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THE METHODS OF DATA COLLECTION
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Snowball Sampling and Its Non-Trivial Nature

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Abstract
Snowball sampling (SS) is one of the popular methods of sampling in social research. The history of the development and implementation of this sampling model sheds light on the conditions of the evolution of the idea of sampling from hidden or hard-to-reach human populations. The seemingly uncomplicated procedure is the source of the method's popularity but also leads to its caricatured forms. This article presents selected elements of the theoretical basis of snowball sampling in its original version and its role in the development of theory related to sampling hard-to-reach populations based on chains of relationships. Special attention is given to the issue of sample representativeness and the conditions for determining the sample size obtained through snowball sampling. The aim of the presentation is to highlight the rational possibilities that the snowball sampling model offers for observational studies on education.

Keywords: chain-referral sampling, hard-to-reach populations, hidden populations, sample size, snowball sampling.

Introduction

Snowball sampling (SS) is a popular method of sampling in social research, particularly in education research. A search in the EBSCO database using the criteria "snowball sampling" and "education research" yields over 2000 records. Its usefulness in accessing student, teacher, and parent communities, which are often difficult to reach externally, is unquestionable. It is appreciated for its flexibility and the ability to gather data from unknown, hidden, hard-to-reach, or socially sensitive populations, such as tabooed groups, stigmatized populations, and those involved in conflict situations. Another reason for the popularity of this method may be the convenience of its procedure, as well as its over half-century of use and dissemination. According to common practices, it does not require laborious planning such as preliminary reconnaissance of the population, sampling framework development, or establishing contact with population representatives. In this sense, it shifts the responsibility for organizing the sample onto the respondents. Consequently, it is a low-cost method. On the other hand, criticisms have been raised regarding its lack of control over sample representativeness, coverage errors, and other systematic errors (bias), as well as the generally high sampling error caused by inflated similarity among individuals due to the cohort effect promoted by this method. Among the drawbacks of SS, it is also the reliance on respondents who are not trained in sample selection. Furthermore, the organizer of the SS sampling does not have access to the recruitment process, which limits the control over the recruitment and prevents determining the relationship between the target population and the survey population. Inferences drawn from data obtained in this way must be limited to the observed set. Therefore, any generalizations beyond this set lack justification and are consequently unwarranted. Despite these limitations, the popularity of SS remains strong.

The idea of SS was introduced in the mid-20th century with the works of Paul F. Lazarsfeld and Robert K. Merton (Handcock & Gile, 2011), and later popularized by James S. Coleman (1958–1959) and presented in an advanced form by Leo A. Goodman (1961). This prompted the development of chain-referral sampling concepts. However, parallel to this, there was also the implementation of a simplified, and even caricatured, version of SS, gaining an advantage where the snowball metaphor created a sense of enlightenment and satisfaction with self-service sampling. The popularization of these simplifications led to associations of SS with a careless approach to observational studies and sampling methods typical of qualitative strategies, to the detriment of the qualitative approach.

Below, selected elements of the theoretical foundation of snowball sampling in its original version and the history of the development of this method will be presented. The aim of this presentation is to highlight the rational possibilities that this idea offers for observational studies in the field of education.

Sampling idea

In observational studies, sampling is a necessary condition for accessing data sources. The goal of sampling is to obtain a representation of the general set in terms of a specific characteristic. This representation is typically based on the properties of the local set, i.e., the sample. The quality of this representation is determined by the goals and criteria derived from them (Glaser & Strauss, 1999; Dorofeev & Grant, 2006; Brewer & Gregoire, 2009; Lohr, 2010). The elements of the set can be people, behaviours, properties, or relationships. Sampling can be exhaustive, where all elements of the general population are included in the sample, or non-exhaustive, where the sample represents only a part of the general population. In research practice, non-exhaustive sampling (partial) is much more common. This is justified by the costs and difficulties associated with reaching all elements of the population. Additionally, some general populations have an infinite number of elements, such as characteristics that can take on any value from a model continuum or hypothetical repetitions of a certain experience indefinitely (e.g., coin tosses or naming the currently experienced state). The quality of the obtained representation of the general population depends on the rules adopted for the non-exhaustive sampling. These rules determine the division between random sampling and non-random sampling. Random sampling ensures that each element of the general population has a nonzero probability of being selected. This allows for controlling the representativeness of the sample relative to the general population in terms of the studied characteristic, the distribution of which is unknown. Non-random sampling lacks these properties. The commonly accepted condition for controlling the representativeness of a sample in finite population observational studies is the construction of an optimal sampling frame. However, this requires at least knowledge of the size of the general population. Such knowledge is unattainable in the case of unknown populations or populations with limited access for some reason. It is possible to resample according to the regularity that as the number of observations increases, the distribution of the characteristic in the sample converges to the distribution of that characteristic in the general population. In statistics, this regularity is expressed in the stochastic convergence theorem. However, multiple replications of sampling are rarely practiced due to time and financial constraints in research. More frequently, instead of replication, one of the sampling algorithms is implemented to obtain a sample size necessary for estimating the properties of the characteristic's distribution in the population, developed as part of the sampling theory. This theory deals with sampling from finite populations, is developed in the area of mathematical statistics and based on the Probability Calculus. This one, in turn, is a mathematical theory that enables estimating uncertainties in the realization of events or quantities that have a random nature, i.e. whose realizations and conditions are unknown. An integral part of this algorithm is the construction of the sampling frame. When it is not possible to create a sampling frame for a population with an unknown characteristic structure, or when the researcher is less interested in implementing a random mechanism and controlling the representativeness of the sample regarding that characteristic, non-random sampling methods are used. SS is commonly classified as a non-random sampling method. However, the classification of SS is a slightly more complex issue.

The snowball sampling model

Snowball sampling (SS) initiated the development of chain referral approaches in sampling theory. Such approaches involve chains of relationships that allow for transitioning from one unit to another based on information or recommendations obtained from those units (Erickson, 1979). Data collected through such sampling are referred to as chain-referral data. James S. Coleman (1958–1959) distinguished SS as one of the sampling methods that enable sampling while considering the social context of individuals who represent a specific population. The sampling plan of SS replicates the sociometric chain of relationships within a given population. Coleman argued that SS assumes access not only to the population of individuals but also to the population of relationships that occur among those individuals. The advantage emphasized by Coleman and his successors is the ability of SS to obtain high-quality representation of an unknown population under conditions of limited access to that population. However, for SS to fulfill its purpose, the representatives must recognize other representatives, be capable of communication, including with the recruiter, and be willing to provide recommendations. The occurrence of interpersonal relationships is necessary condition in this case. The name SS is often associated with the rapid increase in sample size and the layering of successive recruitment stages as the process progresses, analogous to the layers of snow accumulating in a snowball. At the base of this process is the identification of "seeds," which are representatives of the population who initiate the process of reaching out to other representatives. Most likely, this is why snowball sampling is associated with respondents recruiting other respondents which starts with the researcher selecting one or a few initial "seeds." However, the original model of snowball sampling, as presented in its developed form by Leo A. Goodman (1961), involves an initial (not whatever) identification of the social network by the researcher. Based on this, an initial sample is randomly selected, which serves as the irreducible foundation of the SS and reduces the method's systematic bias (Frank & Snijders, 1994).

Simple or complex sampling can be conducted on an accessible part of the population based on a sampling frame prepared for the entire population, with the target subpopulation being the hidden one, or by simply selecting units from the locations where they may be found (Frank & Snijders, 1994). In the case of the inability to establish a sampling frame, particularly for unknown populations, a random initial sample is obtained using the Bernoulli scheme. This scheme consists of a sequence of n independent repetitions of the same random experiment, taking on one of two values: success (S) – the occurrence of the desired event, or failure (F) – the absence of this event. The independence of repetitions means that the outcome of each experiment in the sequence is not dependent on the previous ones and does not affect the others. To satisfy this condition, after being selected, an element should be returned to the set from which it was drawn. Such sampling is called "with replacement." Furthermore, the probability p of success in each of the draws is identical in this scheme and assumes the assumed value. Due to the conditions underlying the Bernoulli scheme, this probability is sometimes referred to as the sample fraction, and the sampling itself as binomial sampling. Based on these conditions, the probability of k successes in n trials can be determined using the following formula:

$$P_n(k) = \binom{n}{k} p^k (1-p)^{n-k},$$

where p represents the probability of success.

The procedure of sampling in the Bernoulli scheme is not demanding. When given access to a specific subset of the population, decisions to include an element from that subset in the sample are made by randomly selecting one of two options: inclusion (success) or exclusion (failure), each with the same probability, $p = 0.5$. In this procedure, a random number generator can be used, or alternatively, a fair coin can be flipped assuming it is ideal. Of course, sampling in the Bernoulli scheme becomes inefficient when the number of available sampling units is $n < 2$.

After randomly selecting the initial sample, subsequent elements are sampled based on recommendations from units within that sample. Sampling occurs in waves, where the first wave includes the initially sampled units, and subsequent waves involve recommendations from those units. Sampling is stopped when no further recommendations are obtained. The resulting sample can be a complete sample if it exhausts all units in the population, or a partial (non-exhaustive) sample with an increased degree of representativeness in terms of characteristics of the population's members.

Predicting the sample size in snowball sampling

The sample size should not be considered an undefined or secondary quantity. It is feasible to estimate the number of recruitment waves and their sizes based on the theory of the phenomenon or probability theory. However, in the snowball sampling (SS) model, there is one explicit criterion that can also be used *ex post facto*. This criterion is known as saturation, which transpires when no new recommendations of additional respondents emerge within the wave (Frank & Snijders, 1994).

In most sampling designs, the sample size is calculated *ex ante* based on the known population size and predetermined conditions of statistical inference. Taking into account knowledge about factors that stratify the population may also be considered. In the case of SS, a random initial sample is taken in the Bernoulli scheme, the size of which is a random variable and can only be determined after the sampling is conducted. It should be emphasized that determining the size of the initial sample takes place before determining the size of the final sample drawn in SS. However, it is possible to indicate *ex ante* solutions for SS, although the condition for their application is the assumption of the number of waves and the number of references. In this place, I present three formulas for calculating sample sizes that are not commonly found in methodological publications.

The first formula applies when the expected number of units recruited by each recruiter remains constant in each expected recruitment wave. The second formula pertains to equally sized waves ($a_1 = a_2 = \dots = a_n$), where each respondent in each wave provides one referral different from the other referrals. To calculate the sample size in each of these situations, the appropriate formula for the sum of a geometric series is used, expressed as:

$$S_n \begin{cases} a_1 \dfrac{1-q^n}{1-q} & , when\ q \neq 1 \\ a_1 n & , when\ q = 1 \end{cases}$$

$$q = \frac{a_{n+1}}{a_n}$$

where a_1 denotes the first term of the sequence, q represents the common ratio of the sequence, and n denotes the number of terms in the sequence.

The third formula deals with recruiting waves that are not equinumerous, where the difference between the sizes of consecutive waves is not constant. In such cases, calculating the sum of the sequence is based on the products of consecutive terms in the sequence:

$$S_n = a_1 + a_2a_1 + a_3a_2a_1 + \cdots + a_n \dots a_3a_2a_1.$$

The application of these formulas can be further illustrated. For three waves of recruitment where each respondent recommends two other units (provides two referrals), the sequence would be as follows: 2^1, 2^2, 2^3. Thus the sample size can be:

$$n_{size} = 2\frac{1-2^3}{1-2^1} = 2\frac{-7}{-1} = 14\text{'}\ q = \frac{2^2}{2^1}$$

Next, considering three waves, each having an equal number of referrals $n_{referrals} = 3$, the size of sample is: $n_{size} = 3 \cdot 3 = 9$. Moreover, for the same number of waves, but with access to two initial respondents (2), where each refers five others (5), and each of these five refers three more (3), the sample size is calculated as follows:

$$n_{size} = 2 + 5 \cdot 2 + 3 \cdot 5 \cdot 2 = 42\,.$$

The presented formulas may aid in determining the sample size, but they should not serve as substitutes for justifying the number of waves and referrals within waves. Such justification should stem from an understanding of the phenomenon and the characteristics of the population.

Sampling schemes inspired by SS

The quality of a sample obtained from a hidden or hard-to-reach population depends on understanding the conditions for sampling individual units at the stage of organizing the initial sample and in subsequent stages. In this regard, limitations of snowball sampling (SS) may arise. Therefore, based on the SS model, the development of additional sampling methods has been initiated with the aim of optimizing representativeness in terms of the studied characteristic, process, or phenomenon.

One of the first methods inspired by SS is Network Sampling (Granovetter, 1976). It was proposed in relation to the study of enormous social networks, which SS may not always be able to address. This method involves sampling multiple samples with replacement from the same population. In each sample, the social structure of its members is reproduced, and the results are then used to estimate the density of links characterizing the social structure of the population.

A similar method in terms of purpose, but more developed, is the Random Walk Sampling (RWS) model (Klovdahl, 1977; 1989). It describes a way of gathering data on complex social networks that develop in interconnected urban areas, where the continuity of the chain of interpersonal relationships is lacking. RWS involves identifying "contact person" (seeds) from whom a list of individuals connected to them is obtained. From this list, "random walk informants" are randomly selected. These informants provide lists of further individuals. In the case of hard-to-reach populations, random walk informants may refer to "index participants" whose network is targeted and studied. RWS utilizes sequential statistical methods, including Markov processes. As a result, RWS allows for statistical inference about the structural properties of large and complex urban social networks to be conducted with a relatively small sample. RWS also emphasizes the sequential creation of the sampling frame.

The next method is Key Informant Sampling (KIS). This method was primarily aimed at reducing sampling error, including coverage error, which is particularly characteristic of SS. This method involves identifying and selecting representatives who possess sufficient knowledge about a specific hidden or hard-to-reach population. With this knowledge, they can characterize behavioural patterns present in the population and its members who exhibit these patterns (Deaux & Callaghan, 1985). Among the advantages of this method is the reduction of the risk of distorted information in SS due to the individual need approval. However, some disadvantages as limited access to detailed or personal information provided by individual informants or institutional bias, which may arise from identification with the population or from the assigned or performed role of the professional. The KIS method is also referred to as Expert Sampling, although they should be distinguished based on procedural differences, such as the creation of an expert panel from selected informants working on representing the studied phenomenon (Patton, 2018).

Another proposal was the Targeted Sampling (TS) model (Watters & Biernacki, 1989). It takes into account the precise localization and recognition of the target population, which involves reaching out to local networks and mapping them in the form of an ethnographic map of the studied population. Subsequently, an initial sample is recruited based on the ethnographic map, mainly to verify the quality of the map itself in terms of representing key groups, subgroups, and social clusters that emerge based on specific characteristics and relationships. The quality of the map depends on the accuracy of the previous fieldwork conducted. The researcher subjectively assesses this quality, and if the ethnographic map is deemed satisfactory, it proceeds to the main sampling stage guided by the map. Based on criteria derived from working on the ethnographic map, units are selected from specific locations, at specific times and in a specific order, including the relationships between subgroup sizes. As a result, it aims to reconstruct the structure of the general population in the sample, encompassing the diversity of social groups, strata, and categories. It is worth noting that by using the ethnographic map as a guide, other forms of sampling, such as quota sampling, stratified sampling, or systematic sampling, can be nested within the TS approach.

At the end of the 20th century, an advanced form of sampling was developed based on the original snowball sampling model but equipped with instruments to improve the sample's fit to the general population and, consequently, enhance estimation efficiency. This form is known as Respondent-Driven Sampling (RDS) (Heckathorn, 1997) and is considered a combination of Lazarsfeld and Merton's original approach with Goodman's approach (Handcock & Gile, 2011). The development of RDS has led to its classification as a family of methods derived from the overarching class of chain-referral sampling, allowing for the conversion of link-tracing into a stochastic method (Heckathorn & Cameron, 2017).

The main issue addressed at the core of the RDS model is related to the problem of randomly selecting an initial sample in a way that controls the bias resulting from voluntarism, the size of social networks, and the withholding of recommendations, known as masking. For this reason, recruitment in RDS is carried out in a manner that allows for the calculation of selection probabilities and extends beyond directly accessible representatives of the population by utilizing their social networks to reconstruct the population's structure. As a result, RDS exhibits significantly higher external validity compared to other forms of chain-referral sampling.

The selection procedure involves the selection of seeds and the documented assignment of their referral coupons. Typically, numerical identifiers serve as the basis, which recruiters provide to the recruited individuals, who then pass them on to the research organizer. The recruitment process proceeds in the same manner in subsequent waves. The identifiers form the basis for reconstructing social networks but also for providing rewards to recruiters. Rewards come in two forms: material (e.g., financial) and social. The latter form involves creating opportunities for members of the participants' own social environment to receive gratification for participating in the study. This approach also reduces nonresponse bias by exerting pressure to promote the study among individuals who are not initially interested. However, the number of possible referrals for each recruiter is limited to reduce the risk of referral creation exploitation.

Documenting the connections between recruiters and recruits provides information about the size of each respondent's personal network. This allows for compensating for the influence of respondents with larger social networks on the sample. Network weighting is the method of compensation, and the theoretical foundation of RDS is based on stochastic modelling using Markov processes and the theory of biased networks. RDS enables the reconstruction of recruitment patterns and, consequently, the structure of the general population based on the social network.

From the perspective of the evolution of sampling methods related to SS, particular attention is given to a solution known as Time-Space Sampling (TSS), also referred to as Time-Location Sampling (Muhib et al., 2001; Stueve et al., 2001). Mentioning it is important for three reasons. Evolutionarily, it stems from the development of SS and, like SS, is designed for researching rare or hard-to-reach populations. Moreover, TSS has played a role in the evolution of newer schemes influenced by methods from the SS group. This is the case with Starfish Sampling (Raymond et al., 2019), which employs TSS and RDS.

The Time-Space Sampling (TSS) seems to be rooted in the works on Site Sampling (SeS). SeS (TenHouten et al., 1971) involves the use of SS in conjunction with the theory of a randomly constructed network. In SeS, a social network is associated with the locations and clustering of individuals within the population. The selection of sample units is based on the division of the target population according to the places and times where its units are located. The statistical model of snowball sampling assumes that all interpersonal choices of all individuals are made independently and randomly. The authors developed statistical procedures to estimate the importance of locations, describe and estimate the distributions of individuals across the places they frequent. For this purpose, data on the population size, the number of people in specific locations at a given time, and individual between-site mobility are used. SeS is, therefore, a solution that utilizes the idea of representative research.

Similarly, to SeS, TSS requires the development of a sampling frame, which is a list of places and times (days and hours), referred to as venue-day-time unit (VDT), from which these VDTs are then randomly sampled. The sampling frame is created based on ethnographic maps and estimates of the places and times where units of the target population are found. These estimates are made by counting the units of the target population in places and times that are relevant in terms of the population characteristics. Based on this, the weights of VDTs are assessed according to appropriate indicators: Standard Enumeration (Type I) and Effective Yield (Type II). Sampling occurs in two or three steps. Firstly, VDTs are randomly selected, and then from the chosen VDTs, individual representatives of the target population are sampled, for example, systematically. Sometimes, separate randomization of the moment in time and loops constituting subsequent waves of sampling are added to the scheme. This method enables reaching hard-to-reach populations by identifying the locations of their units at characteristic places and times for the population. However, its primary limitation is the lack of control over the frequency of the selection of VDTs by individual units and the migration of units over time and space. This can lead to overrepresentation and underrepresentation of specific subpopulations within the target population. Moreover, a significant economic challenge is the identification of all places and time periods that could be relevant for the representativeness of the samples.

Finally, it is worth noting the role of the development of new social media platforms, such as Facebook, through which SS gains a new face in the form of so-called Virtual Snowball Sampling (VSS) (Baltar & Brunet, 2012). The main advantage of VSS is the reduction of limitations in sampling scope. As an adaptation to the conditions of social networking sites, the VSS method, however, requires the same methodology as SS. In the version presented in the literature (Baltar & Brunet, 2012), it appears to be burdened with similar limitations to the trivial from of SS.

"Melting" the trivialized idea

Although snowball sampling (SS) has a history of approximately 80 years, it requires a more advanced procedure than is typically presented in contemporary textbooks and guides to social research methodology. The flexibility in choosing the starting point of sampling and delegating the responsibility for the sampling process to respondents, and then expecting empirical material to be returned in a chain-like manner, cannot be considered a rational approach to understanding the social reality under investigation. In trivial form of SS, which mainly relies on the superficial mechanism of wave-like self-accumulation of collective units, replaces knowledge and engagement in developing the sampling procedure with the goodwill among recruited individuals and the social influence rules as liking or commitment and consistency (Cialdini, 2009). These rules are principles of social influence. It is mainly due to these rules that the trivialized SS achieves participant recruitment. The use of trivial SS is sometimes justified by arguing that SS is typical for qualitative research, where representativeness would have marginal importance. At most, typological representativeness, understood as mapping the structure of the phenomenon under study to provide its comprehensive image, is considered significant (Glaser & Strauss, 1999; Flick, 2009). In this view, the scope of conclusions drawn from the study would be limited to the elements collected within the sample. However, researchers, even those identifying with the qualitative approach, typically aspire to formulate conclusions that extend beyond the sample (Guba, 1981; Morse et al., 2002), allowing them to describe the class to which the selected elements of the set belong, such as individuals, behaviours, characteristics, or relationships.

Another issue with trivial SS is the difficult-to-correct flaw that arises as errors and biases increase in subsequent waves of recruitment. This occurs due to the biased choices and referrals made by respondents, who are more likely to recruit individuals similar to themselves rather than those who are different.

Furthermore, trivial SS also disregards the intended purpose of SS as a method for gathering empirical material that adequately represents the structure of a hidden or hard-to-reach population. Trivial SS provides information and material whose quality in this regard is largely beyond control. What trivial SS undoubtedly ensures is minimizing the effort required in organizing the sampling process. Therefore, caution is warranted when using trivial SS in the context of hidden, hard-to-reach or sensitive populations, and scepticism is warranted when direct relationships between its representatives are in doubt. In such situations, the decision to use SS may be driven by convenience rather than a concern for obtaining a valuable representation of the population from which the sample is drawn.

In light of the above, the use of trivial SS, given the current knowledge about chain-referral sampling, should raise suspicions of a lack of familiarity with sampling principles in observational studies or an attempt to exploit the argument of difficult population penetration conditions.

Conclusions

Snowball sampling (SS) is neither a new nor an optimal method. Therefore, the consequence of the ongoing decades-long refinement of the SS procedure is the existence of a complex and extensive family of chain-referral sampling methods. Particularly noteworthy among them are the RDS methods and newer evolutionary, such as Starfish Sampling. Sometimes these sampling methods are subjected to divisions, although these divisions do not always seem crucial from the perspective of practical use. One approach uses the criterion of population characteristics, i.e., rare or hidden. According to it, within the so-called snowball methods for collecting data from rare populations, SS is foreseen, and in the case of hidden populations, for instance, SeS, TS, and KIS (Spreen, 1992). However, when optimizing the selection of methods for conducting research, this way of addressing may be more important rather for a method historian interested in the circumstances of the genesis of these solutions. From a practical point of view, if SS is chosen as the sampling method, adhering to the principle of optimizing data quality requires following the rules and procedures specific to this sampling approach. As a result, the collected data will indeed be burdened with a systematic error generated by the limitations of this method, but this limitation will be recognized. On the other hand, implementing trivial forms of SS based on a superficial facade disregards the ability to control the sampling biases, and it requires a strong reservation regarding the internal and external validity of such studies. This means that the scope of limitations expands in an uncontrolled manner, giving only the illusion of effective sampling of units for the sample, while the SS itself becomes more about the convenience of the researcher rather than rational minimization of cognitive errors. In such situations, it is also more challenging to justify the *ex ante* or *ex post* decisions, such as those related to sample size.

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