Emergence of leader-follower hierarchy among players in an on-line experiment

Hierarchical networks are prevalent in nature and society, corresponding to groups of actors - animals, humans or even robots - organized according to a pyramidal structure with decision makers at the top and followers at the bottom. While this phenomenon is seemingly universal, the underlying governing principles are poorly understood. Here we study the emergence of hierarchies in groups of people playing a simple dot guessing game in controlled experiments, lasting for about 40 rounds, conducted over the Internet. During the games, the players had the possibility to look at the answer of a limited number of other players of their choice. This act of asking for advice defines a directed connection between the involved players, and according to our analysis, the initial random configuration of the emerging networks became more structured over time, showing signs of hierarchy towards the end of the game. In addition, the achieved score of the players appeared to be correlated with their position in the hierarchy. These results indicate that under certain conditions imitation and limited knowledge about the performance of other actors is sufficient for the emergence of hierarchy in a social group.

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Academic performance and behavioral patterns
Identifying the factors that influence academic performance is an essential part of educational research. Previous studies have documented the importance of personality traits, class attendance, and social network structure. Because most of these analyses were based on a single behavioral aspect and/or small sample sizes, there is currently no quantification of the interplay of these factors. Here, we study the academic performance among a cohort of 538 undergraduate students forming a single, densely connected social network. Our work is based on data collected using smartphones, which the students used as their primary phones for two years. The availability of multi-channel data from a single population allows us to directly compare the explanatory power of individual and social characteristics. We find that the most informative indicators of performance are based on social ties and that network indicators result in better model performance than individual characteristics (including both personality and class attendance). We confirm earlier findings that class attendance is the most important predictor among individual characteristics. Finally, our results suggest the presence of
strong homophily and/or peer effects among university students.

Optimizing targeted vaccination across cyber-physical networks: an empirically based mathematical simulation study

Targeted vaccination, whether to minimize the forward transmission of infectious diseases or their clinical impact, is one of the 'holy grails' of modern infectious disease outbreak response, yet it is difficult to achieve in practice due to the challenge of identifying optimal targets in real time. If interruption of disease transmission is the goal, targeting requires knowledge of underlying person-to-person contact networks. Digital communication networks may reflect not only virtual but also physical interactions that could result in disease transmission, but the precise overlap between these cyber and physical networks has never been empirically explored in real-life settings. Here, we study the digital communication activity of more than 500 individuals along with their person-to-person contacts at a 5-min temporal resolution. We then simulate different disease transmission scenarios on the person-to-person physical contact network to determine whether cyber communication networks can be harnessed to advance the goal of targeted vaccination for a disease spreading on the network of physical proximity. We show that individuals selected on the basis of their closeness centrality within cyber networks (what we call 'cyber-directed vaccination') can enhance vaccination campaigns against diseases with short-range (but not full-range) modes of transmission.
Class attendance, peer similarity, and academic performance in a large field study

Identifying the factors that determine academic performance is an essential part of educational research. Existing research indicates that class attendance is a useful predictor of subsequent course achievements. The majority of the literature is, however, based on surveys and self-reports, methods which have well-known systematic biases that lead to limitations on conclusions and generalizability as well as being costly to implement. Here we propose a novel method for measuring class attendance that overcomes these limitations by using location and bluetooth data collected from smartphone sensors. Based on measured attendance data of nearly 1,000 undergraduate students, we demonstrate that early and consistent class attendance strongly correlates with academic performance. In addition, our novel dataset allows us to determine that attendance among social peers was substantially correlated (>0.5), suggesting either an important peer effect or homophily with respect to attendance.

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Contact activity and dynamics of the social core
Humans interact through numerous communication channels to build and maintain social connections: they meet face-to-face, make phone calls or send text messages, and interact via social media. Although it is known that the network of physical contacts, for example, is distinct from the network arising from communication events via phone calls and instant messages, the extent to which these networks differ is not clear. We show here that the network structure of these channels show large structural variations. The various channels account for diverse relationships between pairs of individuals and the corresponding interaction patterns across channels differ to an extent that social ties cannot easily be reduced to a single layer. Each network of interactions, however, contains both central and peripheral individuals: central members are characterized by higher connectivity and can reach a large fraction of the network within a low number of steps, in contrast to the nodes on the periphery. The origin and purpose of each communication network also determine the role of their respective central members: highly connected individuals in the person-to-person networks interact with
their environment in a regular manner, while members central in the social communication networks display irregular behavior with respect to their physical contacts and are more active through irregular social events. Our results suggest that due to the inherently different functions of communication channels, each one favors different social behaviors and different strategies for interacting with the environment. These findings can facilitate the understanding of the varying roles and impact individuals have on the population, which can further shed light on the prediction and prevention of epidemic outbreaks, or information propagation.

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**Phenomenological theory of collective decision-making**
An essential task of groups is to provide efficient solutions for the complex problems they face. Indeed, considerable efforts have been devoted to the question of collective decision-making related to problems involving a single dominant feature. Here we introduce a quantitative formalism for finding the optimal distribution of the group members’ competences in the more typical case when the underlying problem is complex, i.e., multidimensional. Thus, we consider teams that are aiming at obtaining the best possible answer to a problem having a number of independent sub-problems. Our approach is based on a generic scheme for the process of evaluating the proposed solutions (i.e., negotiation). We demonstrate that the best performing groups have at least one specialist for each sub-problem but a far less intuitive result is that finding the optimal solution by the interacting group members requires that the specialists also have some insight into the sub-problems beyond their unique field(s). We present empirical results obtained by using a large-scale database of citations being in good agreement with the above theory. The framework we have developed can easily be adapted to a variety of realistic situations since taking into account the weights of the sub-problems, the opinions or the relations of the group is straightforward. Consequently, our method can be used in several contexts, especially when the optimal composition of a group of decision-makers is designed.

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The role of gender in social network organization

The digital traces we leave behind when engaging with the modern world offer an interesting lens through which we study behavioral patterns as expression of gender. Although gender differentiation has been observed in a number of settings, the majority of studies focus on a single data stream in isolation. Here we use a dataset of high resolution data collected using mobile phones, as well as detailed questionnaires, to study gender differences in a large cohort. We consider mobility behavior and individual personality traits among a group of more than 800 university students. We also investigate interactions among them expressed via person-to-person contacts, interactions on online social networks, and telecommunication. Thus, we are able to study the differences between male and female behavior captured through a multitude of channels for a single cohort. We find that while the two genders are similar in a number of aspects, there are robust deviations that include multiple facets of social interactions, suggesting the existence of inherent behavioral differences. Finally, we quantify how aspects of an individual’s characteristics and social behavior reveals their gender by posing it as a classification problem. We ask: How well can we distinguish between male and female study participants based on behavior alone? Which behavioral features are most predictive?