hypothetical study. At the end of that study, you are asked to invite a few people you know to participate in that study.
Would you invite this person?

○ Yes (1)

○ No (0)

[IF NET_18 > 1]
NET_INVITE Now, imagine that you have participated in that study. At the end of that study, you are asked to invite a few people you know who are transgender and at least 18 years old to participate in that study.
Of the {NET_18} {TARGET POPULATION} adult people that you know, how many do you think you can invite individually to participate in this study?

_____

[IF NET_INVITE = 0]
NET_INVITE_VALIDATE You said that you cannot invite any people you know to participate in this hypothetical study. Is this correct?

○ Yes (1)

○ No, the number of adults I can invite is: (2)

_____

[IF NET_VALIDATE = 1] NET_INVITE_0_REASONS
What is your main concern when it comes to inviting the people you know to participate in research studies?

_____

Alter's information

Note: Only NET_INVITE > 3 survey flow is shown

REC_INSTRUCTION4 The next few questions will be about the four people you think you can invite to participate in this <u>hypothetical study</u> (You can hover on the blue text for a reminder of the study).

Firstly, what are their nicknames?

○ Person 1 (4) _____

○ Person 2 (5) _____

○ Person 3 (6) _____

○ Person 4 (7) _____

R1_1 The next few questions are about the people you named. Please give your best guess if you do not know the answers to any of the questions.
What's {PERSON 1}'s age?

○ 18-29 years (1)

○ 30-39 years (2)

○ 40-49 years (3)

○ 50-59 years (4)

○ 60-69 years (5)

○ 70 and older (6)

R1_2 What is {PERSON 1}'s race?

- [ ] White (1)

- [ ] Black or African American (2)

- [ ] American Indian or Alaska Native (3)

- [ ] Asian (4)

- [ ] Native Hawaiian or Pacific Islander (5)

- [ ] Other (9)

- [ ] Don't know (99)

R1_3 Is {PERSON 1} of Hispanic, Latino, or Spanish origin or descent?

- ○ Yes (1)

- ○ No (0)

- ○ Don't know (99)

R1_4 What is your relationship to {PERSON 1}?

- ○ Family (parents, spouse, siblings, children, other family/relatives) (1)

- ○ Romantic or queerplatonic partner (2)

- ○ Friend (close friend, casual friend) (3)

- ○ Other (acquaintance, something else) (4)

[IF R1_4 > 2]
R1_5 Are you in a position of influence over {PERSON 1} (e.g., work supervisor, church leader, someone they respect)?

  ○ Yes (1)

  ○ No (0)

R1_6 How long have you known {PERSON 1}? If it is less than a year, please respond with 1.

_____

R1_7 How close are you to {PERSON 1}?

  ○ 1 - Not at all close (1)

  ○ 2 (2)

  ○ 3 (3)

  ○ 4 (4)

  ○ 5 (5)

  ○ 6 (6)

  ○ 7 - Very close (7)

[QUESTIONS R1_1 TO R1_7 WERE REPEATED WITH PERSON 2, 3 4]
R7_4 Imagine you have invited them into this <u>hypothetical study</u>.
Now please rate their likelihood of responding to your invitation, where **1 is the least likely** to respond to your invitation and **5 is the most likely** to respond to your invitation.

	1 (1)	2 (2)	3 (3)	4 (4)	5 (5)
{PERSON 1}	○	○	○	○	○
{PERSON 2}	○	○	○	○	○
{PERSON 3}	○	○	○	○	○
{PERSON 4}	○	○	○	○	○

R10_4 What do you think might be the reasons for not responding to your invitation?

_____

RECIPROCATE_4 Imagine that the people you named have participated in this <u>hypothetical study</u> before you.
Who do you think will invite you to participate in this study?

☐   {PERSON 1} (1)

☐   {PERSON 2} (2)

☐   {PERSON 3} (3)

☐   {PERSON 4} (4)

[CARRY FORWARD CHOICES FROM RECIPROCATE_4]
R_PARTICIPATE_4 Whose invitation would you respond to?

☐   None of them (5)

☐   {PERSON 1} (1)

☐   {PERSON 2} (2)

☐   {PERSON 3} (3)

☐   {PERSON 4} (4)

REASONS What are some things you might consider before responding to an invitation to participate in a survey from a person you know?

- ☐ Duration of the survey (1)

- ☐ Research objective (2)

- ☐ Relationship with the person who invited you (3)

- ☐ Monetary compensation for your time (4)

- ☐ Other (9) _____

Demographic information

D1 The remaining questions ask for more information about you. We will use this information to describe the group of people who completed this survey.
What is the highest level of education you have achieved?

- ○ Never attended any school (1)

- ○ Grades 1 through 8 (2)

- ○ Grades 9 through 11 (3)

- ○ Grades 12 or GED (4)

- ○ Some college, Associate's Degree or Technical Degree (5)

- ○ Bachelor's Degree (6)

- ○ Any post graduate studies (7)

D2 Last week, did you work for pay at a job or business?

- ○ Yes (1)

- ○ No (0)

[IF D2=0] D2_1 When was the last time you worked for pay at a job or business, even if only for a few days?

○ Within the past 12 months (1)

○ 1-5 years ago (2)

○ Over 5 years ago (3)

○ Never worked (4)

D3_1 What is your best estimate of your household's total annual income from all sources before taxes in 2020?
Include money from jobs, social security, retirement income, unemployment payments, public assistance, and income from interest, dividends or rent, and any other money income.

_____

[IF D3 <= 0 OR D3 >= 10000000]
D3_1_CHECK You said your household income in 2020 is {D3}. Is that correct?

○ Yes (1)

○ No, it is: (2) _____

[IF D3 IS EMPTY]
D3_2 We don't need to know exactly, but could you tell me if your household's annual income in 2020 from all sources before taxes was more than $20,000 per year or less

○ Less than $20,000 (1)

○ Equal to $20,000 (2)

○ More than $20,000 (3)

[IF D3_2 = 3] D3_3
Was it more than $50,000 per year or less?

○ Less than $50,000 (1)

○ Equal to $50,000 (2)

○ More than $50,000 (3)

D4 Which social media service do you regularly use?

☐ Twitter (1)

☐ Facebook (2)

☐ Tumblr (3)

☐ Instagram (4)

☐ Reddit (5)

☐ Discord (6)

☐ Slack (7)

☐ None of the above (8)

D5_DISCLOSURE
Think about all the people you know. About what percent of them do you think know that you are **{TARGET POPULATION}**?

____ %

Recruitment instructions

Note: Only instructions for non-seeds are displayed here

RDS_INST_NOTSEED_2
You're near the end of this survey.

In the next page, we will ask for your email address and name in order to for us to send you a $10 Amazon Gift Card.

Your responses in the next page **will not** be directly connected to your responses in this survey.

We would like to ask you to invite TWO people you named that we have randomly chosen to participate in this survey. The invitation instructions will be sent to your email as well. To thank you for your help, you will receive an additional $5 for each person who successfully completes this survey.
We will also be sending an invitation to you for a follow-up survey after two weeks using the same email address.
[END MAIN SURVEY]

[START FOLLOW-UP SURVEY]

<u>Introduction</u>

<u>**Note: Only the version for respondents asked to invite two people is shown**</u>

INTRO Two weeks ago, you have participated in an online survey that had also asked for your help in inviting your friends to participate. We would like to ask a few questions about your experience in inviting your friend to this survey. This will take about 5 minutes of your time.

R1 Previously, you were asked to invite two people to participate in the survey. To help you recall, here are what you have answered about them:

<u>Person 1: {PERSON 1}</u>
 Age: {PERSON 1'S AGE}
 Relationship: {PERSON 1'S RELATIONSHIP}
<u>Person 2: {PERSON 2}</u>
 Age: {PERSON 2'S AGE}
 Relationship: {PERSON 2'S RELATIONSHIP}

R2 Did you try to invite them into the study?

○ Yes, both of them (1)

○ Yes, {PERSON 1} only (2)

○ Yes, {PERSON 2} only (3)

○ No, none of them (4)

○ I don't remember (5)

[IF R2 < 4]
I3 How did you invite them to participate in the study?

☐　Email (1)

☐　Text message (2)

☐　Direct message on social media (3)

☐　Telephone call (4)

☐　In-person (5)

☐　Other (please specify): (6)

[IF R2 < 4]
I3_2 How soon did you give out the invitations after you completed the survey?

○ Within a day (1)

○ Within 3 days (2)

○ Within a week (3)

○ Within 2 weeks (4)

○ I don't know (5)

[IF R2 < 4]
I4 What did you tell them about the study?

☐ $10 payment (1)

☐   Web survey (2)

☐   Survey length (3)

☐   Study objective (4)

☐   Other (please specify): (5)

[IF R2 < 4]
R3 Did you check on them to see if they have completed the survey?

○ Yes (1)

○ No (0)

[IF R2 = 1 OR R2 = 2]
R3_1 Did {PERSON 1} participate in the study?

○ Yes (1)

○ No (0)

○ I don't know (99)

[IF R2 = 1 OR R2 = 3]

R3_2 Did {PERSON 2} participate in the study?

◯ Yes (1)

◯ No (0)

◯ I don't know (99)

[IF R3_1=0 OR R3_2 = 0]
R4 What were the reasons for not participating given by the people you tried to invite?

☐   They were not interested (1)

☐   They already participated in this study before you invited them (2)

☐   They were suspicious about the credibility of this study (3)

☐   They were concerned about the data confidentiality (4)

☐   They had no time (5)

☐   They did not want to participate in a survey (6)

☐   Other (please specify): (7)

[IF R3_1=0 OR R3_2 = 0]
R5 Did you try to invite other people you know to participate in this study?

○ Yes (1)

○ No (0)

[IF R5 = 1]
R6 How many other people did you invite?

○ 1-2 other people (1)

○ 3-5 other people (2)

○ 6-10 other people (3)

○ More than 10 other people (4)

[IF R5 = 0]
I5 Can you tell us why you did not invite anyone?

☐   I am not interested in it (1)

☐   I am too busy (2)

☐   I forgot (3)

☐   I am not sure how to invite people (4)

☐   I am not comfortable with inviting people (5)

☐   I do not know enough people (6)

☐   People are not interested in it (7)

☐   People are suspicious about it (8)

☐   Other (please specify): (9)

[IF R5 = 0]
I6 For other surveys in the future, how can we help people like you be more comfortable with inviting people to participate?

_____

Network size

NET_ALL
For the last few questions, we would like to understand your relationship with your community. You may remember these questions from the time you answered the previous survey. This is to track if there are any changes within the two weeks.
How many {TARGET POPULATION} people do you know, who know you and who live in United States?

_____

[IF NET_ALL = 0]
NET_ALL_CHECK You said you do not know any transgender people who live in United States. Is that correct?

○ Yes (1)

○ No, the number of people I know is: (2)

_____

[IF NET_ALL > 1]
NET_18 Of these {NET_ALL}, how many are 18 years of age or older? If you are not sure, just count them as adults.

_____

[IF NET_18 = 0]
NET_18_CHECK You said you do not know any {TARGET POPULATION} adults who live in United States. Is that correct?

○ Yes (1)

○ No, the number of adults I know is: (2)

_____

[IF NET_ALL = 1]
NET_18_1 Is this person at least 18 years old? If you are not sure, answer with your best guess.

○ Yes (1)

○ No (0)

○ Don't know (99)

[IF NET_18 > 1]
NET_CLOSE Now I am going to ask you questions about the {NET_18} people that you know who are {TARGET POPULATION} and 18 years or older…
How many do you feel close to (that is, you feel at ease with, can talk to about what is on your mind, or call on for help)?

_____

[IF NET_18_1 = 1]
NET_CLOSE_1 Do you feel close to this person (that is, you feel at ease with, can talk to about what is on your mind, or call on for help with this person)?

  ○ Yes (1)

  ○ No (0)

[IF NET_18>1]
NET_INTERACT Of the {NET_18} {TARGET POPULATION} adult people that you know, how many have you interacted with (including talking to, visiting with, calling, emailing, texting, facebook, etc) personally in the past 2 weeks?

_____

[IF NET_18=1]
NET_INTERACT_1 Have you interacted with that person personally in the past 2 weeks? This includes talking, visiting, calling, emailing, texting, facebook, etc.

  ○ Yes (1)

  ○ No (0)

[IF NET_18 > 0]
SCENARIO
One of the main difficulties in research is reaching sexual and gender minorities. We would like to understand how we can leverage your social network to reach people in the LGBT community.
The next few questions will be referring to a **hypothetical study** described below.

 "LGBT Health Study an online survey which is 15-20 minutes long. This survey asks questions about various topics such as physical and mental health, and healthcare access. Participants are compensated $10 giftcard for their time upon completing the survey."   (You will be able to refer back to this description in some of the questions later by hovering over the blue text.)

[IF NET_18 > 1]
NET_INTEREST Of the {NET_18} {TARGET POPULATION} adult people that you know, how many do you think will be interested in participating in this study?

_____

[IF NET_18 = 1]
NET_INTEREST_1 Do you think the person you know will be interested in participating in this hypothetical study?

◯ Yes (1)

◯ No (0)

◯ Don't know (99)

The next few questions will be about who you can invite into this <u>hypothetical study</u>. Please note that you will not be able to go back to the previous questions in this section after you click "Next".
[IF NET_18 = 1]
NET_INVITE_1 Now, imagine that you have participated in that hypothetical study. At the end of that study, you are asked to invite a few people you know to participate in that study.
Would you invite this person?

◯ Yes (1)

◯ No (0)

[IF NET_18 > 1]
NET_INVITE Now, imagine that you have participated in that study. At the end of that study, you are asked to invite a few people you know who are transgender and at least 18 years old to participate in that study.

Of the {NET_18} {TARGET POPULATION} adult people that you know, how many do you think you can invite individually to participate in this study?

_____

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[IF NET_INVITE = 0]
NET_INVITE_VALIDATE You said that you cannot invite any people you know to participate in this hypothetical study. Is this correct?

○ Yes (1)

○ No, the number of adults I can invite is: (2)
_____

DEFINE_KNOW What does "knowing a person" mean to you?

_____

DEFINE_CLOSE How about "feeling close to someone"? What does that personally mean to you?

_____

[END FOLLOW-UP SURVEY]

Appendix D   Weighted (RDS II) and Unweighted Estimates (Recruiters vs. Non-recruiters)

Figure D.1 RDS II weighted and unweighted estimates (recruiters vs. non-recruiters)
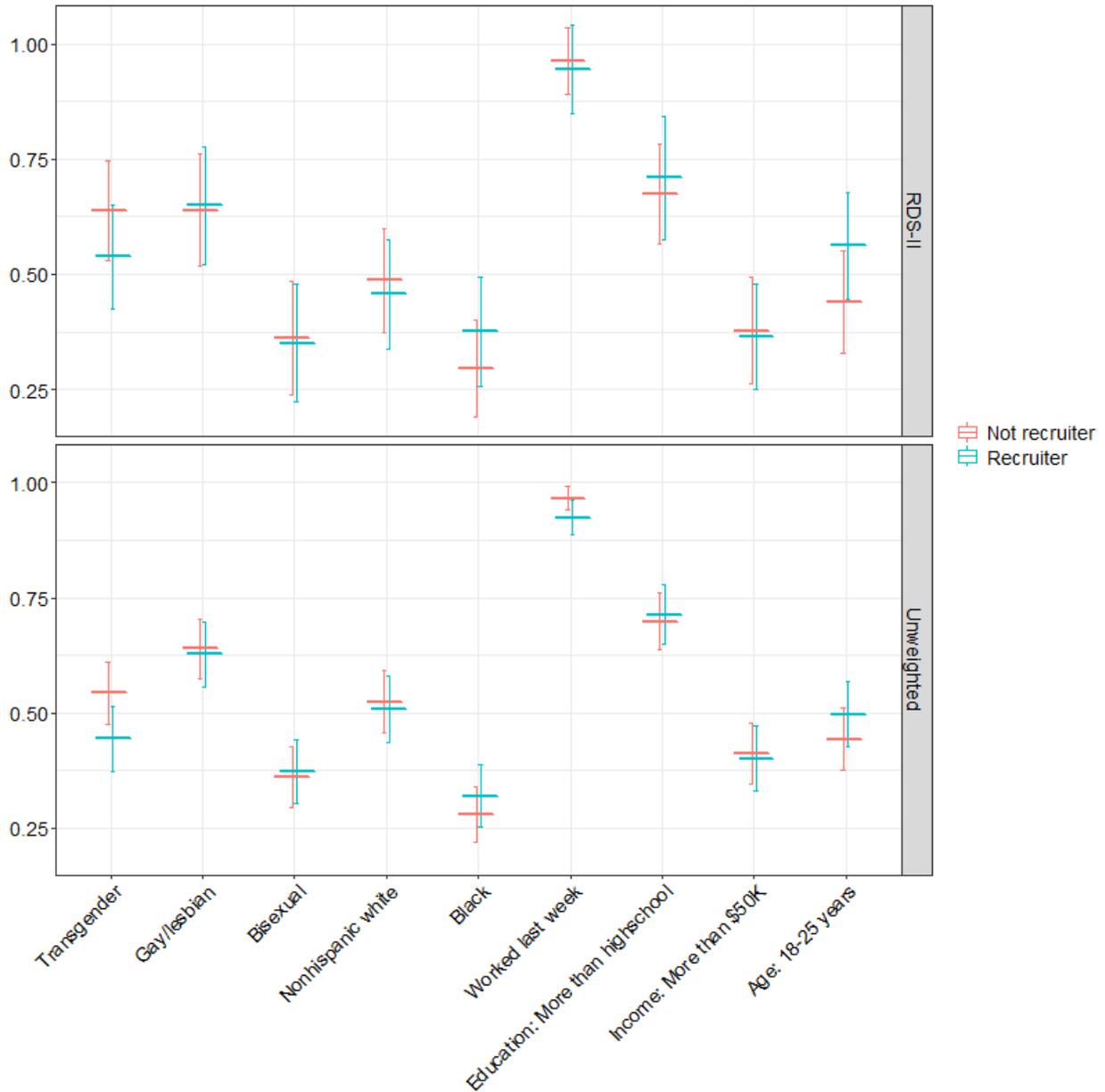
Section A: Study Background

We are interested in your study, [STUDY], {[IF GRANT=1, funded by [GRANT_AGENCY]/ [ELSE IF ARTICLE_JOURNAL=N/A, published in [ARTICLE_JOURNAL]}.

Please answer these questions in regards to the respondent driven sampling (RDS) of this study. If there are multiple waves in this study, focus on the first time when RDS was used.

Think about the target group of the study.

A1. Where was the target group located? Select all that apply.

☐Within the U.S.
☐Outside the U.S.

[IF WITHIN IS SELECTED IN A1, CONTINUE;
ELSE GO TO A1_2]

> **A1_1. Was the target group within the U.S. located across the country, certain states/provinces or certain cities/towns/villages?**
>
> ∘Across the country
> ∘Certain states or provinces
> ∘Certain cities, towns or villages

A1_2. What countries were the target groups outside the U.S. located? If more than one, list them in separate boxes.

> _____
> _____
> _____
> _____
> _____

A2. Which of the following describes the target group? Select all that apply.

☐Persons who inject drugs
☐Other substance users

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☐Commercial sex workers
☐Men who have sex with other men
☐Lesbian, gay, bisexual, queer
☐Transgender
☐Immigrants
☐Racial or ethnic minorities
☐Students
☐General population
☐Other
[IF OTHER IS ELECTED ON A2, CONTINUE;
ELSE GO TO A3]

A2_1. You selected "other". Please specify the characteristics of the target group.

_____

A3. Please select reasons why RDS was selected for this study. Select all that apply.

☐Financial feasibility
☐Proven effectiveness from the literature
☐Based on my team's own experiences from previous studies
☐Recommended by colleagues
☐Required by the funder/sponsor of the project
☐Other

A4. When you planned out the study, which of the following did you consider? Select all that apply.

☐Sample size
☐Seed recruitment
☐Field period
☐Interview mode
☐Formative research

[IF SAMPLE SIZE IS NOT SELECTED ON A4, GO TO A4_2]
    A4_1. What was the planned sample size? Your best guess is sufficient.
    _____ persons

[IF SEED RECRUITMENT IS NOT SELECTED ON A4, GO TO A4_3]
    A4_2. What was the planned number seeds? Your best guess is sufficient.
    _____ persons

[IF A4_2>A4_1, DISPLAY "**You said you planned the seed size to be larger than the sample size. Please check your answers.**" AND ASK A4_2 AGAIN;
ELSE CONTINUE]

[IF FIELD PERIOD IS NOT SELECTED ON A4, GO TO A4_4]
     A4_3. How long was the planned field period, excluding formative research? Your best guess is sufficient.

        _____ months

[IF A4_3<=60, GO TO A4_4;
ELSE DISPLAY "**You said your planned field period is more than 60 months. Please check your answers.**" AND CONTINUE WITH A4_3A]

     A4_3A. How long was the planned field period, excluding formative research? Your best guess is sufficient.

        _____ months

[IF INTERVIEW MODE IS NOT SELECTED ON A34 GO TO A4_5]
     A4_4. What was the mode used for the interview? Select all that apply.
        ☐Face-to-face
        ☐Telephone
        ☐Web
        ☐Paper and pencil

[IF FORMATIVE RESEARCH IS NOT SELECTED ON A4, GO TO A5]
     A4_5. Did you conduct formative research?
        ○Yes
        ○No

[IF A4_5=NO, GO TO A5]

     A4_6. What kind of formative research was conducted? Select all that apply.

☐Focus groups
☐One-on-one in-depth interviews
☐Field observations
☐Other

[IF FOCUS GROUP IS SELECTED ON A4_6, CONTINUE;
ELSE GO TO A4_6_2]
     A4_6_1. Who did you interview in the focus groups? Select all that apply.
☐Persons from the target group
☐Informants not from the target group
☐Other

[IF IN-DEPTH INTERVIEW IS SELECTED ON A4_6, CONTINUE;
ELSE GO TO A5]
A4_6_2. Who did you interview for the in-depth interviews? Select all that apply.
☐Persons from the target group
☐Informants not from the target group
☐Other

A5. Now think about the completion of your RDS study.

> **A5_1. What was the actual sample size? Your best guess is sufficient.**
> _____ persons
> **A5_2. How many seeds did you recruit? Your best guess is sufficient.**
> _____ persons

[IF A5_2>A5_1, DISPLAY "**You said you recruited more seeds than participants. Please check your answers.**" AND ASK A5_2 AGAIN;
ELSE CONTINUE]

> **A5_3. How long did the data collection last? Your best guess is sufficient.**
> _____ months

[IF A5_3<=60, GO TO A5_4,
ELSE DISPLAY "**You said your planned field period is more than 60 months. Please check your answers.**" AND CONTINUE WITH A5_3A]

> **A5_3A. How long did the data collection last? Your best guess is sufficient.**
> _____ months

> **A5_4. Was there any biological testing done?**
> ◦Yes
> ◦No
> **A5_5. Is this a longitudinal study?**
> ◦Yes
> ◦No

A6. Were there coupons in your study?
> ◦Yes
> ◦No
[IF A6=NO, GO TO A6_3;
ELSE CONTINUE]

> **A6_1. Which format were the coupons? Select all that apply.**
> ☐Paper
> ☐Electronic
> ☐Word of mouth

☐Other

A6_2. How were the coupons given to the respondents? Select all that apply.
☐In-person
☐Over telephone
☐Text
☐Email
☐Postal mail
☐Other

A6_3. In your study, were the respondents provided instructions on how to recruit their peers? Select all that apply.

☐Yes, they were coached by the study staff
☐Yes, they were given written materials (e.g., a take-home leaflet)
☐Yes, some other instructions
☐No

A7. Did the data collection progress as planned?
∘Yes
∘No

[IF A7=YES, GO TO A8;
ELSE CONTINUE]

A7_1. What aspects of data collection did not progress as planned? Select all that apply.
☐Seed recruitment
☐Slow recruitment
☐Fast recruitment
☐Participant duplicates
☐Sample composition
☐Other

A8. How did you decide to end the data collection? Select all that apply.
☐Achieved the target sample size
☐Reaching the planned field duration
☐Reaching the budget limit

A9. Were there incentives provided to participants? Select all that apply.
☐Yes, monetary incentives
☐Yes, non-monetary incentives
☐No incentives

[IF NO INCENTIVES IS SELECTED ON A9, GO TO A10;

ELSE IF MONETARY INCETIVES IS SELCTED ON A9, CONTINUE;
ELSE GO TO A9_2]

A9_1. What was the dollar amount of the monetary incentives? Your best guess is sufficient.

$ _____

[IF NONMONETARY INCETIVES IS SELCTED ON A9, CONTINUE;
ELSE GO TO A10]

A9_2. What was the dollar amount of the non-monetary incentives? Your best guess is sufficient.

$ _____

A10. What type of system did you use to manage coupons and/or to monitor the data collection progress? Select all that apply.
    ☐Existing RDS-specific automatized system
    ☐Existing generic automatized system
    ☐Created own automatized system
    ☐Manual system on a computer
    ☐Paper-and-pencil system
    ☐Did not use any system

[IF EXISTING RDS-SPECIFIC AUTOMATIZED SYSTEM IS SELCTED ON A10,
CONTINUE;
ELSE GO TO B1]

A10_1. Which RDS-specific automatized system did you use?

_____

Section B: Evaluation

B1. How would you rate the effectiveness of RDS for participant recruitment for this study?
   ◦Very effective
   ◦Effective
   ◦Somewhat effective
   ◦Neutral
   ◦Somewhat ineffective
   ◦Ineffective
   ◦Very ineffective

B2. Would you recommend RDS to other researchers?
   ◦Yes
   ◦No

B3. Would you use RDS again for recruiting similar groups?
   ◦Yes
   ◦No

[IF B3=NO, GO TO B3_2;
ELSE CONTINUE]
  B3_1. If to use RDS again in the future, is there anything you would do differently?

   _____

[IF B3=YES, GO TO B4;
ELSE CONTINUE]
  B3_2. If not RDS, what recruitment methods would you use instead?

   _____

B4. Are there other groups for whom you would consider RDS for recruitment?
   ◦Yes
   ◦No

[IF B4=YES, GO TO ENDSCRIPT;
ELSE CONTINUE]
  B4_2. What are those groups like?

   _____

ENDSCRIPT. Thank you very much for your participation. We will send you a $10 Amazon giftcode to you email within a business day.

If you have any questions or concerns, please feel free to contact us as rdsresearch@umich.edu.

Please click on "Submit" button below to complete.

Appendix F   Coding Guidelines

Target population

Coded for only those that used RDS data collection (e.g., research is about men who have sex with men [MSM], and female sex workers, but RDS data collection is only conducted for MSM, target population is coded as only MSM). All populations mentioned that RDS is used for is included.

If female sex workers were mentioned, select "Sex workers"

Public health journals

If the journal name contains mentions of "public health", or related public health terms (e.g., AIDS and Behavior, Sexually Transmitted Infections), code as "public health journal".

Examples of journals coded as non-public health specific journals: Conservation And Society, Human Ecology, Journal of Nursing Management

Mode reported

If the text mentions a mode, code it as the reported mode (e.g., telephone interviews).

If the mode is not explicitly reported, but it is clear from the text that it is interviewer administered, code 'interviewer administered' only.

Web mode

If the text described the mode (e.g., "respondents were given a link to a website to complete the survey"), coded as "web"

Incentive

Gift cards – code as monetary

In the case of incentives only given if two recruits participate – average the incentive per recruit

Transportation reimbursement – code as 'Others, specify…" and not "monetary"

If type of incentive is not mentioned, code as missing

Sample size

Target sample size: This is for the whole data collection – add all the sites together. If missing data on any sites, code as missing.

Final sample size: This is for the whole RDS sample, and not the analysis sample. E.g., if the paper is only about female sex workers, but the data collection is for all sex workers – check if the numbers are reported for all sex workers. If not reported for the whole sample, then code as missing.

Seed size

Planned seed size: If number of seeds is reported in methods, assume it is the planned seed size.

Achieved seed size: If number of seeds is reported in the results, assume that is the final number of seeds. If it is not in the results, assume achieved seed size is missing.

Appendix G   Latent Class Analysis Results

Table G.1 *Latent class analysis results*

	Two-class solution	Three-class solution	Four-class solution
Likelihood Ratio G^2	231.8927	202.2175	173.1662
Pearson X^2	2140680	524.675	525.5181
Degrees of freedom	98	86	74
AIC	1037.677	1032.001	1026.95
BIC	1101.98	1129.854	1158.352

Proportion of class membership by target population

Figure G.1 *Proportion of class membership by target population*
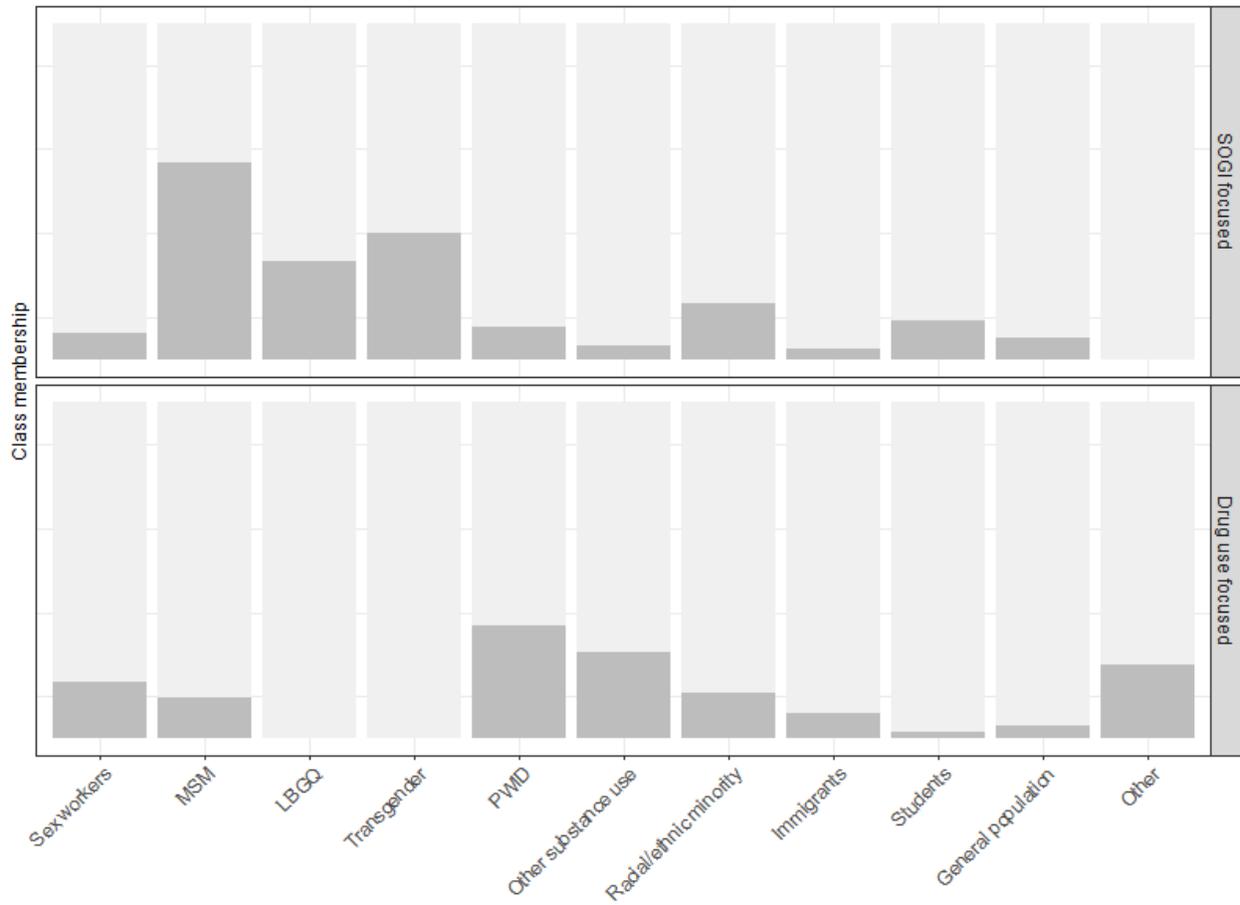
Appendix H   Discrepancy between RDS Researcher Survey and Published Manuscripts

Table H.1 *Discrepancy between RDS researcher survey and published manuscripts*

	N reported in published manuscripts	% Discrepant	Mean difference (RDS researcher study – Published manuscripts)
Target sample size	38	61%	-6.03
Achieved sample size	97	60%	-115.4
Planned seed size	52	71%	0.19
Achieved seed size	38	58%	-7.87

*Note: The median difference between the reported numbers in the RDS researcher study and the published manuscripts from the RDS studies are all 0