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## Respondent-driven Sampling on Directed Networks

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Respondent-driven sampling (RDS) circumvents the difficulties in sampling hard-to-reach population by using their social networks. It has been shown that the RDS is an effective method for generating handful sample. What's more, under certain assumptions, unbiased estimates for population traits can be generated by weighting

the sample with respondents' personal network sizes. For these advantages the RDS has been widely used in HIV-related studies among high risk populations in recent years. However, despite the quite acknowledged evidences that most social networks are directed, all existing RDS estimators are based on assumption that the social relationships between respondents are reciprocal and consequently the RDS recruitment process happens on undirected networks. To investigate the potential bias brought by network directedness, and further generalize the RDS method, we propose several estimators that work both on directed networks and undirected networks. Performances of estimators

are compared by RDS simulations on networks with different degrees of directedness, assortativity, indegree-outdegree correlation and homophily. Results reveal that the most robust estimator is the one which assumes the amount of individuals with trait A in the sample is proportional to the total indegree for individuals of group A in the population. A sensitivity test method is proposed when the sample indegree is not known. Given the widely existence of irreciprocal relationships among social society, we suggest the new estimator to be used in future RDS studies.

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