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Network cognition

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ABSTRACT

We study individual ability to memorize and recall information about friendship networks using a combination of experiments and survey-based data. In the experiment subjects are shown a network, in which their location is exogenously assigned, and they are then asked questions about the network after it disappears. We find that subjects exhibit three main cognitive biases: (i) they underestimate the mean degree compared to the actual network; (ii) they overestimate the number of rare degrees; (iii) they underestimate the number of frequent degrees. We then analyze survey data from two 'real' friendship networks from a Silicon Valley firm and from a University Research Center. We find, somewhat remarkably, that individuals in these real networks also exhibit these biases.

1. Introduction

A growing body of theoretical and empirical research argues that the structure of social networks is a crucial determinant of individual behavior and welfare.[2] In light of the recent development of social networking sites and tools, individuals have arguably become even more aware of the structure of the social relationships in which they are embedded.[3] However, learning and using information about network structure is far from being a simple task. A salient feature of networks is their complexity: there are thousands of potential network configurations even in a group with just a dozen members. Moreover, the nature of social interactions often makes it difficult to record or access information other than through memory, making this a cognitively demanding task.

The objective of this paper is to investigate individual cognition of social networks. Is there significant heterogeneity in the way individuals process, recall and use network information? Are there common systematic biases? Do they affect

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2 See Goyal (2007), Jackson (2008) and Vega-Redondo (2007) for overviews of this work.

3 In a special report, the *Economist* magazine asserts that "social-networking sites [...] have made people's personal relationships more visible and quantifiable than ever before" ("A world of connections," *The Economist*, January 28, 2010).

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individuals' economic decisions? These are some of the questions we address. A distinctive feature of our work is that we use data drawn from a combination of laboratory experiments and surveys from the field. We examine the cognition of the distribution of connections (the so called 'degree' distribution) and how cognition varies with location in the network.[4] Our focus on the distribution of connections is motivated by recent theoretical research highlighting its key role in understanding individual behavior and in investigating aggregate social and economic dynamics in networks.[5]

In the laboratory experiment, we use the following novel methodology: subjects are shown a graphical representation of an imaginary friendship network and they are (randomly) assigned to be a node in the network. After a fixed amount of time (typically 1 min[6]), the network disappears and subjects are asked questions about the structure of friendship relations in the group. For instance, the question "*How many people in the group (including yourself) have exactly x friends?*" allows us to generate the subjects' perception of the degree distribution by aggregating the answers for the different values of *x*.

We find substantial individual heterogeneity in network cognition. However, three main biases emerge clearly. First, subjects *underestimate the average degree in the network*. The cognitive mean degree is (roughly) 4 while the actual mean degree is over 4.6 s, subjects *overestimate the number of rare types* in the network, where the "type" of a node is its degree. Specifically, they perceive that there exist individuals of types 1, 2, 5, 6, and 8, which are actually absent from the real network. Third, they *underestimate the number of frequent types in the network*: there are five nodes for each of types 3, 4 and 7 and subjects perceive a significantly lower number.

The laboratory setting allows a researcher to control the parameters of the experiment, but this tight control raises questions about the scope of the findings. The first issue is internal validation: we choose specific networks to show to the subjects and the network information is shown using a visual representation. A natural question is therefore whether our findings are sensitive to the specific networks used and to our choice of conveying the information with a visual representation. The second issue is external validation: do these biases also arise in actual social networks or are they an artifact of the experimental methodology? We address these concerns by analyzing two well-known survey data sets on social networks. The first data set is the friendship network of a Silicon Valley firm, which was first studied in Krackhardt (1987). The second data set is the friendship network in a University Research Center, which was first studied in Casciaro (1998).

We show that individual cognition of the real friendship networks in these two data sets exhibits the three main biases identified in our experimental work. In particular, individuals in the Silicon Valley firm network perceive a lower mean connectivity than the true mean, they overestimate rare types and underestimate (almost all) frequent types. Individuals in the University Research Center network perceive a lower mean connectivity than the true mean, they overestimate (most) rare types and underestimate (most) frequent types. This congruence of findings from our experiment and from the field data is, in our view, quite striking. It provides corroborating evidence of the existence of the specific cognitive biases that we identified in the laboratory experiments. Moreover, it allows us to make a more general methodological point: the network cognition processes in the laboratory appear to be similar to the cognition processes of individuals located in actual social networks.

The laboratory methodology enables us to make three important additional contributions relative to the analysis of survey data. First, we are able to investigate in a clean way location effects: by randomly assigning subjects to different nodes in the network, we can avoid the endogeneity problems typically present in survey data. We find that indeed *location affects cognition*: low and high "type" (degree) subjects differ in their perception of the network along two dimensions: the perception of other low types, and the identity of key individuals in the network. Second, we are able to study whether the *accuracy of network cognition varies with the architecture of the network*: we find that a mean preserving spread of the degree distribution leads to greater cognitive accuracy.[7] Third, we are able to investigate whether *network cognition affects subjects' economic decisions*. Having answered a range of questions designed to probe how they process and recall network information, our subjects then face two decision problems. Both involve a decision to contribute in a network public good game, where other players' contribution decisions are assigned by the experimenter and communicated to the subject, thereby removing any strategic uncertainty. The subject therefore faces what would be a very simple decision problem if she had complete knowledge of the network: in one problem, the payoff-maximizing strategy is to contribute, while in the other it is more profitable not to contribute. However, the subject does not have access to network information while making her decision: she has to rely on her memory. The memory task is more demanding in one of the decision problems. We find, as expected, that in this case subjects are less likely to choose the action that maximizes their monetary payoff. Moreover, two measures of an individual's cognitive accuracy obtained in the earlier part of the experiment significantly predict behavior. The first is a measure of how accurately the individual perceives very low (degree) types in the network. This is particularly relevant for one of the decision problems, and indeed its effect is only significant for that problem. The second measures one of the cognitive biases we identified earlier, namely the tendency to overestimate the number of

[4] The *degree* of a node is the number of its direct connections. The degree distribution in a network tells us the number of nodes with different degrees. For formal definitions refer to section 2.

[5] See Galeotti et al. (2010) for a study of the relationship between network degree distributions and strategic behavior, and Vega-Redondo (2007) for an exposition of the literature which relates a variety of dynamic processes in networks to the underlying degree distribution.

[6] We decided to allocate 1 min in most cases after obtaining feedback from a pilot.

[7] For formal definitions see Section 2.