Strategic Information Transmission in a Social Network: A Controlled Field Experiment*

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Abstract

Using an app for smartphones we run an experiment among high school students to study the pattern of aggregation of sparsely distributed information when competing agents are arranged in small networks and can share only non-verifiable pieces of information. Our first finding is that the level of cooperation is high, especially among students that belong to the same class. Nevertheless the level of centralization of the network significantly affects the final results, with the most central node reducing the overall level of aggregation. By adding a second node with a high centrality we see that the results change significantly, with more signals traveling through the links. By increasing competition between peripheral nodes instead we see a reduction in cooperation.

*The present chapter shows the results achieved by my coauthors and me, but the final form is due to me alone for the purpose of this thesis. This means that I am the only responsible for errors and imprecisions.

1 Introduction

The way agents aggregate sparsely distributed information is a central topic in the economics literature. Examples of applications range from the theory of organizations, studying how to design the structure of communication inside a firm or a team in order to favor an efficient flow of knowledge, to the study of financial institutions, where strategic retention of information could prevent the correct functioning of the market. In many of these context there is an element of competition such that those who manage to have a better access to information get an advantage or, similarly, those who successfully hide pieces of knowledge to others are more likely to obtain a higher payoff. This paper studies this topic by focusing on a context in which agents are arranged in a network that defines their communication opportunities and can exchange non verifiable pieces of information that ultimately determine the distribution of payoffs. In particular we are interested in studying how asymmetry and competition among nodes alter the pattern of information diffusion.

To do this we use a field experiment with high school students in Italy. The experiment consisted in a game played using a smartphone app over the span of a week. Students were playing in groups of five members and were asked to guess five pieces of information that had previously been distributed among the five participants, one piece of information each. Communication was free in principle, but given the number of participants it was hard to identify in the school who was in possess of the information needed. The networks we used were then created by revealing players the identity of other members of the group. Peripheral players had little knowledge about the identity of the others, while central players received more information. We used three different networks in order to have variation in the structure of links among players. Crucially the scores were such that a bonus was given to the player who could better aggregate the available information. We believe this setup is a good description of what happens in many real life situations. Indeed, even inside an organization or a team, it is in principle possible to reach and exchange information with all the other active nodes. What we use as links can be interpreted as routes in which we expect communication to take place with higher probability. In the context of organizations this could be seen as the structure imposed by the management, while in teams it could be seen as frequent face-to-face interactions among team members.

The first finding is in line with the experimental literature on cheap talk games in which players were usually observed to exchange more information than what one would predict using theoretical models. We never observed the outcome that would constitute the only Nash equilibrium in a standard game with non-verifiable information, meaning the case in which people rely only on the hint they received and avoid exchanging pieces of information with the others. Instead the level of cooperation was quite high, especially among players that belonged to the same class. We find relevant effects of the network structure on the diffusion of information in the network. Central nodes managed to obtain on average higher payoffs, with a higher number of colors guessed correctly and a lower number of mistakes. In particular the network in which the asymmetry was stronger was associated with the lowest level of exchange of signals, but at the same time with the highest share of points going to the central nodes thanks to bonus points. The presence of competition among nodes with a higher centrality substantially reduced inequality in the final outcome and allowed the central nodes themselves to get access to more information, even though the strongest increase was observed for peripheral nodes. The main difference was that in the network in which nodes were competing it was harder for nodes to win alone, hiding information to the other nodes. For this reason bonus points were often divided among a larger audience.

1.1 Literature Review

Among the theoretical contributions that study cheap-talk communication in networks when players have conflicting interests, the papers by Hagenbach and Koessler (2010) and Galeotti et al. (2013) focus on how the heterogeneity in preferences over outcomes affects the shape of the network, intended as the collection of truthful information exchanges among the members of the group.

Classic studies of experiments regarding communication in networks are Bavelas (1950) and Leavitt (1951). More recently, the paper by Bonacich (1990) studies a context that is quite similar to ours, described by the author as a communication dilemma in which players face a tradeoff between sharing information with their links in order to accelerate the aggregation of signals at the group level and retaining pieces of information in order to increase the chances of winning a private reward. Hagenbach (2011) formalizes and generalizes the set-up described in the experiment in Bonacich (1990) and studies the ability of the group to solve communication dilemmas and how the speed at which aggregation takes place depends on the network structure. With respect to these papers we allow subjects to exchange non-verifiable information and this simplifies the set of possible strategies. At the same time we focus on different networks, as we are interested in understanding how competition among nodes changes players' behavior.

More recently, attention has been devoted to the study of how the network structure of communication allows players to coordinate on outcomes when multiple equilibria are possible (Choi and Lee (2014)) or to sustain collaborative norms (Gallo and Yan (2015)). Gallo and Yan (2015) in particular highlight how the introduction of asymmetric nodes in the network reduces the probability that players will avoid playing the Nash equilibrium and choose a collaborative norm, with higher average payoffs. This result is in line with what we find, with less communication when the structure of links is more centralized on one node.

2 Experimental Design and Data Description

The experiment was conducted in May 2017 with students from three high schools in Italy, in total were involved 645 students. Participation was voluntary and we relied on the help of teachers from each school to invite students to take part of the experiment. In order to register to play the game each student had to answer questions from an online survey and then download and install ad app for her phone. The app contained the game and was made available both for Android and iPhone[1], so that we could allow the vast majority of interested students to play. The app contained a mock round with the explanation of the rules of the game and a set of questions made to make sure the participants had no doubt about the functioning of the game. The game took place over the span of a week, with three rounds of two days each. During each round every student was matched with four other colleagues to form a group of five. For this reason, every round, a total of 129 groups was active. During each round players could win from a minimum of 0 euro to a maximum of 15 euro. We then extracted randomly one round to be the one valid for the payments. Rewards were given using Amazon Gift Cards.

The game. The goal of the game was to guess the colors of the clothes of a character. There were 5 pieces of clothing: hat, shirt, gloves, trousers and shoes. Different groups had to guess colors for different characters, where each character was identified by a name. For example Figure 1 refers to a group that had to guess the colors of Andrea's clothes. Clothes, as shown in Figure 1 (a), appeared grey at the start of the round. The player could then change colors at any moment in time, with no cost, by choosing one out of nine possible alternatives (Figure 1 (b)). The only combination that was relevant for the payment was the last combination, the one that was left at the end of the round. The player was allowed to leave clothes as grey and this would be counted as the player not choosing any alternative. The score was calculated according to the following rule: 10 points were assigned for each color that was correctly guessed, while 5 points were removed for each color that was guessed wrongly. Finally, 0 points were assigned for each piece of clothing left grey. On top of this, players could earn a bonus in case they were the ones that had the highest score among the members of the group of five. The bonus was 100 points, to be divided among the eligible players[2]. Each

[1]The app is called *VestiTito* and is still available for download on Play Store and App Store even though now the game is not active.

[2]For example, if only one player had managed to correctly guess 5 colors, the final score would have been 50 (because of 5 colors) plus 100 (for being the only one to get the highest score). Similarly, in case only two players got 40 points, with 40 being the highest score in the group, the bonus would have been 50 each, for a total of 90 points.

point was worth 10 cents, so that each player could win from 0 to 15 euro.

At the beginning of each round the player was given three pieces of information. First, the name of the character she had to guess. Second, the color of one of the clothes. Third, the names of other members of the group she was assigned to. Importantly, the hint regarding the color could be seen only once, hence the player had to memorize it[3]. Also, there was no overlap between the hints given to the players, so that information exchange was in principle possible and beneficial among any couple of players. Since all clothes were equivalent in term of points, the hint regarding the color was not introducing any asymmetry among the players. This was done only through the information regarding the other members of the group. Players could be arranged in three different networks as shown in Figure 2. In these networks each node represents a players. A link connects two nodes if they were informed that they belonged to the same group. For example, Player A in Network 1 was only informed about the identity of Player B, while Player B knew about E also. Therefore each turn players could be assigned to any of the three networks and, given the network, to any of the five positions. It is important to underline that the app itself was not providing any chat to exchange messages with the other members of the group. All the players had to do was to talk with their colleagues. In a context of a high school, with hundreds of students, many of them not even aware of the existence of the game, knowing who to talk to can be considered as a relevant piece of information to hold.

After receiving these pieces of information the players were given two days of time to choose a combination of colors to submit. At the end of the round the players were asked to answer some questions regarding the round the had just played. After that the process was repeated, with new groups being generated. It is important to underline that groups were done in order to avoid two players to play together more than once. This feature of the randomization was known by the players.

Data. During the registration process we asked students to answer a set of questions concerning personality. Moreover players could allow us to download their network of friendships on Facebook, that would be used as a proxy of friendship among students. Surprisingly, for one third of the students we could not collect this piece of information, either because the didn't allow us to have access to their account or because they had no account at the time of the experiment[4].

The app was designed to keep track of any change of color that was made by the players and the timing. This way we are able to reconstruct the history of changes made by the players. Moreover after the end of every round we

[3]In the app we also made sure it was not possible to take screenshots, that would have been an easy and fast way to memorize the hint and reproduce it when needed.

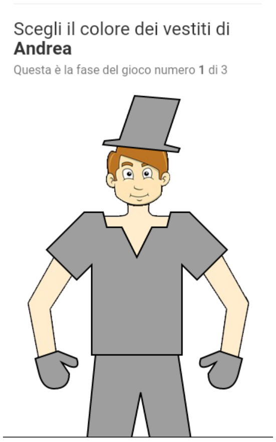
[4]We use Facebook Graph API. If the person accepts and decides to log into Facebook when playing the app, we receive the list of friends that have installed the app and logged into Facebook too.

Table 1: Number of active players per group.

	Five	Four	Three	Two	One	Zero
All	155	99	36	30	30	37
Network 1	48	36	10	9	12	12
Network 2	49	32	15	9	9	13
Network 3	58	31	11	12	9	12
Round 1	39	41	26	17	5	1
Round 2	67	21	4	7	15	15
Round 3	49	37	6	6	10	21

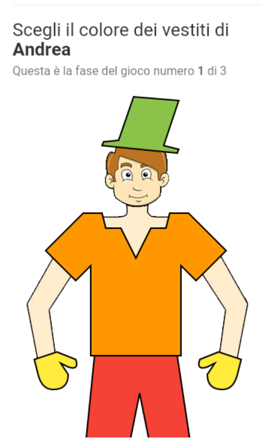
asked a set of questions to the players. First, we were providing them a list of names and they had to choose the one of a person that was assigned to the group. This was done twice. Whenever possible we were using both one person for which they had received the hint and one for which they had not. The first was intended to be test to check whether the player had correctly understood the hint, while the other was intended to check the ability of the player to learn the names of the other participants, either by searching in the school or by asking other members of the group. Second, one question was about the score, as we were asking whether they thought they had achieved the highest score. Finally, in a second page, we were asking about the other members of the group. Each player was given the name of every other member of the group. For each name the player was asked to tell us whether they had exchanged information useful to the game and who had taken the initiative to contact the other.

Sample. In total 645 students registered and downloaded the app, this allowed us to create 129 groups of 5 players per round, for a total of 387. When the game began though, part of the registered players did not participate to the game. Table 1 reports the distribution of the number of active players per group, where we define as "active" a player that logged in during the round and checked the hint she was given. Importantly, when we generated groups of 5 for the second round we started by matching players that had not been active in the first round. This allowed us to obtain a higher share of groups with 5 active players in rounds 2 and 3. In what follows we report results only for groups with 5 active players, as it is unclear how to interpret incentives when one or more players are missing from the group.



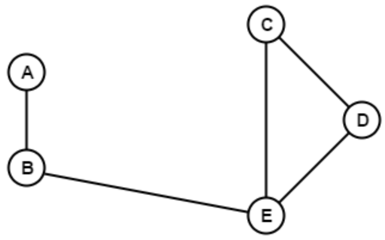
(a) Screenshot 1.

(b) Screenshot 2.

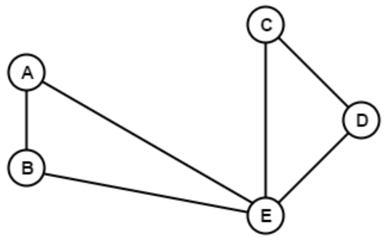


(c) Screenshot 3.

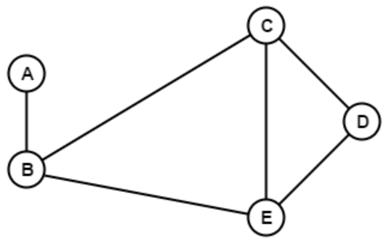
Figure 1: Screenshots from the app.



(a) Network 1



(b) Network 2



(c) Network 3

Figure 2: Networks of contacts.

3 Results

In this section we describe results at the group level that are suggestive of those that appear to be the mechanisms at work.

3.1 Information Exchange Across Classes and Within Classes

Players were arranged in groups so that links could be between students from the same class or from different classes. This seems a relevant dimension to consider if we want to study why players decided to share information. Table 2 highlights an interesting pattern in this dimension. The first column contains the probability that we observe info exchange in one link, meaning the probability that one node ended up guessing the right color for the clothes of the other node and vice-versa[5], the second column consider the probability of not having nay exchange, while the third column considers asymmetric exchanges, that are when one player ends up knowing the other's hint, but not vice-versa. Asymmetric exchanges are particularly interesting because they would appear more frequently along links in which one player manages to take advantage of the other one. First of all we need to highlight that the probability of information exchange is high, especially if we consider as benchmark case what would happen in a standard model of information transmission when information is non-verifiable and players compete to get a higher score. This likelihood is particularly high for links within class and lower across classes. This can be rationalized in several ways, two examples being altruistic preferences or reputational concerns. Second, while Info Exchange and No Exchange show relevant differences across and within classes, the likelihood of Asymmetric Exchange is similar. If we think of the first two columns as being the result of an equilibrium behavior we see that a relevant fraction of players did not manage to optimally respond to their peers.

3.2 Winners

Since the bonus was an important part of the payoff we start by looking at the distribution of the number of winners and the number of correct colors guessed by the winners. Table 3 contains the count for each combination. The first column refers to the cases in which there was only one winner, the second column refers to two winners and so on. We see that the most common outcomes were three winners guessing three colors and five winners guessing

[5]For example, consider the link between node A and node B. Let us assume that A received a hint for the shoes and B a hint for the hat. Then we say that there has been information exchange if at the end of the round B chooses the right color for the shoes and A chooses the right color for the hat. This is a simplification since there are other reasons why both players could end up choosing the right hints. First of all they could be lucky and guess the right colors out of the nine alternatives. Second, other nodes could have told them which is the right color, therefore without having direct exchange of information.

Table 2: Info Exchange Within and Across classes

	Info Exchange	No Exchange	Asymmetric Ex.
Within	0.769	0.047	0.184
Across	0.358	0.431	0.211

Table 3: Hints needed to win.

	One win.	Two win.	Three win.	Four win.	Five win.
One color	0	0	0	1	1
Two colors	0	6	1	2	0
Three colors	8	11	23	1	0
Four colors	7	7	3	8	3
Five colors	11	14	13	15	20

five colors. We see therefore that it was often the cases that all the players, or at least a group of them, managed to coordinate and truthfully share their hints. Interestingly we see that in many other cases we observe the winners collecting more hints, with the extreme case of one individual gathering five hints (this happened 11 times). Table 4 instead reports for each node the probability of being in the winning group. It is possible to notice how node E, that is always the most central, manages to win with a higher probability than the other nodes, with this difference being stronger in network 2, when the informational advantage is higher.

Table 4: Prob. winning by position in the network.

	A	B	C	D	E
All	0.46	0.49	0.63	0.65	0.73
Network 1	0.34	0.43	0.67	0.66	0.64
Network 2	0.5	0.37	0.69	0.54	0.83
Network 3	0.53	0.64	0.56	0.72	0.72

Table 5: Number of colors guessed correctly.

	A	B	C	D	E	Avg.
All	3.08	3.22	3.46	3.41	3.62	3.36
Network 1	2.83	3.13	3.38	3.47	3.51	3.26
Network 2	3.15	2.84	3.48	3.10	3.68	3.25
Network 3	3.22	3.62	3.52	3.60	3.65	3.52

3.3 Diffusion

Another dimension that one needs to consider when comparing different networks is the number of colors that are guessed correctly on average. This is indeed a measure of how efficient the network is in sustaining the diffusion of information. Table 5 shows the average number of colors correctly guessed by network and by position in the network. We see that the average number of correct hints is again higher for node E, especially in Network 2. The difference across nodes is much lower in Network 3, that is also characterized by a higher average among the three networks. It seems therefore that extreme centralization as imposed in Network 2 only benefits one node. By only looking at Table 5 one could think that node E is on average indifferent between Network 2 and Network 3, as the average number of right guesses is practically the same. If we compare Table 5 with Table 6 we see that the previous hypothesis is not true. Table 6 contains indeed the full score for each node, which includes the penalty coming from wrong guesses and the bonus for the winner. We see that the total score for E is significantly higher in Network 2, meaning that a centralized configuration allows E to share the bonus with a lower number of players. Finally, Table 7 contains, for each node, the number of how many other nodes manage to correctly guess its hint at the end of the round[6]. We find that, similarly as in the previous table, Network 3 is characterized by a higher level of diffusion, with the highest values obtained by the most central nodes (C and E).

3.4 Information Sharing Across Links

Another interesting element to consider is to see how the likelihood to share information across links changes in the three networks. Table 8 reports the probability of having information exchange between the nodes that share a link. Table 9 reports instead how similar the overall guesses are if we look at

[6] For example, we see that on average, the hint received by node A is correcly guessed by 1.97 other nodes. Therefore on average the information that is originated from A is the one that diffuses the least among all the other positions.

Table 6: Total points (bonus included)

	A	B	C	D	E
All	35.6	38.2	48	48.10	56.74
Network 1	27	34.9	51.3	53.4	53
Network 2	39.1	27.8	50.2	38.8	62.9
Network 3	39.7	49.8	43.6	51.5	54.7

Table 7: Diffusion by node.

	A	B	C	D	E
All	1.97	2.2	2.6	2.34	2.65
Network 1	1.96	2.21	2.46	2.21	2.49
Network 2	1.75	1.92	2.46	2.35	2.55
Network 3	2.17	2.45	2.87	2.43	2.9

two adjacent nodes. It is here interesting to notice how the results differ across network, especially for the link AB. With respect to Network 1, in Network 2 the positions of A and B are similar, with A having access to node E directly. In Network 3 instead the asymmetry between the two nodes is higher with respect to Network 2. Our finding is that Network 2 is characterized by lower cooperation between the two nodes, that end up exchanging their hints less often and choose final guesses that are less similar than in the case in which node A is peripheral and B has a better access to the rest of the network.

Table 8: Prob. Info Exchange.

	AB	BE	CD	CE	DE
All	0.63	0.45	0.61	0.72	0.67
Network 1	0.65	0.41	0.63	0.77	0.63
Network 2	0.51	0.38	0.65	0.73	0.67
Network 3	0.71	0.52	0.57	0.67	0.72

Table 9: Number of shared hints.

	AB	BE	CD	CE	DE
All	2.7	2.4	2.83	3	2.9
Network 1	2.44	2.17	2.75	3	2.72
Network 2	2.37	2.12	2.73	3.14	2.7
Network 3	3.17	2.81	2.97	2.97	3.2

4 Conclusions

Although preliminary, the results discussed above point towards relevant effects of the network structure on the overall pattern of aggregation of information. Players often manage to coordinate and sustain symmetric exchange of information, but the node that enjoys the most central position can take advantage of it by keeping the level of information sharing lower. Competition among nodes seems to impact the behavior too. Peripheral nodes seem to react to an increase in competition by sharing less. On the other hand, when competition increases among central nodes the effect is positive and the overall amount of information shared increases significantly.

References

Bavelas, Alex. 1950. "Communication Patterns in Task-Oriented Groups" The Journal of the Acoustical Society of America 22,725.

Bonacich, Phillip. 1990. "Communication Dilemmas in Social Networks: An Experimental " American Sociological Review 55(3):448-459.

Choi, Syngjoo and Jihong Lee. 2014. "Communication, coordination, and networks." Journal of the European Economic Association, 12(1):223-247.

Galeotti, Andrea, Christian Ghiglino and Francesco Squintani. 2013. "Strategic Information transmission networks." Journal of Economic Theory 148(5):1751-1769.

Gallo, Edoardo and Chang Yan. 2015. "Efficiency and equilibrium in network games: An experiment." Cambridge-INET Working Paper Series, 1503.

Hagenbach, Jeanne. 2011. "Centralizing information in networks." Games and Economic Behavior 72:149-162.

Hagenbach, Jeanne and Frédéric Koessler. 2010. "Strategic Communication Networks" The Review of Economic Studies 77:1072-1099.

Leavitt, Harold J.. 1951. "Some Effects of Certain Communication Patterns on Group Performance" Journal of Abnormal and Social Psychology 46:38-50.

Mobius, Markus, Tuan Phan and Adam Szeidl. 2015. "Treasure Hunt: Social Learning in the Field." Working Paper.