Association for Psychological Science

Current Directions in Psychological Science
2014, Vol. 23(2) 109–114

DOI: 10.1177/0963721413517118
cdps.sagepub.com
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The Social Brain: Psychological Underpinnings and Implications for the Structure of Organizations

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Abstract
The social-brain hypothesis refers to a quantitative relationship between social-group size and neocortex volume in monkeys and apes. This relationship predicts a group size of approximately 150 for humans, which turns out to be the typical size of both social communities in small-scale societies and personal social networks in the modern world. This constraint on the size of social groups is partly cognitive and partly temporal. It gives rise to a layered structure in primate and human social groups that, in humans, reflects both emotional closeness in relationships and the frequency of contact. These findings have potentially important implications for the way in which human organizations are structured.

Keywords
relationships, brain size, cognitive constraints, endorphins, time constraints, social networks, teamwork

The social-brain hypothesis (SBH) is an explanation for the fact that monkeys and apes have unusually large brains compared with all other mammals and birds. The SBH claims that primates need large brains because they live in unusually complex societies that involve many interdependent relationships that change dynamically through time: To be able to make decisions about how to act, animals need to be able to manipulate and manage information about the changing state of the social group—who is in and who is out—and this is computationally demanding (Dávid-Barrett & Dunbar, 2013). One important reason for this is that primate social groups, particularly those of Old World monkeys and apes, are based around bonded (as opposed to casual) relationships (Dunbar & Shultz, 2010) that are used to buffer individuals against the stresses created by living in large groups (Dunbar, 1998, 2011b).

In this article, I summarize the evidence for the SBH and explore its implications both for human social relationships and for the size and organization of human work groups.

Communities, Brains, and Cognition

One of the core findings of SBH is that the typical group size for a species can be predicted from the size of its neocortex (in particular, the size of the frontal lobe). The equation for this relationship in the apes (the primate family to which humans belong) predicts a "natural" group size for humans of about 150 (Fig. 1), or about three times larger than that of the most social monkeys and apes. This turns out to be the typical size of both communities in small-scale societies and personal social networks in contemporary society (Dunbar, 1993, 2008), as well as the modal number of friends listed on Facebook pages (Wolfram, 2013).

That this is likely to be a consequence of a cognitive constraint has been confirmed by a series of neuroimaging studies. Lewis, Rezaie, Browne, Roberts, and Dunbar (2011) and Powell, Lewis, Roberts, García-Fiñana, and Dunbar (2012) used voxel-based morphometry and gross stereological analysis, respectively, to show that regions in the prefrontal cortex (and, to a lesser extent, the temporal lobes) correlate with the size of face-to-face social networks. Kanai, Bahrami, Roylance, and Rees (2012) found a similar relationship with the number of Facebook

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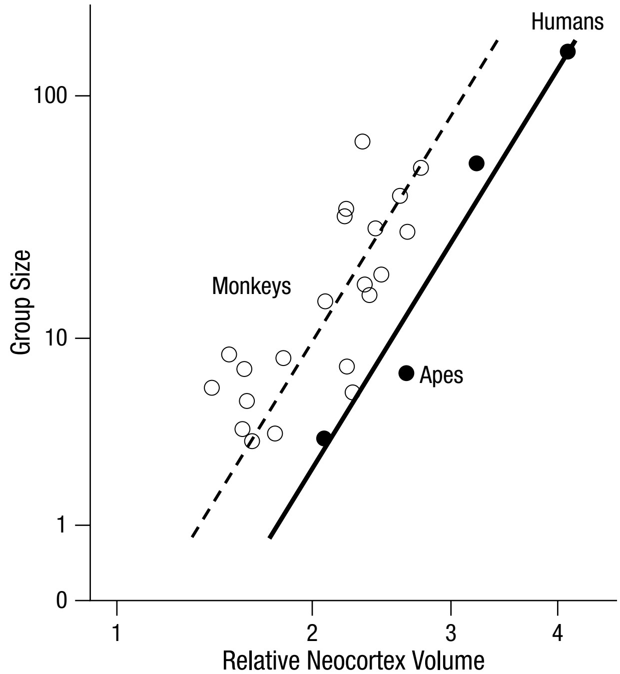

Fig. 1. The social-brain hypothesis predicts a relationship between a species' mean social-group size and the relative size of its neocortex (usually defined as neocortex volume divided by the volume of the rest of the brain). Apes (solid symbols) lie on a separate grade relative to monkeys (open symbols), which suggests that they need more cognitive processing to support their groups than monkeys do (and which implies, in turn, that doing so involves more complex kinds of socio-cognitive behavior). Data shown were drawn from Dunbar (1998).

friends. Importantly, these studies also confirmed that the SBH predicts differences between individuals within species, as well as differences between species.

The size of social networks has also been shown to correlate with individuals' mentalizing abilities (Lewis et al., 2011; Powell, Lewis, Dunbar, García-Fiñana, & Roberts, 2010; Stiller & Dunbar, 2007). Mentalizing is most familiar in the context of *theory of mind* (the ability to understand another individual's beliefs about the world). Formal theory of mind forms the basis of a naturally recursive sequence that, in normal human adults, has a limit at about five belief states. In other words, we can have beliefs about four other people's beliefs simultaneously at any one time. The neural network that seems to underpin this ability, usually known as the *theory-of-mind network*, involves regions in the prefrontal cortex and in the temporal lobe (Van Overwalle, 2009). This network integrates information on different aspects of social situations: Processing others' belief states, for example, may recruit elements in the temporo-parietal junction, whereas thinking about their traits recruits the medial prefrontal cortex (with evidence that the ventral part of the medial prefrontal cortex is especially important: Ma et al., 2013). Path analysis suggests that there is a specific causal relationship in which the volume of a key prefrontal cortex subregion (or subregions) determines an individual's mentalizing skills, and these skills in turn determine the size of his or her social network (Powell et al., 2012).

Although there may well be a significant genetic basis for the social-brain effect (as implied by the comparative data across primates), mentalizing competences are subject to significant learning effects during development. This could well mean that the brain regions involved in the mentalizing circuit increase in volume as a result of experience during formative developmental periods. This is especially likely to be true of the prefrontal cortex regions, given that these do not fully myelinate and stabilize until the mid-20s in normal humans. Evidence from primates supports the suggestion that the learning of social skills is important. The best predictor of neocortex volume across species is the length of the juvenile period (the period between weaning and puberty; Joffe, 1997)—precisely the period during which individuals learn and practice the social skills that later become so crucial for negotiating the adult social world.

Social Brain and Network Structure

Our social world naturally consists of approximately 150 individuals, but it is far from being homogenous. We do not treat all of our friends equally: We differentiate among them both emotionally and in terms of the frequency with which we contact them. Both personal social networks and small-scale societies are structured in exactly the same way, as a series of relationship layers (Hamilton, Milne, Walker, Burger, & Brown, 2007; Zhou, Sornette, Hill, & Dunbar, 2005). These layers are hierarchically inclusive, with a distinct structure: Each layer is three times bigger than the one inside it (Fig. 2), with the successive layers consisting of roughly 5, 15, 50, and 150 individuals. We know that these circles continue for at least two more layers (at 500 and 1,500 individuals, reflecting acquaintances and people whose faces we can put names to, respectively). Successive layers correspond to decreasing levels of emotional closeness and frequency of contact, with the boundaries between adjacent layers being associated with a precipitate drop in these indices.

This structuring is a consequence of how we create relationships. In monkeys and apes that have bonded social groups (Dunbar & Shultz, 2010), relationships involve a two-process mechanism (a psychopharmacological element that is time dependent and a cognitive element that directly involves the social brain). The psychopharmacological element centers around beta-endorphins triggered by social grooming (Depue &

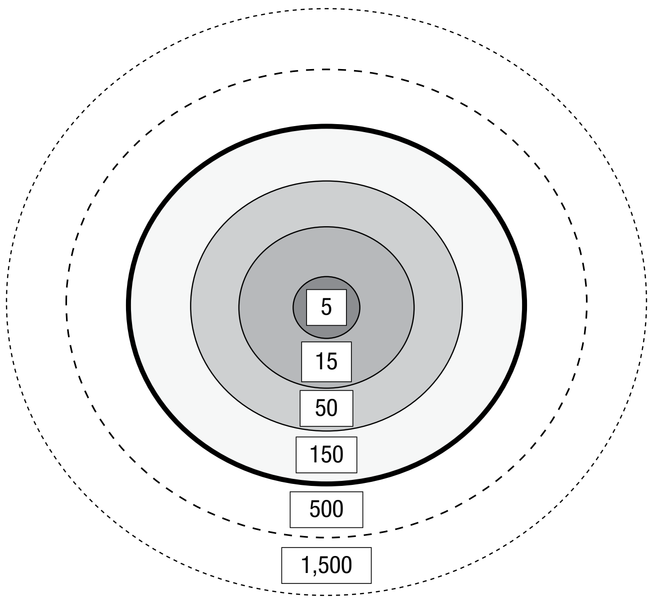

Fig. 2. Human personal social networks are structured into a series of hierarchically inclusive circles based on emotional closeness and frequency of contact. The 150 circle, indicated by the bold line, defines the limit on the number of bilateral relationships of obligation and reciprocity. Outside of this lie at least two further circles: The circle of 500 adds in everyone whom we would count as acquaintances, and the outermost layer of 1,500 includes everyone whose face we can put a name to.

Morrone-Strupinsky 2005; Dunbar, 2010; Keverne, Martenz, & Tuite 1989; Machin & Dunbar, 2011). Endorphins are natural opioids that create a sense of relaxation and contentment and seem to provide a platform on which a cognitive relationship of trust and obligation can be built. This second cognitive component involves the kinds of social cognition associated with mentalizing and seems to relate to how well we can anticipate and predict others' behavior.

In primates, the endorphin "rush" is triggered by social grooming and is probably mediated by a specialized neural pathway: the afferent C-tactile fibers that respond specifically to light stroking (Vrontou, Wong, Rau, Koerber, & Anderson, 2013). Intimate touch is important for building and servicing human relationships, but social grooming of this kind is very much a one-to-one activity, which imposes a constraint on the number of individuals we have the time to do it with. During the course of recent human evolution, we seem to have developed at least two other systems (namely, laughter and music) that allow us to produce this effect simultaneously in a larger group of people. Both of these turn out to be very effective at triggering endorphin activation (Dunbar, Baron, et al., 2012; Dunbar, Kaskatis, MacDonald, & Barra, 2012).

This endorphin-based component to the bonding system is time-consuming: Monkeys and apes can spend as much as 20% of the day engaged in social grooming (Lehmann, Korstjens, & Dunbar, 2007). Humans also devote about 20% of their day to social interaction—consisting mostly, of course, in conversation, but also including physical touch and other forms of casual intimacy (Sutcliffe, Dunbar, Binder, & Arrow, 2012). Dividing 20% of even an entire week (equivalent to approximately 22.5 waking hours) among 150 people is equivalent to interacting for approximately 9 minutes with each person—barely enough interaction for more than a nodding acquaintance. Instead, we distribute our available social time roughly in proportion to the perceived intimacy of our relationships (Hill & Dunbar, 2003; Roberts & Dunbar, 2011): We devote around 40% of our available social time to our 5 most intimate friends and relations (the subset of individuals on whom we rely most) and the remaining 60% in progressively decreasing amounts to the other 145 (Sutcliffe et al., 2012).

Kinship is an important additional structuring principle for personal social networks. About half of the slots in our networks are taken up by the members of our extended family (Roberts & Dunbar, 2011; Roberts, Dunbar, Pollet, & Kuppens, 2009). Indeed, we give priority to family members, such that people who come from large extended families typically have fewer friends (Roberts et al., 2009). The dynamics of the two halves of the network (family and friends) are very different. Relationships with family members are more robust in the sense that their persistence in the network does not depend on the frequency of interaction, whereas friendships deteriorate rapidly if they are not reinforced by regular contact (Roberts & Dunbar, 2011). Psychologically, this may reflect the fact that making decisions about how to behave toward family members requires less work and less information processing: Family relationships come at less cost because we need to know only how they relate to us, not the detailed history of our past interactions. This may allow us to manage more family members than friends for the same cognitive load.

Because the quality of relationships differs between layers, it seems likely that individual layers are associated with different kinds of relationships that provide us with specific social and psychological services (Sutcliffe et al., 2012). For example, the inner core of 5 people (the "support clique") comprises the people we rely on for emotional support during crises; the next layer of 15 people (the "sympathy group"; Buys & Larson, 1979) seems to provide core social partners whom we see regularly and from whom we can obtain high-cost instrumental support (e.g. loans, help with projects, child care); in contrast, the outermost layer of 150 people (the "active network") corresponds to an extended network that provides us with information through weak ties (Granovetter, 1973), as well as low-cost support.

Implications for Institutional Organization

These structural properties of social networks, based as they are on deep psychological mechanisms, have potentially important implications for the structure of organizations, and hence for many areas of psychology. There is extensive evidence, for example, to suggest that network size has significant effects on health and well-being, including morbidity and mortality, recovery from illness, cognitive function, and even willingness to adopt healthy lifestyles (Chou, Stewart, Wild, & Bloom, 2012; Christakis & Fowler, 2007; Fowler & Christakis, 2008; Holtzman et al., 2004; Smith & Christakis, 2008; Thorsteinsson & James, 1999; Tilvis et al., 2012). However, few of the studies in this area have asked whether these benefits are optimized by particular sizes of networks.

The relevance of human network structure to organizations is well exemplified by military organization, which seems to follow the same "rule of three" seen in personal social networks (Fig. 2). All modern armies have a hierarchically inclusive structure, with units at each level having approximately the same sizes as in personal social networks: sections of approximately 15 that are grouped into platoons of approximately 50, which in turn form companies of approximately 150, battalions of approximately 500, regiments of approximately 1,500, brigades of approximately 5,000, divisions of approximately 15,000, and so on (Dunbar, 2011a). Military units differ from both personal networks and civilian organizations in that they rely on strict rules of behavior and discipline enforced by draconian punishment. This is primarily because they have an explicit, and rather limited, function and are subject to stringent task requirements (lives are at stake on the battlefield if the organizational structure is inadequate for the task). The question of whether these units' sizes are optimal in some way—and, if so, why—has yet to be investigated.

Nonetheless, there is evidence to suggest that the historical success of communes has depended on their size at foundation, with groupings of around 150 being particularly successful (Dunbar, 2011a). This likely reflects the fact that communities of this size strike a balance between the minimum size for effective functionality and the maximum size for creating a sense of commitment to the community (and, hence, willingness to compromise on self-interest). It has been claimed that the success of GoreTex as a company is due to its insistence on organizing its production around units of 150 individuals (Gladwell, 2002). In creating what he referred to as his "flat lattice" (rather than hierarchical) management structure, the founder of GoreTex was motivated by the observation that in very large businesses, trust and cooperation rapidly break down once organization size exceeds about 200 individuals. Although there has been some interest in applying these principles to business organization (Nicholson, 2003), so far few organizations have taken the risk of reorganizing themselves in this way. One exception is the Swedish government, which reorganized its revenue-collection system into units of approximately 150 clients.

The psychology of teamwork has been extensively explored, with a focus mainly on brainstorming. The results have been mixed, with some studies demonstrating greater productivity but most suggesting negative effects (often attributed to production blocking and constraints on conversation flow: see Gallupe et al., 1992; Isaksen & Gaulin, 2005; Stroebe & Diehl, 2011). These studies have typically focused on comparisons between working alone and working in groups of four and have not attempted to assay for optimal group size. They have also invariably used groups of strangers. It may well be that brainstorming is not an appropriate task for small groups. Groups of approximately five people may be functional for more practical, objective-oriented tasks, such as problem solving or construction, in which close coordination is needed; debate might work better in large groups (e.g., most company boards, in which debate and questioning is important, typically consist of 12–15 people).

These differences in functionality may well reflect the role of mentalizing competences. The optimal group size for a task may depend on the extent to which the group members have to be able to empathize with the beliefs and intentions of other members so as to coordinate closely, as well as manage conversations without suppressing anyone. If this demand is high (as in a practical task with a specific goal), then the work group may have to be smaller. The efficiency of such a group may then be influenced by heterogeneity in the mentalizing competences of its members. Homophily is a major factor determining whom one forms close friendships with, as well as what levels of altruism one shows toward them (Curry & Dunbar, 2011, 2013), and in this respect, mentalizing competences may be an important dimension allowing friendships to function coherently. Buys and Larsen (1979) noted the frequency with which teams of 12 to 15 people occur in team sports and other forms of organizations in which a level of psychological engagement (but not necessarily deep emotional support) is needed. The role of time investment in the maintenance of friendships may thus be an important variable influencing work-group efficiency.

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Declaration of Conflicting Interests

The author declared no conflicts of interest with respect to the authorship or the publication of this article.

Funding

R. I. M. Dunbar is supported by an Advanced Grant from the European Research Council.

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