Perspective-taking and memory capacity predict social network size

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Abstract

Human social networks typically consist of a hierarchically organized series of grouping levels. There is, however, considerable variation between individuals in the sizes of any given network layer. We test between two possible factors (memory capacity and theory of mind) that might limit the size of two different levels within human social networks (support cliques and sympathy groups). We show that the size of an individual’s support clique (the number of individual’s in the innermost circle of friends) is better explained by individual differences in social cognition (mentalising skills). However, the size of the sympathy group (the most frequent social partners) is better explained by individual’s performance on memory tasks.

Keywords: Social network; Support clique; Sympathy group; Memory capacity; Theory of mind

1. Introduction

Research on social networks has often focused on two main issues: one has been to determine the typical and/or limiting size of social networks, while the other has been to elucidate some of the factors that give rise to individual differences in network size. There has been considerable investment of research effort in the first topic, much of which has raised fundamental questions both about the nature of social networks and how they should be defined, as well as about how networks should best be sampled (see, among many others, Bernard et al., 1990; Killworth et al., 1990, 2003).

Bernard et al. (1990), for example, have shown that different definitions yield networks whose sizes differ consistently across both individuals and populations. The sizes of support cliques
(those from whom emotional support would be sought) are invariably very small (typically 2–10 individuals), whereas the total number of individuals known is several orders of magnitude larger (typically ∼2000). Other intermediate grouping sizes have also been identified (Killworth et al., 1990; Hill and Dunbar, 2003). In a recent analysis, Zhou et al. (2003) were able to show that these various grouping levels form a hierarchically clustered sequence with a consistent scaling ratio of 3. In effect, an individual sits in the centre of a personal social network that has the form of a series of concentric circles of acquaintanceship containing, roughly, 5, 15, 50, 150, 500, 1500 individuals, with their circles reflecting successively declining emotional closeness and frequency of contact (Hill and Dunbar, 2003). (Note that each of these values is inclusive of the groupings within them.) This consistency raises the question of what limits network size at any given level.

Despite the consistency of this patterning in network sizes, there is considerable individual variation in network size at any given level. For example, at the larger scale in an individual’s social network (that corresponding to all the people who are known individually and with whom one has a personal relationship), the mean size consistently averages about 150, but individual values can range between 100 and 300 (Hill and Dunbar, 2003). Similarly, on the smaller scale of regular contacts (those individuals contacted at least once a month), the average is typically 12–15, but the range varies between 6 and 20 (Dunbar and Spoors, 1995).

While there are certainly ecological limits on the size of both human and primate social groupings (Carneiro, 1970, 1987; Dunbar, 1996; Johnson and Earle, 2000), our concern here is rather with individual differences in network size. The latter are more likely to be due to intrinsic factors. Among these, life events such as divorce, illness or old age (e.g. Milardo, 1988) and gender (see Bernard et al., 1990; Dunbar and Spoors, 1995) have been explored in some detail. Considerably less attention has been given to psychological factors such as personality traits or cognitive capacities. Individual differences in core cognitive abilities seem a likely candidate in this respect, given the evidence in support of the “social brain hypothesis” which identifies differences in neocortex size (and, hence, some aspect of cognitive capacity) as the principal explanation for species differences in social group size among the primates (Dunbar, 1993, 1998; Barton, 1996; Barton and Dunbar, 1997).

Given that the social brain hypothesis suggests that social group size is limited by the organism’s ability to manage its social relations at the cognitive level (Barrett et al., 2003), an obvious explanation for the variance in social network size among individuals lies in differences in social cognition. Theory-of-mind (ToM, also known as mentalising or mind-reading) is the ability to attribute states of mind to others (Premack and Woodruff, 1978; Wimmer and Perner, 1983) and it is widely thought to be crucial to the human capacity to manage our complex social world. Although its ontogeny has been extensively studied over the past two decades, relatively little is known about its subsequent development after early childhood. To date, only one study (Kinderman et al., 1998) has attempted to explore the limits of mentalising in normal adults. Moreover, while the social costs of the absence of mind-reading skills are well understood from clinical studies (Adolphs, 2003), we know almost nothing about how individual differences in the social cognitive abilities of normal adults affect their capacity to negotiate their way through the undoubted complexities of the adult social world.

An alternative explanation for these individual differences in social network size would be some aspect of memory capacity. While it is unlikely that sheer memory for faces (or the ability to match names with faces) is likely to be a constraint (the limits on this are significantly larger than the limits on social network size, probably in the region of 1500–2000 individuals), it could well be that the ability to integrate and maintain an updated mental database of the social relationships among the members of a network may impose limits on the number of individuals that can be
maintained as part of a coherent personal social network. This could reflect some very basic property of memory (indexed, for example, by something as simple as short-term memory) or it might involve more complex aspects of memory that involve maintaining and updating a mental database describing the dyadic and polyadic relationships between the members of the network.

In this paper, we aim to do two things: first, we explore the range of individual variation in social network size at the two smaller scales (circles of acquaintance corresponding to 5 and 15 individuals) and, second, we ask whether this variation in network size is related to individuals’ ability to manage their social world. For these purposes, we consider a relatively simple (and hence easily quantified) index of an individual’s social world, namely the size of the more intimate layers of their social network. We target these because there is evidence from comparative studies across primates (including humans) to suggest that the size of these innermost layers may impose limits on the size of social groups that can be maintained, and they may themselves be limited by relative neocortex size (Kudo and Dunbar, 2001). We then test between two alternative hypotheses that might explain individual differences in social network size, namely the capacity to remember facts about the world (including hence, presumably, facts about the social world) and the ability to take social perspective (to mentally rotate the intentions of other group members in a multi-dimensional mental hyperspace).

Mentalising capacity is commonly viewed in terms of “intentional” states (an individual’s understanding of states of mind, typically exemplified by the use of words like believe, intend, suppose, think, and so on). Intentionality so defined forms a naturally reflexive hierarchy that corresponds to increasingly embedded mindreading (I suppose that you intend that I believe that you want me to understand that...). Kinderman et al. (1998) showed that, not only is there a natural upper limit to the number of levels of intentionality that normal adults can handle, but also that there is considerable inter-individual variation in the highest achievable levels of intentionality and that individual differences in this respect correlate with an index of causal attribution (the ability to correctly attribute blame). It thus provides us with a natural metric for at least some relevant aspects of social cognition.

2. Methods

2.1. Participants

The study used an opportunity sample of subjects who were domiciled widely across the UK and came from a range of occupations and backgrounds. To avoid developmental effects and confounds due to declining social engagement in old age, participants were restricted to the age range 18–65 years. Participants were first asked to complete a questionnaire about their recent social relationships, and were then tested on a series of intentionality tasks. Participants were debriefed after the experimental session. In all, 69 participants were tested; four were subsequently removed as they had filled in one or both of the questionnaires incorrectly. The final data set consisted of 65 participants, 29 male and 36 female.

2.2. Materials and method

2.2.1. Cognitive competences

The design was similar to that used by Kinderman et al. (1998), except that subjects were tested on their own rather than in groups. A series of seven short stories (each approximately 200 words long) depicting a social situation (such as a man trying to find a way to ask a woman out on a
date) was read out to the subject. Five of the stories were the same as, or based on, those used in the Kinderman study. The remaining two stories contained extra levels of intentionality and were included to ensure that all participants reached the upper limit on their performance. After each story had been read out, the participants answered questions about the story.

For each story, a separate booklet was prepared containing a randomly assorted series of questions that differed in level of intentionality, interspersed with an equal number of factual recall questions (memory questions). Each question contained two statements, one true and the other false, and the participant was asked to choose the one that was correct. The questions contained varying amounts of embedding, either in terms of levels of intentionality or, in the case of memory questions, different numbers of elements. At one level, the memory questions control for the subject’s comprehension of complex sentences and understanding of the questioning procedure, but were not necessarily intended to mirror the levels of mind-reading embeddedness characterising the perspective-taking questions; rather, they are simply a measure of participants’ ability to remember the factual content of a story. However, in addition, they provide us with a more general index of memory capacity. For these purposes, we have opted for the simplest possible measure of memory capacity (short-term memory for facts) in order to differentiate as clearly as possible between mentalising ability and pure memory capacity, with textual source being held constant. In contrast, the theory-of-mind questions required complex mentalising over a character’s perspective on a social situation. An example of one of these stories, and its list of questions, is given in Appendix A.

Note that, in this study (unlike that of Kinderman et al., 1998), the participant’s belief state was included in the intentionality sequence. Thus, in this study, second order questions relate to what the participant thought a character knew within a story. (Kinderman et al. (1998) defined this as a first order intentional task, so one level of intentionality should be added to all their results in order to yield the correct level of intentionality.) The most complex mentalising questions contained nine orders of perspective-taking (including the participant’s own perspective, defined as level 1). Not all stories contained such high levels: rather, in order to provide a range of perspectives, stories varied between levels 4 and 9 in their mentalising depth (including the participant’s own belief state).

While the memory questions were indexed only as the number of correct responses to the complete set presented, the intentionality questions were broken down into separate levels of intentionality in order to identify the level at which a participant first failed. Because we are interested in individual participants’ performance on perspective-taking, it is necessary to adjust for the fact that participants have a 50% chance of answering a given intentionality level question correctly even when choosing answers at random; in addition, they might make a mistake on a lower level even though otherwise correctly handling perspective-taking at higher levels of intentionality. We therefore considered performance on perspective-taking questions in two ways. One was to identify the first level at which an incorrect response was recorded; the second used a negative-marking procedure to correct for errors caused by random answering. In the latter case, the overall number of correct answers was first calculated for each participant, and this was then converted into a level of intentionality using a weighted means method (see Appendix B).

2.2.2. Social network questionnaire

Since our concern is with individuals’ core social relationships (“friendships”), participants were asked to list all the people that they had initiated contact with in the past month. We used this time limit because previous studies (Dunbar and Spoors, 1997, Hill and Dunbar, 2003) showed that, at least within UK populations, it reliably distinguishes an individual’s core social grouping
(the sympathy group) from the wider set of social contacts. The requirement that the participant must have initiated the contact was intended to exclude casual contacts so as to focus the list on genuine friends and social partners. Participants were explicitly asked not to include work colleagues seen only in a work environment (unless they considered them to be genuine friends) or contacts with professionals (such as doctors, plumbers, etc.) or other casual acquaintances (e.g. brief encounters in the street or a bar). They were also asked to identify both those individuals in their lists who were kin and those whom they would turn to if they wanted to seek advice or comfort in connection with a major personal problem (e.g. terminal illness, death of a loved one, or a serious accident).

Following Dunbar and Spoors (1995) and Hill and Dunbar (2003), these data were used to identify two key social groups for each participant, namely the support clique (the number of individuals from whom one seeks support: typically 4–7 individuals) and the primary social network or sympathy group (the number of individuals that one contacts at least once a month: typically 12–15 individuals). These groupings are approximately equivalent to the number of individuals contacted at least once a week and once a month, respectively (Dunbar and Spoors, 1995; Hill and Dunbar, 2003).

2.3. Statistical analyses

The data were checked for normality using a Kolmogorov–Smirnov test. Neither the perspective-taking score ($p = 0.960$) nor social clique sizes ($p = 0.090$) differ significantly from a normal distribution ($N = 65$ in both cases). The data also show homoscedasticity of variance (Levene statistic: $L = 1.113$, d.f. = 8.56, $p = 0.369$). Similarly, memory and intentionality questions also exhibit homogeneity of variance (Levene statistic: $L = 2.215$, d.f. = 128, $p = 0.139$). Parametric tests are therefore used throughout.

3. Results

Mean sympathy group size averages $20.9 \pm 13.4$ for males and $20.2 \pm 11.5$ for females, while support cliques average $5.14 \pm 4.6$ for males and $6.55 \pm 4.6$ for females (Fig. 1). The difference in the latter case is not, however, significant ($F_{1,63} = 0.053, p = 0.819$). These values are a little higher than, but within the range of variation of, sympathy group sizes reported in the literature, but are close to the mean size for support cliques (see Dunbar and Spoors, 1995; Hill and Dunbar, 2003; Zhou et al., 2003).

Overall, the level at which participants first failed perspective-taking questions (indexed as the re-scaled weighted average score) was approximately normally distributed with a peak at level 5 (mean = 5.03: Fig. 2). [Note that this value is one level higher than that reported by Kinderman et al. (1998) because the latter study did not include the subject’s perspective when determining the limiting scores.] Although there is complete overlap in the ranges of male and female scores, women had significantly higher scores than men (means of 5.53 versus 4.41, respectively: $F_{1,63} = 7.01, p = 0.010$). There is a significant correlation across individuals between performance on memory questions and performance on mindreading tasks (Fig. 3: $F_{1,64} = 40.87, p < 0.001$), irrespective of whether we use raw number of correct scores, proportion of correct scores or the rescaled intentionality level. However, irrespective of how they are measured, memory performance only explains about 35% of the variance in performance on mindreading tasks.

We therefore entered each of the two indices of social network size as the dependent variable in a multiple regression with rescaled intentionality score and the proportion of correct memory
questions as independent variables. Table 1 shows that memory score is the only significant predictor of sympathy group size, but that intentionality score is the only significant predictor of support clique size. While we have used the rescaled intentionality scores here for consistency, in fact using the raw proportions of intentionality and memory questions answered correctly yields the same results.

Fig. 4 plots the relationship between clique size and rescaled intentionality score. Although there is a significant linear relationship (Table 1), the data could also reflect a polygonal distribution: such a pattern may be expected when an independent variable (in this case, achievable level of intentionality) merely sets an upper limit for a dependent variable (in this case, clique size) rather than determining its exact value (Blackburn et al., 1992). In such cases, an upper bound slope that describes the upper limit for the distribution may provide a better estimate of the true
Fig. 3. Proportion of mindreading (intentionality) questions answered correctly plotted against the proportion of memory questions answered correctly. Males, solid circles; females, open circles.

Table 1
Multiregression analysis of determinants of sympathy group size and clique size

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sympathy group</th>
<th>Support clique</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficient</td>
<td>$t_{62}$</td>
</tr>
<tr>
<td>Constant</td>
<td>−24.24</td>
<td>−1.70</td>
</tr>
<tr>
<td>Intentionality</td>
<td>1.36</td>
<td>1.43</td>
</tr>
<tr>
<td>Memory</td>
<td>44.68</td>
<td>2.29</td>
</tr>
</tbody>
</table>

Fig. 4. The relationship between clique size and performance on mindreading tasks (indexed as rescaled intentionality level). The equation for the best fit regression line (solid line) is $Y = 0.546 + 1.068X$. Following Blackburn et al. (1992), an upper bound slope (broken line) has also been estimated: $Y = 1.679 + 2.404X$. 
relationship. The range of group sizes observed below this level can be interpreted as being due to other contributing social, circumstantial and/or environmental factors. For Fig. 4, the upper bound slope (calculated using the method given by Blackburn et al. (1992)) provides a much improved fit ($r^2 = 0.840; F_{1,9} = 41.99, p < 0.001$), suggesting that the level of intentionality might only limit the maximum possible clique size rather than determine it.

4. Discussion

The results confirm the core finding of Kinderman et al. (1998) that there is an upper limit on performance on mindreading tasks at the equivalent of fifth order intentionality. In the study by Kinderman et al. (1998), the proportion of all participants correctly answering a question at a given level of intentionality declined precipitously when questions contained more than five levels of perspective-taking. In the present study, we demonstrate that this result holds for individuals as well as populations.

The major finding of this study, however, is that perspective-taking competence correlates with (and perhaps places a limit on) the number of core contacts that an individual can maintain as a coherent social entity (clique size). Clique size was here indexed as the support clique, defined by Dunbar and Spoors (1995) as the number of individuals on whose advice and/or help one would depend at times of great social or financial trouble (roughly equivalent to those individuals contacted at least once a week: see Hill and Dunbar, 2003). The significant correlation between clique size and performance on the mentalising task suggests that there is an association between perspective-taking ability and clique size that is independent of performance of memory tasks. The fact that there is a distinct upper bound to the observed relationship might be taken to suggest that one’s perspective-taking ability imposes a limit on the maximum possible clique size that one can maintain rather than actually dictating the typical (i.e. mean) clique size. Below this bound, a broad range of clique sizes would be expected, with observed clique sizes being subject to social, demographic, lifehistory and other circumstantial factors (Dunbar, 1996).

Clique size represents the number of people that an individual will turn to with a personal problem and therefore represents the core social group for that person. Cliques are embedded within a larger network of about 12–20 people (sometimes referred to as the sympathy group) who form the core of an individual’s social world at any given moment. These constitute the set of individuals who are contacted at least once a month, and with whom stable social relationships are maintained over a period of time. Our findings suggest that this grouping is much less dependent on perspective-taking capacities, but instead correlates with memory performance.

Our index of memory performance is a measure of short-term memory rather than long-term memory (which we might have anticipated to be more important for longer term relationships). Moreover, in order to differentiate it clearly from mentalising abilities, it focuses deliberately on memory for basic facts about the world rather than social facts. Since social facts are more likely to be remembered than non-social facts (Mesoudi et al., in press), this could have important implications. Nonetheless, we imagine that these two forms of memory are likely to be correlated, if only because social phenomena themselves necessarily also involve facts about events. There are, of course, well known cognitive limits to the number of pieces of information that can be processed at any one particular time (Cowan, 2000; Miller, 1956). Participant performance in memory tasks such as those used by Kinderman et al. (1998) and in the present study could therefore be affected by cognitive limits on the amount of information that
can be held in mind. Miller (1956) suggested that there was a limit of seven plus or minus two items that can be stored in the short-term memory. However, in a subsequent meta-analysis, Henderson (1972) suggested that, realistically, the cognitive limit probably lay at four items, a view echoed by Cowan (2000) who suggested that, in short-term memory recall, there is a limit of four chunks of information, plus or minus one. Baddeley (2000) has argued that the cognitive constraint might not be in short-term memory as such, but rather in the episodic buffer and the central executive. The episodic buffer allows for the integration of information from the short-term memory and the central executive. It is in principle possible that, in a perspective-taking task, the episodic buffer might limit the number of perspectives that can be taken and mentally rotated at any one moment. However, the lack of any significant relationship between memory capacity and clique size when performance on intentionality tasks is partialled out tends to argue against this possibility. In contrast, the fact that the size of the primary social network (sympathy group size) is better predicted by memory capacity suggests that the ability to retain information about relationships when these are not physically present (Barrett et al., 2003) may be important in managing the wider network of relationships within which individuals are embedded. The relationship between the processing capacities of the mind and perspective-taking competencies and their consequences clearly merit further investigation.

What remains unclear at this stage is how perspective-taking acts to constrain the size of one’s social clique. In part, the problem itself arises because, despite more than a decade of intensive work on the topic, we do not really understand what is involved in theory of mind (second order intentionality) (Roth and Leslie, 1998; Barrett et al., 2003). We have a good understanding of its natural history, but not its nature. The fact that achievable level of intentionality correlates with (and appears to set a limit on) the size of the social clique is sufficient to suggest that we urgently need studies that can unpack the cognitive processes involved in intentionality. However, one possibility is that the limit is set on the innermost circle (average five individuals) by the fact that, as we have shown here, humans can cope only with five orders of intentionality (i.e. the mental states of five individuals). In other words, the limit is set by the fact that Ego has to hold simultaneously in his/her mind the mental perspectives of five individuals for that cluster to be coherent and remain so through time. It is then possible that the higher layers are emergent “small world” properties of this inner core of relationships.

Acknowledgment

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Appendix A. Mentalising task

We provide details here of one of the stories (Emma’s dilemma) as read out to participants, and the list of mentalising and memory questions participants were then asked to complete.

A.1. Emma’s dilemma

Emma worked in a greengrocer’s. She wanted to persuade her boss to give her an increase in wages. So she asked her friend Jenny, who was still at school, what she should say to the boss. “Tell him that the chemist near where you live wants you to work in his shop.”
Jenny suggested. “The boss won’t want to lose you, so he will give you more money” she said. So when Emma went to see her boss that is what she told him. Her boss thought that Emma might be telling a lie, so he said he would think about it. Later, he went to the chemist’s shop near Emma’s house and asked the chemist whether he had offered a job to Emma. The chemist said he hadn’t offered Emma a job. The next day the boss told Emma that he wouldn’t give her an increase in wages, and she could take the job at the chemist’s instead.

A.1.1. Questions

Participants were asked to indicate which answer they thought was the correct one for each question. Memory (as opposed to perspective-taking) questions are indicated by an asterisk.

1. (a) Emma worked for a greengrocer
   (b) Emma worked in a chemist’s

2. (a) Emma wanted more money
   (b) Emma wanted a different job [level 2]

3. (a) Emma’s friend, Jenny, worked in a bank
   (b) Emma’s friend, Jenny, was still at school

4. (a) Jenny thought the boss would believe Emma’s story
   (b) Jenny knew the boss would not believe Emma’s story [level 3]

5. (a) Emma told her boss, the greengrocer, that she had been offered a job in a bank.
   (b) Emma told her boss, the greengrocer, that she had been offered a job in a chemist’s

6. (a) Emma thought the boss believed that the chemist wanted her to work for him
   (b) Emma thought the boss knew that the chemist had not offered her a job [level 4]

7. (a) Emma’s boss, the greengrocer, asked the chemist if he had offered Emma a job
   (b) Emma’s boss, the greengrocer, asked Jenny if Emma had been offered a job

8. (a) Jenny thought that Emma believed that the boss knew that the chemist did not want Emma to work for him
   (b) Jenny thought that Emma hoped that the boss would believe that the chemist wanted Emma to work for him [level 5]

9. (a) The chemist’s shop, where Jenny had suggested that Emma tell her boss that she had been offered a job, was in a different town
   (b) The chemist’s shop, where Jenny had suggested that Emma tell her boss that she had been offered a job, was near where Emma lived

Appendix B. Re-scaled weighted arithmetic mean

Equation for weighted mean (Szulc, 1965)

\[
\text{weighted mean} = \frac{\sum w_i x_i}{\sum w_i} = \frac{w_1 x_1 + w_2 x_2 + w_3 x_3 + \ldots + w_n x_n}{w_1 + w_2 + w_3 + \ldots + w_n}
\]

where \(w_i\) the individual weight and \(x_i\) the individual value.

In this study, the weight is the level of intentionality corresponding to any given question. In a story with nine levels of intentionality, the sum of the weights is 44 (the participant’s own perspective, which constitutes level 1, is excluded) and the sum of \(w_i x_i\) is 135. This means that the highest score attainable with the weighted mean is 3.068. To obtain a result representative of
a value along the scale of weights, the initial equation can be rescaled as follows:

\[ \frac{\sum (w_i x_i) v}{\sum w_i} \]

where \( v = \frac{\sum (w_i) w_{\text{max}}}{\sum w_i x_i} = 2.9333 \) and \( w_{\text{max}} \) the maximum weight (in this case 9).

By multiplying the sum of \( w_i x_i \) by a scaling value \( v = 2.9333 \), we obtain a number that when divided by the sum of the weights yields an answer that represents the level of intentionality at which the participant fails on a scale 0–7. This method provides an approximate level of intentionality at which each participant typically fails. The benefit of using this method is that it takes into account that a participant might fail a low order question yet, by chance alone, succeed at a higher level.

References

Miller, G.A., 1956. The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychological Review 6, 81–97.


