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Multi-agent models of social dynamics in children

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Abstract

A series of computational models are presented which address the question of how peer relations change over time. We examine data from a standardized metric (CDC) that places school children in one of five categories: Popular, Rejected, Neglected, Controversial, and Average, and how such classifications change over time. A simple random model is shown to not match the empirical data, while a computational model and an ACT-R model are shown to match equally well, even though they are highly architecturally distinct. To test these models' ability to give useful predictions in other domains, we introduced variation among the individuals in the models. For both models, we observed equivalent behavior that was consistent with the empirically known effects of Hostile Attribution Bias, variations in social skill, and shyness among others. This indicates that both models are capturing inherent underlying regularities of the social dynamics of peer relations in children. The relationship between these models and its implications are discussed.

Keywords: Multi-agent; Cognitive modelling; Dynamic systems; ACT-R; Sociometrics; Child development

1. Introduction

Popularity is generally thought of as something dependent on who we are: on our personality and social skills. However, in this paper we examine the opposite proposal: that popularity has very little to do individual behavior. To do this, we take a dynamic, multi-agent approach to modeling popularity. That is, we examine how popularity is distributed across time within a dynamic network of interacting agents (see Sun, 2001; Sun, 2006 for discussions on multi-agent modeling).

There is a tendency to think of popularity as something that resides within a person, but it is actually a distributed property of the group. An individual's popularity is a function of how many people like them. The notion that popularity resides in a person may be a result of viewing popularity as the outcome of our personality and/or social skills, so that when someone says that a person is popular, what is meant is that the person possesses the means to be liked. In contrast to this view, we propose that popularity is an emergent property of the dynamics of the group interaction. This means that where an individual ends up in the social environment depends on where they are deposited by the forces generated by the dynamics of the group interaction.

To investigate this we used multi-agent models of children's friendship interactions and compared the results to the empirical data from studies in this area. In particular, we were interested in the relationship between the emergent properties of the system as a whole and the cognitive properties of the individual. Since there is no normative method for doing this (see Sun, 2006 for examples and discussion), we used two principles of cognitive modeling to guide us. First, the *simplicity principle*, has been put forward as a fundamental principle of cognition by Chater and Vitanyi (2003). Essentially, the idea is that the brain tries to do things in the simplest way possible. As Chapter points

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out, a wide range of cognitive phenomena seem to conform to this principle. We used this principle as one basis for creating our models. We called the second principle that we used the *architecture principle* as it was based on Newell's concept of cognitive architectures (Newell, 1990). The idea behind this principle is that all the different things that we do have to be performed by the same brain, and therefore the same cognitive architecture. Thus, while it is useful to create unrelated models of different cognitive abilities, ultimately it should be possible to implement all of those models in a single architectural system that, following the simplicity principle, is as simple as possible. To explore the architecture principle we used ACT-R (Anderson & Lebiere, 1998), which is a cognitive architecture that has been used to accurately account for hundreds of different cognitive effects.

We first developed a simple computational model of the process of friendship formation and compared its behavior to real-world results. We then constructed a model using ACT-R and compared it to the real world results and also to the results of the simple computational model. Interestingly, the final ACT-R model suggested a qualitatively different explanation than the simple model.

2. Background

Individual factors do influence popularity; a child could be unpopular because they are shy, aggressive, and/or socially incompetent (Newcomb, Bukowski, & Pattee, 1993). However, only a moderate amount of the variance is explained by these internal factors. Indeed, in Rubin and Mills (1988) review, the R^2 values tended to be in the 0.25–0.30 range, with one exception at 0.43. This indicates that only a moderate percentage of the differences in social status can be directly attributed to individual factors. The rest may be due to a variety of unmeasured factors, including the dynamics of group interactions. The major difficulty in addressing the effects of group dynamics is the complexity of the individual's interaction with other individuals and the resulting potential for complex feedback loops. This complexity makes it difficult to predict how a particular event may impact an individual's life.

One methodology for addressing this type of situation is to develop multi-agent models. The goal in developing these models is the same as that of developing any scientific theory: to explain and predict behavior. The model is created based on known empirical results. Once a suitable model is found, it can be used to predict of other aspects of the behavior. These predictions can then be empirically tested. Ideally, once a sufficiently accurate model is created, it would be possible to perform exploratory research on the model. For example, one could investigate the impact of a particular intervention technique on the model before attempting it on real people.

In this paper, we present our work developing a model of peer relations over time within school-aged children. Our models were constructed to predict the same popularity categories used by the standard sociometric measurement techniques. Importantly, the models allowed us to observe how these relations change over time, and allowed us to investigate the impact of internal factors, such as personality and social skills.

3. Existing research

The study of the measurement of children's peer relations (i.e., *sociometric classification*) begins with Moreno's (1934) research. His work on describing individuals in terms of the *attraction* and *repulsion* felt towards others, and by others towards them, spawned a wide variety of measurement techniques, each attempting to develop a useful scale for the investigation of the causes and effects of children's social experiences (see Cillessen & Bukowski, 2000 for a review).

One of the results of this research is that a simple, one-dimensional scale is not sufficient to capture useful information. In particular, we generally need to distinguish at least three categories: individuals who are viewed positively by peers, individuals who are viewed negatively, and individuals who are ignored. To do this, most modern sociometric techniques involve distinguishing two measurement dimensions: *preference* and *impact*. A person who is ignored would be one with a low impact, while someone who is actively disliked might have a high impact, but a very low preference rating.

The most popular and widely used measurement scheme is known as CDC Classification. It is named after its creators, Coie, Dodge, and Coppotelli (1982), and classifies people into one of five categories: *Popular*, *Rejected*, *Controversial*, *Neglected*, or *Average*. To facilitate its use across as wide a range of ages and situations as possible, its methodology is quite simple. Using interviews or questionnaires, each person is asked to name three people in their peer group that they like, and three people that they dislike. These scores are than standardized within class to control for the number of possible nominations received. The simplicity of this measurement is important for measuring popularity in young age groups. Using the survey results, each individual is given an *Acceptance* score (the total number of times that person is listed by other people as someone they like) and a *Rejection* score (the number of times they appear on the 'dislike' lists). A *Preference* value (Acceptance minus Rejection) and an *Impact* value (Acceptance plus Rejection) are also created, where Preference refers to whether you are more liked or disliked and Impact refers to how much people pay attention to you. Individuals are then classified into the five categories according to the rules shown in Table 1.

Given the wide use of this system, and the accompanying availability of a wide variety of experimental results based on the CDC classification scheme, we decided to use it as the basis of comparison for our computational modeling results. It is worth noting that other methods do exist in the literature (such as Newcomb & Bukowski,