Dunbar's Number: Group Size and Brain Physiology in Humans Reexamined

Jan de Ruiter, Gavin Weston, and Stephen M. Lyon

ABSTRACT Popular academic ideas linking physiological adaptations to social behaviors are spreading disconcertingly into wider societal contexts. In this article, we note our skepticism with one particularly popular—in our view, problematic—supposed causal correlation between neocortex size and social group size. The resulting Dunbar's Number, as it has come to be called, has been statistically tested against observed group size in different primate species. Although there may be reason to doubt the Dunbar's Number hypothesis among nonhuman primate species, we restrict ourselves here to the application of such an explanatory hypothesis to human, culture-manipulating populations. Human information process management, we argue, cannot be understood as a simple product of brain physiology. Cross-cultural comparison of not only group size but also relationship-reckoning systems like kinship terminologies suggests that although neocortices are undoubtedly crucial to human behavior, they cannot be given such primacy in explaining complex group composition, formation, or management. [*neocortex, Dunbar's Number, kinship terminologies, group size*]

要約

より広い社会的背景で、生理的適応を社会的行動に結びつける世論が、秩序なく強くなっているように思われる。本論文の中では、(私たちの意見からすると問題ありなのだが特に一般的な、つまりそれは大脳新皮質と社会グループの規模についての短絡的な相関関係に、私たちの懐疑の焦点を当てたい。ここで由来するDunbar's Numberと呼ばれるようになるに至ったものは、異なった霊長類の集団の中の観察されるグループ規模に対して統計学的に試されてきた。方や人間以外の霊長類の集団におけるDunbar's Number仮説を疑う道理もあろうが、ここでは人に対するこのような弁明的仮説の適用に限定する。私たちは、人間の情報処理能力は単に脳の生理機能としてのみ理解することはできないことを主張したい。集団規模だけでなく、親族術語体系を包括する 人間関係の異文化間の比較は、大脳新皮質が間違いなく人間の行動において決定的である一方で、ここで説明される様な複雑なグループ構造や構成や管理の中で、大脳新皮質がそのような優越権を付与されるべきなでないということを提案しているのだ。

SAMENVATTING In bredere maatschappelijke contexten lijkt de populariteit van ideeën die een direkt verband leggen tussen fysiologische adaptaties en sociaal gedrag verontrustend toe te nemen. In dit artikel bespreken we één populaire, maar problematische vooronderstelling: een direkt oorzakelijk verband tussen neocortex grootte en sociale groepsgrootte. Dit vooronderstelde verband, aangeduid als Dunbar's Number, is statistisch getest bij verschillende soorten primaten. Alhoewel er wellicht redenen zijn om te twijfelen aan de hypothese van Dunbar's Number bij niet-menselijke primaten, beperken we ons hier tot menselijke populaties, gekarakteriseerd door hun culturele manipulaties. We stellen dat bij mensen het verwerken en beheersen van informatie niet begrepen kan worden als een eenvoudig product van hersenfysiologie. Cross-culturele vergelijkingen van systemen waarin relationele aspecten, zoals bijvoorbeeld kinship terminologie, worden meegenomen geven aan dat, alhoewel neocortices zonder twijfel een cruciale rol spelen, zij niet mogen worden opgevat als primair in het verklaren van complexe groepscompositie, -formatie of -regulatie.

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The relationship between neocortex volume relative to body and group size is an interesting area for cross-species comparison. Since the early 1990s, evolutionary anthropologist Robin Dunbar has focused on these themes. Dunbar (1992) explains that there was evidence in favor of a selection pressure related to greater social cognition required in larger groups. He argues that there is a direct correlation between the number of neocortical neurons and the number of social relationships that can be monitored. He proposes that we suffer from information overload beyond a certain group–neocortex size relationship, specifically in tightly bonded grooming cliques. At the center of Dunbar's argument is the idea that neocortex size is a constraint on group size, although actual group size is further determined by ecological factors. In this article, we discuss whether the hypothesized enabling link between neocortex and group size can be applied to species with highly elaborated systems of cultural transmission and development. The figure that has come to be known as Dunbar's Number (Dunbar 2010)—approximately 150 individual relationships—represents the cognitive ceiling beyond which our capacity to maintain such individual relationships is seriously hampered by neocortical limitations. Extrapolated from primate limits, Dunbar evidences this figure through a preponderance of communities with populations fitting comfortably within a range of 100–200. These include hunter-gatherer communities; military units; businesses; *Domesday Book,* 18th-century, and Neolithic villages (Dunbar 1993); and Christmas-card networks (Hill and Dunbar 2002), among others.

Since appearing in Malcolm Gladwell's immensely popular *The Tipping Point* (2000), Dunbar's Number has become popular and discussed in ways that few ideas from anthropology ever will. The blogosphere is ablaze with various recruitment and management figures debating implications of this figure for interstaff relations and staff–customer relations (see Lieberman 2010 or Smith 2010 for examples). A quick web search reveals churches, salesmen, web designers, and others discussing the implications of Dunbar's Number for their occupations and organizations. Despite Dunbar's Number receiving broad attention within evolutionary and biological anthropological literature, Dunbar's ideas have gone largely uncriticized and entirely unremarked on within social and cultural anthropology despite the fact that they deal with sociocultural issues and attract media attention under the banner of anthropology. Despite much of the print media and blog-based debate displaying the healthy cynicism one expects from the blogosphere, a slow turn from observation to normativity is apparent in the reception of these ideas, which we feel is problematic. We approach this article from across the sociobiological divide, drawn together by a shared concern and need to engage critically with these ideas as they start to permeate public debate. We urge caution regarding the normative shifts accompanying the spread of Dunbar's Number.

Dunbar is not alone in suggesting inherent limitations on group size. Clive Gamble (1998), drawing on Palaeolithic social network size, argues that group size was primarily limited by the social use of resources. Christopher McCarty and colleagues (2001), researching personal network size across the United States, find striking similarities in the network sizes across various differing types of social groups across the United States (more on this later). But where Dunbar and his coauthors differ from other analyses is in their argument that these group sizes are based on neocortical limitations and that, in turn, human sociality corresponds to evolved capacities and constraints. Others, such as David Geary (2005), also note how larger brains are primarily a social rather than ecological adaptation.

Dunbar and Susanne Shultz's social brain hypothesis suggests that sociality is the driving force behind evolutionary increases in neocortical capacity rather than vice versa. They state: "To maintain group cohesion, individuals must be able to meet their own requirements, as well as coordinate their behavior with other individuals in the group. They must also be able to defuse the direct and indirect conflicts that are generated by foraging in the same space" (Dunbar and Shultz 2007:135). The psychologists James K. Rilling and Alan G. Sanfey (2011:29–31) note the vital role of the prefrontal cortex (part of the neocortex) in social decision making, playing a key role in reciprocal altruism, deception, and the sharing of resources among other social activities.

Although there are perhaps limits to this social brain hypothesis (regarding being observable in highly social non-primates, see Cheney and Seyfarth 2007:133–141; regarding differences in social and technological intelligence, see Cheney and Seyfarth 2007:141–143), it is clear that complex social behavior requires well-adapted brains. Indeed, Richard Byrne and Nadia Corp (2004) found a correlation between deception rate and neocortex size in nonhuman primates. Dunbar and Shultz argue that adaptations resulting in complex social behavior among primates are based on the social upscaling of pair-bonded types of relationships (Dunbar and Shultz 2010; see also Chapais 2008). They note that "large relative brain size is associated explicitly with pair-bonded (i.e., social) monogamy" (Dunbar and Schultz 2007:1346). Although there is occasional inconsistency regarding the figure of 150 representing a mean (Dunbar 1993) or a maximum (Hill and Dunbar 2002), Dunbar's work generally suggests that beyond a ceiling of 150, our ability to replicate this level of intimacy breaks down.

Such research deserves further scrutiny to ascertain the limitations regarding the application of Dunbar's Number as a normative limit on group aggregation. Although the figure of 150 may suggest human neurological capacity, we argue that humans have culturally, bureaucratically, and technologically derived solutions to exceed such limitations. The specific issues we address in this article arise from the problematic concept of "relationships" in Dunbar's Number. We demonstrate the importance of transactions in relationships beyond the scaled-up pair-bonded relationships or grooming-type relationships that are central to Dunbar's analysis. We explore how humans are able to aggregate beyond Dunbarian limits without the implied instability as well as outline our reasons for caution regarding the number's normative application.

CAPACITY BEYOND NEOCORTICAL CAPACITY

Relationships vary in substance and form within and between groups. Although our ability to form relationships of substance may be, at least in part, evolutionarily grounded through pair bonding (Dunbar and Shultz 2007, 2010), we are not restricted to binary classifications of relationships as either pair bonded or superficial. The substance of specific relationships changes over time as we invest time and energy in maintaining and shaping their form and content. Michael Carrithers argues that through cultural adaptation of patterns of kinship, exchange, and politics, humanity began to establish new understandings of how we interrelate:

> There arose, that is, the exceptionally plastic ability for each person to enter into many forms of relationship simultaneously, and into new forms of relationship even in adult life. . . . And with this ability there appeared the forms of causation associated with it: not just ecological causation, but now distinctly human (social, political and economic) causation. [Carrithers 1990:196]

In turn, these capacities perhaps made us better able to purposefully engage in "niche construction" (Odling-Smee et al. 2003).

Dunbar's assumption that the evolution of human brain physiology corresponds with a limit in our capacity to maintain relationships ignores the cultural mechanisms, practices, and social structures that humans develop to counter potential deficiencies. One way of thinking of capacity beyond neurological capacity is represented by the theory of extended mind. Such ideas, in which the body is an integral part of our responsiveness, attempt to address the question of where the mind stops and the rest of the world begins (Barnard 2010). This idea has come mainly out of artificial intelligence research and has led to concepts such as situated, distributed, and embodied cognition (Clark 1999; Pfeifer and Bongard 2007). This is a first step away from what is now being labeled a "neurocentric" or "intercranial" view of cognition, which poses that a sharp boundary cannot be drawn between cognition taking place in the brain of the cognizer and supportive physical and nonphysical structures outside that brain. In embodied cognition, structures outside the skull play a role in an intelligent response. Reflexes such as blinking and complex bodily actions like balance demonstrate such bodily cognition. Andy Clark and David Chalmers (1998) advanced a significant next step, proposing that objects function as an extension of the cognitive process such as rearranging one's letters when playing Scrabble. In the same vein, language and other cultural attributes can be seen as part of the cognitive process. Embodied cognition and externalism are both involved in most physical activities. Ice hockey, for example, involves balancing while making strategic decisions regarding external entities.

Extended-mind theorist Merlin Donald (2002:xiii) notes that the symbolic and cognitive tools we use to think are borrowed from culture, resulting in "hybrid" social-biological minds. As we may ease the burden of learning a whole pantheon of Catholic saints by relating them to specific days, rituals, and feasts through the calendar of saints, we can also use such calendrical methods to note patterns of reciprocation between friends or relatives (other calendrical systems serve other mnemonic purposes: e.g., see Aveni 2000). The exchange of birthday cards or gifts allows us to closely monitor and maintain patterns of reciprocity by establishing links between one variable (dates) and another (people). Drawing such ethnotemporal parallels allows us to increase our potential to engage properly in patterns of reciprocation.

Hill and Dunbar demonstrate an appreciation of similar calendrical gift giving in their analysis of Christmas-card networks (Hill and Dunbar 2002), which observe an upper limit of 149 people. Their sample targets a particular type of relationship based around individual's Christmas-card lists. But again the nature of the relationships involved is hard to qualify as cards are often used to maintain contact with people who have become distant. By reducing costs to a minimum (standardizing costs around a card and stamp), a mechanism is available that offers massive potential scope for efficient reciprocity, a method used by individuals and businesses alike. More generally material culture (Miller 1987), spanning from filing cabinets to community centers, provides us with the tools to govern relationships with increasing efficiency (see Barham 2010).

Relationships are also ameliorated by other nonmaterial means. By naming certain types of relationships, other taxonomic structures allow us to track increased volumes of reciprocal exchanges. The use of labels—be they kinship terminology, ranks, or job titles—allows us to see efficient affinities between people. They act as cultural shorthand, enabling development beyond initial limitations. Clearly, this is not simply a product of post-Enlightenment rationalization; Proto-Nostratic kinship terminology is speculated to have existed as early as 15,000 B.C.E. (Hage 2008). Although other species undoubtedly recognize their own kind to varying extents, the increasingly complex reckoning of kin allows shortcuts in cognition as we draw parallels between our relationships and those of others. Such relationship reckoning is based not on powerful computational power (neocortex size) but, rather, on relatively "cheap" information-processing mechanisms. Kinship terminologies, for example, are surprisingly undemanding computationally (see Read 2001, 2006; Read and Behrens 1990) and can be reproduced using kinship algebras.

Such algebras are predicated on two simple principles: reciprocity and transitivity (see Leaf 1972, 2005). The first, reciprocity, suggests that kinship terms are reciprocal in an experiential way (i.e., if X has a term for Y, then Y must have a term for X), while the second, transivity, states that relationships between categories (or terms) are transitive and transformable to other relationships. Comparisons between a number of different kinship systems ("kin-term maps," to use Leaf's and Read's terminology) imply that although there is considerable variation at the level of expressed terms, there are relatively few generative algebras producing such variation. Rather than signifying a unitary mind (à la Lévi-Strauss), this hypothesis proposes that there are physiological limitations to the ways in which humans process information. So to the extent that Dunbar's neocortex focus posits a minimal enabling adaptation to generate any sort of kinship algebra, there is a good fit with available data. However, some kinship algebras enable more complexity in term generation than others. Without going into the more mathematically complex arguments of Dwight Read (although these are worth pursuing), it is obvious that there are more and less precise kin-term maps when it comes to ordering relationships or keeping track of individuals who get assigned specific terms.

In English kinship terminology, all cousins are conflated (both by gender and descent), and matrilineal and patrilineal terms are a mirror image of one another. In Shipibo kinship, in contrast, matrilineality, patrilineality, gender of speaker, and gender of cousin all generate distinct terms (Read 2005:50). In Punjabi kinship terminology, birth order for certain categories of kin terms also generates a distinctive term, as does specific place within the descent group for collateral terms (i.e., father's sister's offspring is not the same as mother's sister's offspring, father's brother's offspring, and so on; see Leaf 1972; Lyon 2004). Furthermore, there is some evidence that at least transitionally human populations can maintain multiple kinship algebras across different generations: that is to say, different generations within the same population employ distinct yet overlapping kinship algebras, which are mutually intelligible (see Jamieson 1998 for a preliminary presentation of the coexistence of competing kinship terminologies).

The causes and consequences of such variation in complexity fall outside the scope of this argument, but it is worth noting that social and terminological complexity need not correspond. The mere fact that Punjabi kin terms have more elaborated strategies for distinguishing collateral relatives, for example, does not necessarily render cousins more important within Punjabi society. To determine the relative importance of categories of kin, we need to know the terminological system as well as practices around kinship. One hypothesis of such terminological and social systems may be that where one finds complexity in terminology one would expect to find high priority placed on the terminological referents. Clearly such a hypothesis would need testing in every case because both kin terms and patterns of social relations are subject to change over time, and such change may occur at different rates (again see Jamieson 1998 for evidence of shifting kin terminologies among the Miskitu).

RELATIONSHIPS

An ideal rebuttal of Dunbar's limitation of our capacity to handle an excess of 150 relationships would provide an empirical refutation through groups of more than 150 individuals. To a limited extent, this is possible: Robert Layton and Sean O'Hara, for example, observe various hunter-gatherer groups with memberships above 150. They note that "many hunter-gatherer communities number between 250 and 500 individuals. . . . A few hunter-gatherer communities are apparently even larger (1,000–3,000), or even 10,000" (Layton and O'Hara 2010:101). Marcus Hamilton and colleagues' (2007:2196–2197) analysis of a dataset of 339 hunter-gatherer societies also demonstrates many communities numbering over 1,000 members. As hunter-gatherers are one of the community types that Dunbar (1993) demonstrates to have a mean group size of 150, such large group sizes would seem inconsistent with his suggested ceiling number. As Dunbar also notes that workplaces are another aggregation that is often limited to 150 individuals, then we might look toward successful working environments with more members. Pixar, allegedly the "world's happiest workplace" (*Otago Daily Times* 2009), has over 1,100 staff in their main site. Every one of *Fortune*'s 2010 list of the best companies to work for employs between 1,142 and 218,000 staff (CNN Money 2010). Additionally, although *Domesday Book* villages may have had a mean size of 150 (Dunbar 1993), 18 towns had populations of 2,000 or more (*Domesday Book* 2010).

Unfortunately, such a litany of large groups does little to nullify Dunbar's coefficient of group size as larger groups may contain a number of smaller groups with more modest memberships. Regarding hunter-gatherers, Layton and O'Hara note: "the literature does not state whether individuals could move between bands throughout this larger population" (Layton and O'Hara 2010:101). More broadly, their article concerns issues of group-size fluctuation through processes of fusion and fission. Larger groups consist of smaller interlocked groups that divide for activities such as hunting and foraging (Layton and O'Hara 2010:92–94) and recombine to pool resources such as child minding and other band-related activities at a central camp (Layton and O'Hara 2010:92–94). Similarly, larger businesses could be seen to consist of a number of smaller clusters engaging in similar patterns of fission and fusion. Such tessellation is not necessarily at odds with Dunbar's Number.

In an interview in the *Observer,* Dunbar states: "There are social circles beyond it and layers within—but there is a natural grouping of 150" (Krotoski 2010:26). Russell Hill, Alex Bentley, and Dunbar observe that humans and nonhuman mammals are alike in having "multi-level social systems" (Hill et al. 2008:749). This being the case, we ought to expect each scale to represent a particular type of relationship: family, bond group, clan, and subpopulation, for example (Hill et al. 2008:749). Elsewhere Dunbar refers to groups larger than 150 as "unstable aggregations" (Dunbar and Shultz 2007:135). As such Dunbar sees these scales correlating to both intimacy and stability.

However, severely at odds with Dunbar's research, McCarty and colleagues (2001) found a very different figure when looking for mean network size in the United States. Using two separate methodologies and applying them to various different types of social networks, they discovered a mean network size of 291. It is our contention that the key problem here is an inherent plasticity in the mean number, derived from an inherent flexibility in the concept of "relationships." Prior attempts at estimating network size produced radically different results because of the problem of defining "who should be included in a respondent's network" (McCarty et al. 2001:28). In short, network size is dependent on the types of relationship one includes within a given network.

If the rationale behind Dunbar's Number is our (in)ability to maintain relationships, then we must look more closely at what is meant by *relationships.* Dunbar's idea of what constitutes a relationship is quite precise. In Molly Milton's television series *The Virtual Revolution* (2010), Dunbar states of Facebook "friends": "While you can have this huge network of people you know in some vague sense—most of those relationships I wouldn't call relationships. . . . They're voyeur[ships]." This conceptualization of what constitutes a relationship is tautological. If someone has more than 150 Facebook "friends," then they somehow cease to be relationships. Circuitously, a relationship becomes that which fits within the parameters of Dunbar's Number. So when groups arise over 150, it is possible to say, "Well, but those aren't relationships as I define them." But contemporary human populations are typified by our ability to form and manage relationships of immense variety. An understanding that groups are nested hierarchically within other groups masks this circuitous logic.

The group size identified by Dunbar appears to refer to the maximum number of individuals with whom an animal can maintain social relationships through personal contact. For humans, like chimpanzees, this may involve a fission–fusion form of social organization (Dunbar 1993:681). Dunbar is therefore not limiting his analysis to continuously proximate groups but instead is referring to group maintenance in any form maintained through "grooming-type" behaviors—that is to say, transactional behavior directed toward the establishment and maintenance of bonds. Such behavior is an extension of pair-bonded behavior (Dunbar and Shultz 2007), but because such a description based on the social-brain hypothesis applies to all social relationships, we are again left with an inadequate definition.

Key to understanding how humans maintain relationships is the fact that we consistently reaffirm them through a general (although imperfect and often imbalanced) pattern of reciprocation. Such reciprocation of favors, services, or resources forms an important basis in the study of relationships both in primatology (e.g., Cords and Aureli 2000; de Waal 1995; Dunbar and Schultz 2010; Henzi and Barrett 2002; Silk 2003) and social anthropology (Mauss 2000). The size of the neocortex enables greater or lesser numbers of individuals to be tracked, which would appear to be a necessary prerequisite for relationship maintenance. This is achieved through what Dunbar calls "grooming"-type behavior—which actually extends beyond grooming itself into other activities such as gossip and language use more generally (Dunbar 1996).

The term *relationship* is a heuristic tool for understanding what is happening socially between embodied agents. The grey areas as to what constitutes an agent in this context are profuse. Dunbar's idea of relationship, which we could refer to as a "grooming relationship," prioritizes the face-to-face contact of agents—a factor that precludes many types of relationship with transactional elements. Other types of relationship require tracking of transactions without face-to-face contact, placing burdens on our neocortices, for which accounting is also needed. A more inclusive term might be *transactional relationships.* In this way, such relationships might be viewed as something occurring between entities rather than independently of them. Such a transactional approach makes no presumption of the positive nature of these interactions as grooming does; meanwhile, it also notes the necessity of tracking transactions and the requirement of reciprocation. It is this slightly refined understanding of relationships that we will be drawing on here, the implications for which should become apparent in due course.

Grooming and gossip, the two forms of bonding behavior used most frequently by Dunbar to illustrate his point, have social and ecological significance beyond bonding itself. The time spent doing either is not simply quantifiable in terms of surpluses and deficits. Grouping these two behaviors may be more problematic than Dunbar acknowledges. For example, grooming another monkey as consolation soon after an attack while in the presence of the attacker may have consequences for the groomer in terms of future coalition partners and thus has a different intensity than grooming in other contexts (Fraser and Aureli 2008). The reciprocal and transactional nature of grooming makes it an apt practice through which to approach other practices (incl. gossip) in the maintenance of social relationships. However, it must be noted that gossip is a more complex social process (Weston n.d.) and ought not be entirely reduced to overly tidy groominglike functions or transactions. The fractious nature of gossip interplays with the cohesive bond of sharing hearsay to make it more socially complex than grooming.

Humans must also recognize deficits in transactions with individuals who have not "groomed." Negative relationships also demand social bookkeeping and introduce reciprocal transactions of their own (see Black-Michaud 1980 regarding the Maussian nature of blood feud). Nodes in networks of social relationships need not necessarily be positive. "Frenemies" represent a relatively recent lexicographical acknowledgement of types of relationships in which individuals are at first glance friends but are better understood as competitors or enemies. Humans need to know who not to befriend and why. It is also important to track stigmatized persons (Goffman 1963) because the risk of poor bookkeeping is that proximity to stigmatized individuals can result in contagious stigma. In blood feuds and other rivalries, the knowledge of one's enemies' kinship and friendship circles is as important as the knowledge of one's own. Do humans also have a limit of 150 enemies? Must they forget a friend for each new enemy? What of face-to-face formalized relationships? Student–teacher relationships require establishment and maintenance of bonds through reciprocal interactions but within finite time frames and institutional parameters. In a compartmentalized or institutionalized world, relationships are diffuse in form yet equally require bookkeeping.

Although all relationships change over time, most have a horizontal, contemporaneous, or synchronic dimension. Yet certain types of relationship only make sense diachronically. Ancestor worship, for example, demands forms of reciprocity even after the death of a family member, sometimes for generations (although these practices may change over time [Kawano 2004] and may be mediated through priests [Keesing 1970:757] or other intermediaries). Intergenerational feuding (Schwandner-Sievers 1999) draws on similar diachronic bookkeeping as families maintain antipathy toward others long after the initial bookkeeper died. Are these relationships? Are the relationship limits of the neocortex restricted to human–human relations or are ghost–human, ancestor–human, and animal–human relations sometimes equally transactional and thus also entities that make demands on our neocortical capacity? It seems reasonable to assume so, which would immediately invalidate a direct comparison between species of very different mental ability.

If we include these types of relationship within our capacity for interrelated transactional behavior, we are already shifting the parameters and nodes that constitute the social groups that ought be encompassed within Dunbar's Number and must in turn realize that the scope of human relationships has changed significantly over the last 250,000 years. Although a soldier may be a member of a military unit, he or she also has nonmilitary friends, family, ancestors, pets, enemies, acquaintances, and other types of relationships connected to any number of nodes or agents outside of the military unit. Dunbar does accommodate some of this:

> Nor does it follow that a species' social system consists only of a single type of group: it is now clear that most primate species live in complex multi-tiered social systems in which different layers are functional responses to different environmental problems. . . . Rather, the neocortical constraint seems to be on the number of relationships that an animal can keep track of in a complex, continuously changing social world: the function subserved by that level of grouping will depend on the individual species' ecological and social context. [Dunbar 1993:681]

The relatively finite range of Dunbar's Number does not sit well with the panoply of fields across which many contemporary humans must move among and interact within. If the neocortex is finite, this increase in expanse of human interaction can only be explained through two things: (1) the improvement in the pedagogy of structuring relevant information needed to track transactions and (2) the discovery of methods equivalent to grooming that make relationships "cheaper" to maintain.

When one scales groups up beyond those covered by the range of Dunbar's Number, we need increasingly advanced mechanisms in which to collectivize energy expenditure to maintain groups. Dunbar (1996) suggests that gossip represents a "cheap" mode of grooming. Beyond gossip and language, humans have developed rituals that provide opportunities to collectivize and reinforce commitment and participation in the group. Blood sacrifices can be made for group prosperity. Émile Durkheim (1915) and Bronislaw Malinowski (1936) suggested that totemic worship is understandable as the worship of the group through the worship of the totem with solidarity maintenance of the group deriving from ritualized collectivization. Moments of collective violence such as riots or mob-based vigilantism (Burrell and Weston 2008) may play a similar role in circumstances in which belief in the righteousness of violence is collective and subsequent conditions of silence are properly maintained. National sporting events and their respective anthems, flag ceremonies, and prematch gift exchanges provide us with collectivization rituals or even international reciprocation. National holidays, memorials such as tombs to unknown soldiers (Anderson 2006:9–10), performance of traditional practices, arts, and a host of other factors help us imagine the cohesiveness of groups beyond the capacity of the neocortex. This is culture allowing us to move beyond what is perhaps a very reasonably observed neocortical limitation. Mass rituals allow us to collectivize our energy expenditure and permit us to form groups that would otherwise be impossible to maintain through face-to-face contact.

Organizationally we, as a species, have derived cultural patterns and inventions that help us exceed most of our limitations. Neocortex size would seem to be another such limitation that culture and efficiency allow us to supersede. Cultural adaptations allow us to build on rule-based patterns of behavior (Puga-Gonzalez et al. 2009), which humans, alongside other species (Hildenbrandt et al. 2010), have evolved to efficiently address adaptive demands. The human neocortex may be finite, but human capacity appears malleable and expansive in different sociocultural and technological contexts. Systematizing education provides a uniformity (linguistically, semiotically, and technologically) that foregrounds the efficiency of future interactions, structuring education so that we first learn how to learn. The capacity of the neocortex may well have remained relatively undeveloped for a quarter of a million years, but its efficiency is enhanced through pedagogical improvements.

Information processing is part of being human (see Fischer et al. 2005; Leaf 1972; Lyon 2005). The neocortex is vital in providing the ability to achieve complex bonds; however, it would appear to be a rather poor predictor of group size, beyond a certain type of social relationship that represents an upscaled pair bond within culturally situated human populations. The power of culture is that a great many adaptations require no genomic change but, rather, can be satisfied instead by cultural change.

As part of the rationale of the social brain, relationships can be seen from a functional perspective as a pattern of reciprocal interactions between two individuals representing reciprocal interests and benefits, which thus provide social stability. The argument is that the inability to monitor reciprocity leads to a problem of free riders and associated lack of social cohesion or break down of stability in a group (Dunbar and Schultz 2010). This is a good hypothesis, and at least in principle it is testable in nonhuman primate groups. The difficulty lies in monitoring reciprocal interactions within groups of a species at, below, and above predicted optimal group size to demonstrate that cooperation is reduced at larger group sizes as an alternative hypothesis to ecological constraints (de Ruiter 1986). But such a study has not been proposed or carried out. In human industrialized societies, it would be much more difficult to study this because of the multiplicity of types of relationships, but hunter-gatherer groups would be appropriate for such studies.

Although the effects of relationship capacity should be the primary concern in the testing of the social-brain hypothesis, first defining and then measuring relationships themselves is also important. Despite difficulties, primatologists have begun to make the concept operational, allowing for empirical testing. One approach is studying relationships damaged in conflict situations (Aureli and de Waal 2000). Marina Cords and Philippo Aureli (2000) break down relationship quality that can be used to measure bondedness. Another way to measure the quality of a relationship is to note behavioral responses to separation. This response has been used as an index of strength of bonds in primates (Mason and Mendoza 1998). An alternative measure of relationships suggested by Dunbar and Schultz (2010) is biochemical parameters, and where feasible this would be an additional, although not necessarily superior, method. Research in humans would be more methodologically complicated, but it would be possible to take different measures of relationship, as mentioned above, and investigate these in different communication contexts such as telecommunications and Internet social networking.

TECHNOLOGICAL AUGMENTATION

Fiona Coward and Clive Gamble (2008) note that the maintenance of social relationships through material culture was a key contributor to humanity's rapid encephalization. As such, material culture has always been central to human interpersonal relationships. Emergent information-communication technologies (ICTs) have massive potential in regard to facilitating group size beyond Dunbar's Number. ICTs bring about changes in the potential maximal and average group sizes that are the norm for those individuals embedded within societies in which such technologies are pervasive (see Fischer et al. 2008). This is not the result of human neocortices suddenly becoming better or larger but because it is possible to offload tasks to an external or "extended" mind (Clark and Chalmers 1998). Such extensions interact with the ego user and assume much of the necessary grooming to maintain significantly larger group sizes, in the process exposing what Donald (2002:149) refers to as "the myth of the isolated mind."

In their examination of the social impact of mobile phones in Jamaica, Heather Horst and Daniel Miller (2006) observe the extent to which network size emerges as a culturally salient and distinctive property of the region. They report surprisingly high numbers of individual contact details stored on mobile phones—some so numerous that the users require multiple mobile phones or multiple SIM cards on which to store them all. Such contacts are drawn on for diverse reasons spanning from organizing church social events to arranging sexual liaisons (Horst and Miller 2006:45, 82). But among these strategic uses, there are some who use these extensive lists explicitly as a form of social capital (Bourdieu 1986), using contacts directly or indirectly to obtain money in times of need.

Although "low income Jamaicans may not articulate the importance of connections in terms of social capital" (Horst and Miller 2006:110), each contact requires consistent grooming, in good times and in bad, so that when a favor is asked for, there is an established relationship that frames the request. Because these requests cannot be too frequently directed toward any one individual, there is direct benefit to having larger numbers of contacts. Here we not only see technology facilitating networks larger than Dunbar's Number but also understand the strategic advantage such an approach provides. Rather than suggesting that mobile phones have enabled Jamaicans to have larger networks, we propose that the particular conditions of Caribbean social relations were fertile ground for mobile-phone technologies. Such ICTs facilitated an elaboration of greater networking demands and higher group-size maximums that existed within the region.

Social-networking sites allow us cheaper-still methods of maintaining relationships. Applications on Facebook that allow "poking" or "gift exchanges" of apparently no substance demand almost no time or energy expenditure on behalf of transactors yet allow individuals to cheaply maintain patterns of reciprocation. Social-networking sites provide facilities to remind users of birthdays along with other gift-giving and well-wishing occasions. Watching status updates in itself may not fulfill the same role as gossiping about common events, but commenting on these updates and the knowledge such updates provide is useful in future face-to-face contact. Although it may cheapen certain relationships in ways that sacrifice depth for breadth, such sites offer instrumentally useful bonding potential.

Donna Haraway states that "by the late twentieth century . . . we are all chimeras, theorized and fabricated hybrids of machine and organism; in short, we are cyborgs" (Haraway 1991:150). Marilyn Strathern, in response, writes of the erosion of divisions "between the natural and the artificial, between matter and consciousness, or between who makes and who is made in the relations between human and machine" (1991:36). Even technologies that are seemingly unconnected to memory or social interaction—such as washing machines, rider mowers, or irrigation devices—provide labor-saving potential that transforms social relations and enables ever-greater social and economic specialization and interdependency (both of which require rather impressive relationship-reckoning systems). It is this specialization that allows human actors to achieve exponentially more collectively than we are able to individually.

The human body and human brain may have finite capacities, but through the collectivization of endeavor we can exceed these limitations. Transportation methods permit us to move faster than our bodies would otherwise allow; pulleys, levers, and machinery enable us to lift loads we would otherwise be incapable of moving; likewise ICTs are the latest achievements in a long history of materially facilitated interaction that allow us to efficiently track, interact, and reciprocate among groups in excess of Dunbar's Number. If an adaptation toward enhancing such capacities is useful, we will create the tools to support these changes.

CONCLUSION

The correlation between neocortex size and group size across primates is clear, but many human groups exceed this size. What may look promising as a possible explanatory mechanism in cross-species studies must be more carefully scrutinized for intraspecies variation. Crossing culture, forms of social organization, social class, gender, age, occupation, economic mode, and a host of other variables reveals considerably more plasticity in group size than Dunbar's Number would imply. We take this as persuasive evidence that although fundamental physiology of neocortex size and architecture is undoubtedly a prerequisite for a great many human behaviors and ideational systems, it is largely irrelevant when determining optimal or maximal group size in contemporary human populations. The breadth in forms and content of relationships in contemporary culture and the technological, technical, and cultural methods for ameliorating our neurophysiological capabilities should alert us to our capacity to exceed certain biological constraints.

Dunbar argues that

> the problem for modern humans is that we have a natural group size of about 150 individuals. . . . At some point in our evolutionary history, hominid groups began to push against the ceiling on group size. The only way they could have broken through this ceiling so as to live in groups larger than about 80 individuals was to find an alternative mechanism for bonding in which the available social time was used more efficiently. [Dunbar 2004:102]

Where we beg to differ is in respect to the fact that our species has never ceased to look for "alternative mechanisms" for bonding. Where Dunbar sees the human group-size ceiling at 150, we see cities, nations, and other complex social networks, however abstracted from face-to-face contact, as evidence to the contrary. In fact, it is our ability to abstract and successfully wield these abstractions that leads to stability—not the size of the group in and of itself. Reducing substantively different relationships such as coworkers and pair-bonded couples to the same category produces more questions than answers, undermining subsequent normative extrapolations.

If Dunbar is correct, human group size would be limited to 150 without need for knowledge of his number or its meaning. However, in those situations in which larger group size is beneficial or culture or technology offer increased capacity, why should groups feel the need to limit their memberships? As Dunbar explained in his interview with Krotoski, his answer is as follows:

> Our problem now is the sheer density of folk—our networks aren't compact. You have clumps of friends scattered around the world who don't know one another: now you don't have an interwoven network. It leads to a less well integrated society. How to re-create that old sense of community in these new circumstances? That's an engineering problem. [Krotoski 2010:26]

His suggestion that our alienation will be alleviated through limiting group size is clear. Dunbar's Number then becomes an engineering solution but assumes inherent instability, seeing larger groups as "unstable aggregations." But surely a social capital–oriented argument that "more alliances are better than less alliances" is equally valid?

The potential for a correlation to transform into something more normative has problems, which to us are obvious. The jump from a possible biological connection between brain size and group size to ideas that groups should be limited to 150 individuals is a large one. We feel the observed coefficient is different from a formula for the construction of idealized social environments. With Dunbar's recent publication of *How Many Friends Does One Person Need? Dunbar's Number and Other Evolutionary Quirks* (2010), he has set sail between the Scylla and Charybdis of publicly accessible knowledge and the simplification of complex theory. The book suggests distrusting anyone who has more than 150 Facebook friends—clearly a normative prescription that ignores the empirical evidence of the flexible group-size range across contexts and cultures. Increasingly since *The Tipping Point* (Gladwell 2000), Dunbar's ideas have been incorporated into mainstream thought (*Economist* 2009; *Wall Street Journal* 2007). When the Swedish Tax Authority used Dunbar's Number to reorganize its offices into groups of 150 workers, it demonstrated that such normativity has real consequences (*Local* 2007). Despite our concerns, this office reorganization may well confer some real advantages to someone. But such success or failure is, like Dunbar's Number, an ostensibly testable proposition—even though the experimental basis on which it would be carried out is inevitably riddled with cultural presuppositions about what constitutes appropriate indicators of "happiness," "productivity," and "economic benefit."

Geoffrey Pullum notes in *The Great Eskimo Vocabulary Hoax* that certain "facts" such as the fundamentally disproven "notion that Eskimos have bucketloads of different words for snow" (Pullum 1991:160) are all-too-readily embraced by an uncritical public. "Once the public has decided to accept something as an interesting fact, it becomes almost impossible to get the acceptance rescinded. The persistent interestingness and symbolic usefulness overrides any lack of factuality" (Pullum 1991:159). Although Dunbar's Number is certainly no Eskimo snow–like inaccuracy, it is the relatively unquestioned rapidity with which the idea is being absorbed into public thought and action that is slightly perturbing. Academic scrutiny ought to be in some way proportionate to the application of the work. We are not sure this has occurred in relation to Dunbar's Number.

Clearly neither Gladwell nor Dunbar are entirely responsible for the application of Dunbar's Number once it had been discovered. Nigel Oseland, an environmental psychologist, recently included Dunbar's Number in an article on "The Impact of the Psychological Needs on Office Design" (Oseland 2009), demonstrating the migration of the idea to policy and architecturally oriented spheres. As such, we would like to suggest that these new normative applications of Dunbar's Number imply that it would be prescient to test the normative applicability of the figure in contrast to those incidents in which groups are allowed to find their own equilibrium, ceiling, or (where applicable) optimum size.

In an era in which research is increasingly assessed in terms of impact, we ought not discourage those who raise their heads above the parapets. We do, however, need to be mindful that public audiences may not be so aware of the limitations of research. This is particularly important in spheres in which research may lead to us limiting or censuring behavior. There is much to be gained from popularizing ideas—but anthropologists and those in related fields, as a unified whole, need to intervene to make sure that such findings are accurate before there is an overcommitment to these ideas. Across social, cultural, and biological anthropology alongside human behavioral ecology, phylogenetic research, and other strands, we need to test the veracity of anthropological ideas as they become increasingly popular. As Nettle (2009) notes, following the advances made in evolutionary psychology, any previously assumed boundaries between sociocultural anthropology and evolutionary or biological anthropology are quickly disappearing. Incidences in which biological ideas enter social realms are going to become more frequent as a result. Resulting ideas deserve scrutiny from across the discipline of anthropology.

Although relationships may be hard to quantify or qualify, other areas are entirely testable. Jamie Tehrani and Mark Collard (2002), among others, have shown the value of applying phylogenetic research to culture—ideas that could be extended into looking at pair bonding as a basis for relationality as opposed to mother–offspring or sibling-based bonds or "affect hunger" (Goldschmidt 2005) more generally. Human behavioral ecologists could explore the applicability of Dunbar's Number in "non-natural" happiness or productivity in office spaces. These are falsifiable hypotheses. Although there is an inherent difficulty in proving or disproving the fission–fusion nature of larger groups in relation to stability, human behavioral ecologists might want to hazard a go. In short, to ensure that Dunbar's Number—and, in the future, other similarly dogmatically embraced ideas—are not accepted blindly, there is a need for greater interdisciplinarity across the subdisciplines that fall beneath the broader anthropological or human-sciences umbrella. Until such research demonstrates the contemporary applicability of Dunbar's Number cross-culturally, we feel obliged to remain skeptical of its application.

Jan de Ruiter *Department of Anthropology, Durham University, Durham DHI 3LE, United Kingdom*
Gavin Weston *Department of Anthropology, Durham University, Durham DHI 3LE, United Kingdom*
Stephen M. Lyon *Department of Anthropology, Durham University, Durham DHI 3LE, United Kingdom*

NOTES

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