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Influences on and from the segmentation of networks: hypotheses and tests

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This article discusses (a) the influence of network structure on the diffusion of (new) cultural behavior within the network and (b) the influence of external events, especially of social programs, on the diffusion of (new) cultural behavior, and on the network structure. Hypotheses are formulated and tested on data from a study on the diffusion of petty crime in pupils' networks in high schools. To test these hypotheses we propose and use a new measure of network structure: the segmentation index.

1. Introduction

In a study on the influence of schools on petty crime activities of pupils (Baerveldt, 1990, 1992), at 14 schools network data about pupils' social networks were gathered. An important finding of this study was that integration of pupils in school prevents petty crime but that schools have no influence on this integration. It was expected that friendship with delinquent pupils predicts delinquent behavior, which implies a differentiation in criminal behavior over the network. It was also expected that pupils distinguish themselves from pupils outside their personal network by displaying behavior that stressed the differences with those pupils. This agrees with findings of classical studies on youth culture (for instance Hall and Jefferson, 1976) and main theories on culture (for instance Elias, 1939) which stress the importance of cultural distinctions. In the study a new concept, segmentation, was introduced to test hypotheses about these roles of network structure.

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The concept of segmentation expresses, intuitively, the partition of the social network into subgroups with high within-group and low between-group densities of (positive) relations. Freeman's (1992) definition of groups as disjoint components in a social network obeying a weak version of transitivity could be a suitable framework for a definition of segmented networks. This definition is applicable if the relation is not dichotomous (on/off) but graded (allowing the distinction between weak and strong ties). Other subgroup definitions, e.g. LS sets (see Seidman, 1983 and Borgatti *et al.*, 1990), could also be used for a definition of segmented networks.

However, we are not quite satisfied with a definition of segmentation based on disjoint subgroups. The reasons are that (1) subgroups in social networks are not always disjoint or clearly delineated, and (2) we prefer to view segmentation as a matter of degree rather than as a state of affairs that can be absent (no disjoint subgroups) or present (disjoint subgroups). Therefore we take a different approach. We define segmentation as the degree to which there is, for the actors in the network, a contrast between their personal network and the rest, one might say, between in-group and out-group. The measure for segmentation proposed in Section 4 expresses the average social distance between actors who are not directly related.

Related to segmentation are the concepts of segregation and differentiation: all three concepts refer, in various ways, to the extent to which the social networks break up into subgroups. Segmentation refers only to the relational structure, whereas segregation and differentiation also refer to characteristics of the individual actors. Segregation means that subgroups are formed in correspondence to pre-existing individual classifications. This is discussed and a measure is proposed by Freeman (1978). Differentiation means that subgroups are formed in correspondence to evolving differences between individual actors, often differences in role or function. In the present study, the extent to which the social network 'falls apart' is the independent, explanatory variable, of which the effect is studied on the behavior of actors. In order to retain the distinction between independent variable (network structure) and dependent variable (actor's behavior), the relevant concept here is segmentation, as it is a function of network structure only.

In Section 2, four general hypotheses about the role of the structure of social networks will be stated with a short theoretical argumentation (an article about the theoretical basis is in preparation). Three of them use the concept of segmentation. In Section 3 we will define a measure for segmentation and give some examples. In Section 4 we will show how the hypotheses can be tested. We will use the data of the study on petty crime that is mentioned above. Section 5 comprises conclusions and a brief discussion of the results.

2. The hypotheses

First we state a hypothesis on the influence of the personal network on cultural behavior.

Hypothesis 1. People conform more to the cultural behavior of other people when they have (more) ties with those other people.

Hypothesis 1 can be argued as follows. Cultural conformism is useful for people when they expect more rewards from conforming to the cultural behavior and expectations of other people than from not doing so. These expected rewards can be, for example, social status, good reputation (implying a promise for future rewards), better jobs, or security against external dangers. Since we are primarily interested in the network structure, we neglect in this article the content of the expectations. Also we do not question the relation between expectations of people and their social reality. However, it is interesting to differentiate with respect to 'the others'. It is not possible to conform to everyone, so people have to choose to which others they want to conform. Assuming that it is more rewarding to conform to people they have ties with (significant others), we formulate a simple answer to this question: people tend to conform more to people with whom they have (more) social ties.

The second general hypothesis needs the concept of segmentation.

Hypothesis 2. When networks are more segmented, the average influence of ties on cultural behavior, as stated in hypothesis 1, is stronger.

This hypothesis articulates the intuition that people in complete social networks where cultural distinctions play an important role have (a) to conform more to others in their personal network and (b)

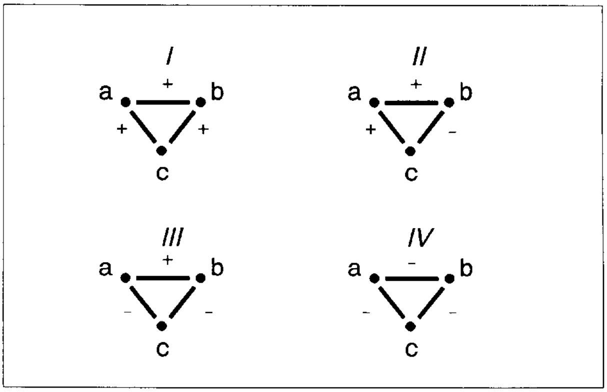

Fig. 1. Possible structures of triads.

to differ more from the others outside the personal network. The concept of segmentation makes it possible to translate this intuition into a hypothesis on the network level.

At this point it is instructive to contrast our second hypothesis on segmentation with the perspective of the theory of balance and clusterability (Heider, 1958; Davis, 1967; Davis and Leinhardt, 1972). Balance theory starts from a micro social level: the triad, defined as the system of ties between three persons (indicated here by *a*, *b* and *c*). In balance theory the ties between people can be either positive or negative (indicated by + or −). As shown above in Fig. 1, this gives four possible structures for triads (we follow Roberts, 1976).

In triad I *a*, *b* and *c* like each other and in triad III *a* and *b* like each other but there is a dislike relation with *c*. These are called balanced triads because, according to Heider, these triads can work well together. In triad II *a* likes both *b* and *c* but *b* and *c* dislike each other and in triad IV everyone dislikes everyone. These are called unbalanced triads because there is a tension in the triad. A network of dyads with + or − signs, i.e. a network of ties which are positive or negative, is called a signed graph. A signed graph is called balanced if all triads in the graph are balanced. According to a theorem by Harary (Harary, 1954; Cartwright and Harary, 1956) this is equivalent with a structure with (maximally) two groups with positive ties within each group and negative ties between members of different groups. It is possible to generalize balance theory in diverse directions. First, it is possible to define balance for digraphs, that is for graphs where ties have a direction (ties can be presented here as arrows). Second, it is possible to define relative balance, that is the amount to which a graph is balanced. Third, it is possible to generalize from symmetric likes and dislikes between persons to other types of relationships between all sorts of actors. A culture theory can be derived from balance theory by introducing transitivity. A relation R (which may be directed or undirected) over a graph V is transitive if for all actors a, b, and c, the two relations $R(a, b)$ and $R(b, c)$ imply $R(a, c)$. If we define by R_+ the positive relationship in signed graphs, R_+ is transitive in all balanced graphs V. According to balance theory, we can expect that actors in V are divided in one or more groups of people that like one another. Since 'like one another' often implies 'like to be like one another' we may conclude that cultural behavior is spread within the disjoint groups of a balanced graph.

At first sight, balance theory provides us an instrument for explaining the diffusion of cultural behavior. But it neglects an important part that we mentioned in our introduction: the role of cultural distinctions. The process of isolation of communists in the Cold War in western countries, the political/religious segregation in Holland, and the segregational processes in youth culture strongly suggest that there will be an even stronger tendency than balance theory predicts: within the groups there will be a tendency to conformism to a common culture, but between the groups there is no conformism and often even a stronger cultural segregation. There seems to exist something like cultural opposition between groups. This is also stated by figuration sociology (see for instance Elias, 1939; Elias and Scotson, 1965). We call the development of distinct and often antithetic cultural profiles, the 'process of profiling'. The process of profiling is an essential element of network dynamics and should be included in theories about cultural change. We cannot theoretically describe this process by balance theory and transitivity for several reasons. First, balance theory and transitivity describe cultural change as a process that takes place entirely at the level of dyads or triads. Within balance theory it is possible to formulate hypotheses about influences of triads on actors, but not about influences on actors from other groups of which the actors are not a member. It is, for instance, not possible to predict what influence the image of an other group has on the individual. Also, it is not possible to formulate hypotheses about mutual antagonistic influences between different groups on the group level. Second, consider a network with several groups where (some) ties between the groups do exist, so that the entire network is connected. Balance theory suggests that if the network remains connected, there will ultimately occur a convergence of behavior in the entire network. We think that this conclusion conflicts too much with empirical evidence and keep to our second hypothesis.

Next we investigate the relation between influences from outside and the internal network structure. We ask two questions. First: 'What is the influence of network structure on the effects of external events?'. Second: 'What is the influence of those events on network structure?'. Our perspective is from the network. We call an event an external event when this event cannot be described in terms of the individuals and relations within the network. Examples of such events are the opening of new shops, economic or political changes, programs for social change, traffic accidents, conferences, and talk shows on television. Some of these events will influence cultural behavior, some not. We are only interested in the events that have at least some cultural impact.

What are the consequences of such an event? When in networks the process of profiling, and as a consequence also the segmentation, is stronger, there is more chance that people see the associated possibility for cultural change as a mode to stress the cultural difference between their in-group and their out-group. As a consequence, some groups convert so that some other groups will not: the cultural dispersion will increase more as the segmentation is stronger. But the average behavior will be less affected, because of the presence of non-conforming groups. So we formulate as a hypothesis:

Hypothesis 3. When networks are more segmented, external events with a cultural impact will (a) have less influence on the cultural average and (b) increase more strongly the cultural dispersion within the network.

Events, by changing the contact patterns within the network, can also influence the segmentation of networks. Especially the induction of new inter-group contact patterns will diminish segmentation.

Hypothesis 4. As events induce more new contact patterns independent of the existing network structure, it is more probable that these events diminish the segmentation of the network.

Hypotheses 3 and 4 can be explicated for a special class of external events: interventions. Interventions are special events because cultural change is their aim. Therefore, the chance that they do influence cultural behavior is bigger. There are a great variety of interventions for cultural change because there are a great variety of types of cultural behavior. There are, for mistance, intervention programs for the prevention of petty crime, the changing of teaching methods, AIDS prevention by safer sex, and programs for selling jeans or cars of a special design. Also there is a great variety in strategies and means of influence. Mostly, interventions are evaluated per type of cultural behavior and often also per type of strategy. In general we predict, according to hypothesis 3, that interventions will have less average influence but will increase dispersion when the networks are more segmented. Also, according to hypothesis 4, the interventions reduce segmentation when new contact patterns are induced.

3. Measuring segmentation

How can we measure segmentation? In Section 2 we discussed some problems that arise in the definition of segmentation. We gave the following definition of segmentation: 'A network is more segmented if the social distances between persons who do not have a direct tie with each other, are larger'. The (social) distance between two people in a network is defined as the length of the shortest path between them. E.g. if there is a tie between two persons, then their distance is 1; if there is no tie between them but there is another person with whom both have ties, then their distance is 2. If there is no path between two persons, their distance is infinite. We shall only consider undirected relations, implying that the distance from i to j is not distinguished from the distance from j to i. In a network of N persons, there are $N(N-1)/2$ distances, some of which may be infinite. Our definition of segmentation reflects a particular kind of dispersion of these $N(N-1)/2$ distances, namely, the contrast between the distances equal to 1 on the one hand, and the 'long' distances on the other hand. When is a social distance to be considered long? In our opinion, for many sorts of relations, such as friendship or acquaintance, 2 defines a close distance (having a common friend), 3 is intermediate, 4 is a long distance and 5 is very long.

If the relation is friendship, two persons at distance 4 have no friends who are friends of each other. Persons at distance 5 have not even friends who have a mutual friend. Thus, they are not likely to be brought in relation with each other through channels of friendship. As a consequence, a network is strongly segmented when most distances between persons are either 1 (direct ties) or at least 4 or 5 (long distances), while distances 2 or 3 do not occur much.

A segmentation measure for networks represented by undirected graphs can now be defined as follows. Let D_r be the number of pairs of people (i, j) in the network at a mutual distance of r; since the total number of pairs is $N(N-1)/2$, the fraction of pairs at distance r is $F_r = 2D_r/\{N(N-1)\}$. For example, F_1 is the fraction of pairs with a direct tie between them, i.e. the density of the network; F_∞ is the fraction of pairs without a path between them. Note that finite distances in a network of N persons cannot exceed $N-1$. The figure that depicts F_r as a function of r for $r = 1, 2, \ldots, N-1, \infty$ gives an interesting graphical impression of the degree of segmentation of the network: large segmentation requires that F_2, F_3, and possibly F_4 are small relative to the other F_r's. In order to define a numerical measure, first define P_r as the fraction of pairs at distance r or greater:

$$P_r = F_r + F_{r+1} + \ldots + F_{N-1} + F_\infty = 1 - (F_1 + F_2 + \ldots F_{r-1}).$$

The proposed measures for segmentation are S_3, defined as $S_3 = P_3/P_2$, and $S_4 = P_4/P_2$. These measures satisfy $S_r \leq 1$, and indicate the fraction of persons who are distant from each other among those who are not directly related. Note that S_3 and S_4 are defined only if $P_2 > 0$, i.e. the density is less than 1. To give examples we will calculate the segmentation indexes S_3 and S_2 of figures 2, 3 and 4 below.

In Fig. 2, we see a network without groups that is almost completely transitive. Here, $N = 6$ and $D_1 = 11$, so $F_1 = 2D_1/\{N(N-1)\} = 22/30$. D_2, being the numbers of pairs with distance 2, equals 4, so $F_2 = 8/30$. The largest distance between two points (actors) in the graph equals 2, so $F_3 = F_4 = F_5 = F_6 = 0$. This implies $P_2 = 1 - F_1 = 8/30$, $P_3 = 1 - F_1 - F_2 = 0$ and $P_4 = 0$. The segmentation index $S_3 = P_3/P_2 = 0$ and also $S_4 = P_4/P_2 = 0$.

Figure 3 represents a network with two groups of different size and one bridge between them. The transitivity of this network is rather

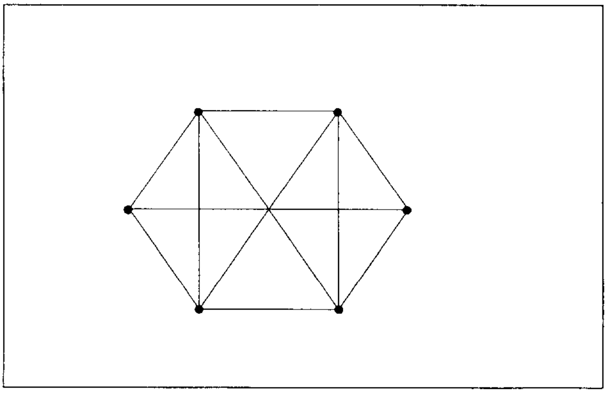

Fig. 2. Network without groups.

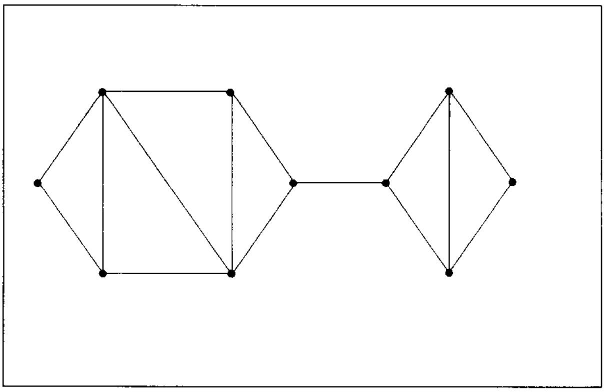

Fig. 3. Network with two groups of different size and one bridge between them.

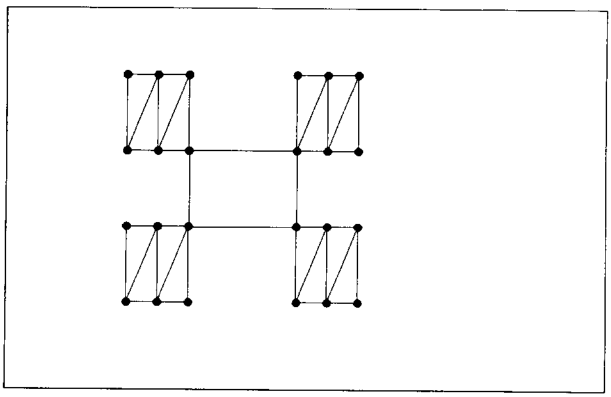

Fig. 4. Network with four groups.

large but at first hand the network looks also quite segmented. Note that $N = 10$ and $D_1 = 15$, so $F_1 = 30/90$. $D_2 = 10$, so $F_2 = 20/90$, $F_3 = 16/90$, $F_4 = 14/90$, $F_5 = 8/90$, $F_6 = 2/90$ and $F_r = 0$ for $r > 6$. It follows that $P_2 = 1 - F_1 = 60/90$, $P_3 = 1 - F_1 - F_2 = 40/90$ and $P_4 = 1 - F_1 - F_2 - F_3 = 24/90$. So $S_3 = P_3/P_2 = 40/60 = 0.67$ and $S_4 = 24/60 = 0.40$.

In Fig. 4 we see a network with four groups. It is quite transitive and at first hand it looks even more segmented than the previous network. Note that $N = 24$, $D_1 = 40$ and $F_1 = 80/552$. Also, $D_2 = 44$ so $F_2 = 88/552$ and $D_3 = 60$, so $F_3 = 120/552$. We calculate $P_2 = 1 - F_1 = 472/552$, $P_3 = 1 - F_1 - F_2 = 384/552$ and $P_4 = 1 - F_1 - F_2 - F_3 = 264/552$. As a consequence, $S_3 = P_3/P_2 = 384/472 = 0.81$ and $S_4 = 264/472 = 0.56$.

The previous examples considered S_3 and S_4 and these indices will be appropriate for most types of networks and ties. But, more generally, one can also consider $S_r = P_r/P_2$. Of course, $S_3 \geq S_4 \geq \ldots \geq S_\infty$. $S_r = 0$ if the *diameter* of the network (the largest occurring distance) is less than r. If all persons in the group have a distance smaller than 3 (for S_3) or 4 (for S_4), we say that there is no segmentation in the network. S_r is 1 if all distances are either 1 or larger than $r - 1$. Since the existence in the network of a distance t satisfying $3 \geq t \geq N - 1$ implies the existence of a distance 2, in a network with $S_r = 1$ for $r \geq 3$ there can be no pairs at distance 2: if $S_r = 1$ the network breaks up into a number of disjoint cliques. The network is then considered to be completely segmented. In general, a high value for S_r (a large segmentation) means that the 'social bridges' between people without direct ties are non-existent or long: that is, there are relatively few relevant indirect ties. Which is the most suitable value of r to consider S_r as a measure for segmentation, depends on the type of relation and type of network; e.g. a suitable value of r for acquaintance would be smaller than one for friendship. The measure S_r has been defined now for undirected relations, but it is easy to define a directed version.

4. Testing the theory

In this section we want to show how the main hypotheses of Section 2 can be tested. We use the results of a study on prevention and diffusion of petty crime committed by high school pupils (Baerveldt 1990, 1992). The study was commissioned by the Select Committee on Petty Crime and carried out for the Research and Documentation Centre (WODC) of the Dutch Ministry of Justice. In this study a survey of 870 pupils in 14 schools gave information about the ties of friendship (network structure), delinquent behavior (petty crime, i.e. minor offenses like shoplifting, unarmed fights and graffiti), and integration in school (penalties in school, attitude towards school and teachers, truancy).

The main theory can be tested using these data if we make the next specifications:

(1) We specify cultural behavior as delinquent behavior (petty crime), measured as the number of delinquent acts committed in one year.
(2) We specify individuals as pupils, aged 15–17 years, of the third (and lowest) ability group in the third grade of intermediate level secondary schools in the Netherlands.
(3) We specify the external event as a special form of intervention: the educational climate of the school as induced by staff and teachers. We look especially at the behavior of teachers towards pupils at school. This includes interactions in the classroom and styles and methods of teaching. We also consider the organization of schools: rules, attention for pupils, special lessons, etc.
(4) We specify ties as ties of friendship. Pupils were asked to write down the codes of their 'best friends' (3 at most). For analysis we use undirected ties. So, A and B have a tie if A chooses B as best friend or B chooses A or they choose each other.
(5) We specify social networks as the pupils' networks within the third grade (therefore excluding the extra-school peer group). This is possible because most of the 'best friends' of these pupils are in the pupils' network (control question in the survey).

It is important to note that the pupils' networks are mainly 'social'. There is very little influence of institutions on the content of relationships. In the Netherlands there are (almost) no formalized positions in the pupils' network. So, the network dynamics is largely free from institutionalized relationships.

The examined pupils' networks are comprised of all pupils of the third form of the lower stream (MAVO-3) of 14 three-stream (MAVO/HAVO/VWO) schools in larger towns in the Netherlands. In 13 schools the MAVO-3 pupils' formed a connected network, one school included two disjoint networks. The networks differed strongly in the number of pupils: the smallest network comprised 17 pupils, the biggest network comprised 127 pupils.

The examined networks seem to be very important for the pupils: 63% of the pupils answered that their very best friend was a pupil of the same school, and for 46% their best friend studied in the same year in the same stream (MAVO-3). The 873 pupils were asked to write down the codes of at most 3 'best friends' in MAVO-3 (the same year and the same stream). Of them 864 (99%) indeed answered the question. Most of these pupils (76%) wrote down the maximum of 3 friends, so it is probable that the number of ties in the analyzed network is restricted. However, this causes no problems because it is not likely that the comparative analyses we used are strongly influenced by this restriction.

4.1. Measuring effects of friendship on petty crime

To measure the effects of friendship on petty crime we use the spatial correlation coefficient known as Geary's c (see, e.g. Cliff and Ord, 1973 and Sprenger and Stokman, 1989). Freeman (1978) used this coefficient for a dichotomous dependent variable as a measure for segregation, quite in correspondence to our use of the coefficient. It can be defined as follows. We consider a network represented by the adjacency matrix w_{ij} ($w_{ij} = 1$ or 0 according to the presence or absence a tie from i to j) and a variable z with value z_i for person i. Geary's c can be defined as

$$c = \frac{\text{average squared difference on } z \text{ between adjacent persons}}{\text{average squared difference on } z \text{ between all persons}}$$

or more formally as follows (where the relation is represented as a directed relation)

$$c = \frac{(1/D)\Sigma_{ij} w_{ij}(z_i - z_j)^2}{[1/\{N(N-1)\}]\Sigma_{ij}(z_i - z_j)^2},$$

where N denotes the number of persons and D the number of directed ties, i.e. $D = \Sigma_{ij} w_{ij}$, in the network. If $c = 1$ there is no network autocorrelation, if $c < 1$ then adjacent persons are more similar than average so the network autocorrelation is positive, if $c > 1$ then the network autocorrelation is negative. To have a better comparability across networks we use the standardized coefficient c_{adj} (Sprenger and Stokman, 1989: 439–443). c_{adj} has minimum -1 and maximum $+1$ and can be directly interpreted as the network autocorrelation coefficient. A positive value indicates that pupils tend to commit minor offenses more often when their friends do so. When $c = 1$ (no autocorrelation) $c_{\text{adj}} = 0$. In this paper also z-scores are computed for c_{adj}. These scores are based on a randomization model (Sprenger and Stokman, 1989: 439–443).

4.2. Results

4.2.1. Friendship and petty crime

Our main version of hypothesis 1 stated that people conform more to the cultural behavior of other people when they have (more) ties with those other people. According to the specifications given above we have tested the next specific hypothesis.

Specific hypothesis 1. Pupils commit more offenses if their friends in the pupils' network commit more offenses.

We analyzed the 15 pupils' networks with the standardized Geary's c as ascribed above. In 14 of the 15 networks this standardized spatial correlation coefficient is positive, 11 correlations are greater than 0.25 (see Table 1). So the general results support the hypothesis.

4.2.2. Segmentation and the relation between friendship and petty crime

Our main version of hypothesis 2 stated that the conforming influence of ties on cultural behavior is stronger when networks are more segmented. According to the specifications given in Section 3 we have tested the next specific hypothesis.

Specific hypothesis 2. When the pupils' networks are more segmented, the influence of friends on petty crime, as stated in hypothesis 1, is stronger.

Table 1
Friendship and petty crime

Network number	Number of pupils	Standardized spatial correlation c_{adj}	z-value of c_{adj} (randomization model)
1	28	0.31	1.50
2	46	0.29	1.52
3	67	0.19	1.03
4	96	0.26	1.52
5	80	0.28	1.90
6	80	0.45	2.61
7	59	0.25	1.62
8	70	−0.09	−0.52
9	62	0.38	2.07
10	26	0.58	2.09
11	127	0.27	2.32
12	96	0.23	1.29
13A	17	0.44	1.76
13B	27	0.45	2.14
14	61	0.08	0.45

Note that this hypothesis refers to 3 levels of aggregation: (1) pupils (petty criminal behavior), (2) pupils' personal networks (influence of friends), (3) complete networks (degree of segmentation).

It would be preferable to test this hypothesis with an explicit mathematical multi-level model for the relation in time between behavior and network structure. So, this mathematical model would have to be longitudinal as well as multi-level. Since our data are cross-sectional and this explicit mathematical model is not yet available, we have chosen to test the hypothesis by correlating measures across networks. Segmentation of the network is measured by S_r (see Section 3). We have correlated these segmentation measures with the adjusted spatial correlation coefficient c_{adj}. The specific hypothesis predicts a correlation between these two measures. Table 2 below gives c_{adj}, S_r and some of the building components of S_r (the F_r) of the pupils' networks.

Since we cannot make any distributional assumptions about spatial correlations or S_p we measure correlations by Spearman's rank correlation R_{Sp}. The empirical data did not yield significant correlations. The Spearman rank correlation R_{Sp} of the (adjusted) spatial correlation c_{adj} with S_3 is not significant ($R_{Sp} = -0.19$, $p > 0.05$, $n = 15$). The same holds for the correlation of c_{adj} with S_4 ($R_{Sp} = -0.07$,

Table 2
Segmentation and spatial correlations of petty crime

Net work	Number of pupils	Fractions F_i: percentages of pairs with distances i						Segmentation indexes				Spatial correlation c_{adj}
		F_1	F_2	F_3	F_4	F_5	F_∞	S_3	S_4	S_5	S_∞	
1	28	0.11	0.09	0.16	0.13	0.08	0.31	0.90	0.71	0.57	0.35	0.30
2	46	0.06	0.08	0.07	0.08	0.08	0.34	0.92	0.84	0.75	0.37	0.37
3	67	0.05	0.07	0.10	0.12	0.11	0.27	0.93	0.82	0.70	0.29	0.19
4	96	0.04	0.06	0.10	0.12	0.13	0.10	0.93	0.83	0.70	0.10	0.27
5	80	0.04	0.07	0.11	0.15	0.17	0.12	0.93	0.81	0.66	0.13	0.28
6	80	0.06	0.06	0.08	0.09	0.08	0.39	0.94	0.86	0.77	0.41	0.36
7	59	0.06	0.13	0.20	0.26	0.20	0.00	0.87	0.65	0.36	0.00	0.25
8	70	0.05	0.05	0.05	0.05	0.04	0.60	0.95	0.90	0.85	0.63	−0.12
9	62	0.06	0.11	0.17	0.23	0.20	0.06	0.89	0.70	0.45	0.07	0.40
10	26	0.09	0.05	0.03	0.01	0.00	0.82	0.95	0.92	0.90	0.90	0.53
11	127	0.03	0.04	0.06	0.10	0.12	0.19	0.96	0.89	0.79	0.20	0.29
12	96	0.03	0.07	0.13	0.18	0.19	0.08	0.93	0.80	0.62	0.08	0.22
13A	17	0.19	0.19	0.22	0.15	0.10	0.12	0.76	0.49	0.31	0.15	0.51
13B	27	0.10	0.09	0.11	0.05	0.01	0.62	0.90	0.77	0.72	0.70	0.47
14	61	0.06	0.09	0.11	0.15	0.16	0.10	0.90	0.78	0.62	0.10	0.13

$p > 0.05$). Also S_5 and S_∞ do not yield significant correlations (for S_5: $R_{Sp} = 0.09$, $p > 0.05$, $n = 15$, for S_∞: $R_{Sp} = 0.43$, $p \approx 0.05$, $n = 15$). So, we did not find support for specific hypothesis 2.

There are several possible reasons why specific hypothesis 2 was not supported by our data. First, of course, it is possible that the theory is false. Second, the translation of the hypothesis into the predicted correlation between S_r and C_{adj} is not based on an explicit multi-level model, so that this translation is open to criticism. Third, it is possible that the variation in segmentation of the pupils' networks is too small and/or the influence too weak to reach significant results for this amount of data. In that case the theory should be tested for networks with more variation in segmentation, and/or for a larger number of pupils' networks. Indeed, we have tested a Spearman correlation on just 15 cases. For such a small number of cases, the true (population) correlations should be very high to have a test with good power.

4.2.3. The influence of interventions: teachers' approaches

We can test hypothesis 4 on our data if we see school culture, organization, and teachers' approach as interventions for cultural change. It is not possible to test the influence of other 'events' as in hypothesis 3, because we have no data about such events. Hypothesis 4 stated that as interventions induce more new contact patterns independent of the existing network structure, it is more probable that the segmentation of the network decreases. We have focused on the teachers' approach to pupils, especially on the way of organizing the teaching in the classroom. We state that when pupils have to work more in groups, they will have to make more contacts that are bridges between social subgroups. Based on this, and according to Section 3, we can formulate the next:

Specific hypothesis 4: As pupils have to work more in groups, there will be less segmentation in the pupils' network.

The extent of working in groups was scored by observation of lessons. During two weeks, all lessons (except sports) were observed. Each working hour (50 min) was divided in four equal observation periods. In each observation period, working in groups was scored when, by intervention of the teacher, pupils had to work together in groups of at least two persons for at least 4 min. Per working hour these periods of working in groups were counted, so a score was possible from 0 to 4. These scores were aggregated per school to an 'average group working score' (for more information see Baerveldt, 1990). The average group working scores were correlated (Spearman's ranking correlation R_{Sp}) with the segmentation indexes S_r.

Spearman's R_{Sp} of S_3 and the group working score is not significant so ($R_{\mathrm{Sp}} = 0.06$, $p > 0.05$, $n = 15$). Also, for the other S_r, R_{Sp} are not significant (S_4: $R = 0.01$, $p > 0.05$, S_5: $R_{\mathrm{Sp}} = 0.08$, $p = 0 > 0.05$, S_∞: $R_{\mathrm{Sp}} = 0.25$, $p > 0.05$). So, there is no support for hypothesis 4. However, it is not strange that there is no support for specific hypothesis 4. We already mentioned methodological problems at the introduction of this test. Also, on the studied schools, working in groups was rare. The empirical study showed that differences between schools (as to organization, teachers, teachers' approach of pupils) were too small to have much impact on pupils' behavior (see also Baerveldt, 1992).

5. Conclusions and discussion

In Section 2 we formulated four main hypotheses about the relation between social networks and the diffusion of cultural behavior. Three of these hypotheses involved the role of segmentation of networks. In Section 3 we proposed a measure for segmentation. In Section 4 we made a first attempt to test the hypotheses. We formulated and tested three specific hypotheses on data from a Dutch study on the influence of schools on the petty crime of pupils. As was hypothesized pupils commit more offenses when their friends in the pupils networks do that too. So it can be concluded that network relations explain, at least partially, delinquent behavior of pupils. This type of cultural behavior spreads via social ties. However, we could not find strong support for our other hypotheses. We did not find a significantly positive correlation between the segmentation index of networks and the spatial correlation between petty crime and friendship in the networks. Also, we did not find the expected effect of group teaching on segmentation. This can be explained by diverse methodological reasons, for instance a lack of variance of the independent variables (segmentation, working of pupils in groups), a low number of cases (15 networks) and the use of one-level methods of analysis for multi-level hypotheses. However, the introduced hypotheses and measure can be expected to be fruitful for the understanding of cultural diffusion within social networks.

The theoretical contribution of this paper is the formulation and testing of hypotheses on the diffusion of cultural behavior. However, we introduced our hypotheses with just a short theoretical motivation. A more elaborated publication on the theory behind these hypotheses is in preparation.

One theoretical question that has to be solved is how far the hypotheses can be generalized. In this paper we introduced ours as a theory about networks with informal or social relations between people, but the theory can be easily expanded to other kinds of relations like formal relations, market relations, and power relations, and also to other kinds of actors like organizations. However, there are some problems associated with this extension. Consider, for instance, the innovation of an agricultural production method by farmers in a real market situation. This innovation can be seen as a type of cultural behavior. A high degree of segmentation will in the short run be a barrier against new agricultural production methods (cultural change) because some farmers do use them, *so* others do not (distinguishing themselves). But when these new methods are better, the competitors will have to use the new methods eventually or simply disappear from the market. So here in the long run, segmentation will not lead to segregation. This means that we might refine our theory.

Another interesting question is how the changing of the content of relationships is influenced by network structures. For example, relations of social friendship can change into economic relations (cf. old boy networks in organizations). In this case it is interesting to examine whether more segmentation of economic networks also leads to more use of old boy networks. Another example is the change of the role of the social network of youngsters that goes with their life course. It would be interesting to examine how the changing contents of their relationships with adults also changes the segmentation of the peers' social networks.

We presented measures S_r for a new concept: segmentation, but these measures should be further investigated. The relation between segmentation and transitivity merits further attention. More intuition should be developed about when values found for S_r are to be considered high or low. Also, we should be able to evaluate the segmentation of large networks. In our data the networks were comparatively small (19–129 pupils), so it was possible to measure all relations of friendship between the pupils. But for large networks this will not be possible, and ways have to be found to estimate S_r from some kind of sampling procedure.

Testing our theory we encountered the problem that we had to test a theory that is multi-level by nature on one-level data. It would have been preferable to translate the theory into an explicit statistical model incorporating individuals, their personal networks, and entire networks as distinct levels. For lack of such a model, the theory was tested by correlating network-level measures. The development of a longitudinal multi-level network model for this theory, and of statistical methods to test it, remains an interesting task for the future.

Further, we had no compelling arguments to choose between Geary's correlation coefficient c or its adjusted version c_{adj}. The advantage of c_{adj} is that it is scaled to have extreme values of ± 1; the advantage of the 'raw' c is its direct interpretation as the ratio of average squared differences between related to average squared differences between any persons. Moreover, even for c_{adj} we lack the intuition to decide what constitute high or low values, and it is hard to make comparison across networks.

We wish to stress the importance of a reconstructed and tested network theory for social engineering. Unfortunately, there arc not many studies of the effects of interventions like crime prevention agricultural innovation programs, AIDS prevention campaigns, and courses on teaching or management that include an examination of the network characteristics of the 'treated' network. Here we will mention three arguments for a network approach. First, we hypothesized that the effects of many social programs can be greatly influenced by simple network characteristics like segmentation. It follows from hypothesis 3 that it is possible to predict the success of social programs better by examining the segmentation of the 'treated' network. We predicted a smaller average effect but also more dispersion in the effect when the network was more segmented. Second, hypothesis 4 suggested a way to weaken the effects of segmentation: making bridges between groups diminishes segmentation and therefore stimulates the diffusion of cultural behavior. This suggests that it can be useful for intervention programs to aim directly at the social or formal relations between people. Crime prevention programs in a segmented neighborhood can have better results when the program induces bridging contacts. Third, low profiles can help to avoid the effects of segmentation. Aids prevention campaigns can have better results when they present prevention methods as a question of low profile like tooth brushing and not as a method for special 'risk groups' that often form segments in society.

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