Small worlds, material culture and ancient Near Eastern social networks

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Abstract

The cognitive, psychological and sociological mechanisms underpinning complex social relationships among small groups are a part of our primate heritage. However, among human groups relationships persist over much greater temporal and spatial scales, often in the physical absence of one or other of the individuals themselves. This paper asks how such individual, face-to-face social interactions were 'scaled up' during human evolution to the regional and global networks characteristic of our modern societies. One recent suggestion has been that a radical change in human sociality occurred with the shift to sedentary and agricultural societies in the early Neolithic. This paper presents the results of a focused study of the long term development of regional social networks in the Near East, using the distribution of different forms of material culture as a proxy for the social

relationships that underpinned processes of trade, exchange and the dissemination of material culture practices. Long-term developments in social networks in the Near East are assessed in robust quantitative terms and their implications for the evolution of large-scale human societies discussed.

> *In Ersilia, to establish the relationships that sustain the city's life, the inhabitants stretch strings from the corners of the houses, white or black or grey or black-and-white according to whether they mark a relationship of blood, of trade, authority, agency. When the strings become so numerous that you can no longer pass among them, the inhabitants leave: the houses are dismantled; only the strings and their supports remain.*
>
> (Italo Calvino 1974, *Invisible Cities*. London: Picador, pp. 62)

Introduction

A wealth of evidence from primatology indicates that highly complex social relationships are part of our primate heritage (see e.g. refs in Lehmann et al this volume). Nevertheless, human culture remains distinctive in terms of its sheer temporal and geographical scale. Research into how and when this 'scaling up' of human social relations occurred is largely divided between two opposing chronologies. Work focusing on the biological and neurological substrates for sociality in primates, humans and in the hominin fossil record has suggested many the relevant palaeoanthropological developments seem to occur after

500,000 years ago, being tentatively associated with (particularly late populations of) *Homo erectus* sensu lato (review in Grove and Coward 2008). This would see all modern human cognitive capacities in place at the evolution of genetically and anatomically modern *Homo sapiens* possibly up to 200,000 years ago but certainly before 50,000bp (see e.g. Klein 1999 for review), a logical and persuasive position given that modern humans across the globe display the same cognitive capacities and are remarkably genetically homogeneous (see references in Lahr & Foley 1998, 142).

However, such an early chronology is at odds with one based on material culture change, which identifies the impressive developments of post-anatomically modern human prehistory (notably the Middle-Upper Palaeolithic transition and/or the so-called 'Neolithic Revolution') as the definitive break-point(s) in the journey from 'hominin brain' to 'human mind'. The tension between these early and late chronologies has created what Renfrew has called the 'sapient paradox' (e.g. 2007; 2008).

It is certainly true that group size – a central factor in the early chronology's constellation of cognitive evolution underwent perhaps its biggest increase not during hominin evolution per se, but well after the appearance of modern humans as the first permanent villages developed in the Near East during the Epipalaeolithic and early Neolithic (ca 12,000-8,000 radiocarbon years ago; e.g. Kuijt & Goring-Morris 2002). These developments are thought to form part of an 'explosion' of material culture that proponents of a late chronology argue represents a definitive break with the mobile hunter-gatherer lifeway *Homo sapiens* had pursued for over 100,000 years beforehand. These changes are claimed to be dramatic enough to represent a radical new form of social life, and perhaps even of cognition and/or language (Humphrey 2007): a new ‘symbolic material culture’ stage of cognitive evolution to Donald’s scheme of cognitive evolution (1991) held to be ‘characteristic of early agrarian societies with permanent settlement, monuments and valuables’ (Renfrew 1998), i.e. firmly aligned with the appearance of Neolithic cultures (see also e.g. Watkins 2004, 105; Runciman 2005).

Some problems associated with this late chronology have been discussed elsewhere (e.g. Gamble 1999; Coward & Gamble 2008, in press). However, the real problem with both the early and the late chronologies is their reliance on ‘flick of the switch’ metaphors: the identification of a moment when hominin brains become human minds. Origin points- and revolutions-focused explanations have a long history and an enduring cultural appeal (e.g. Gamble 2007); however, it has more recently been argued that the development of distinctively ‘human’ cognitive capacities was a much more gradual and long-term process (Coward & Gamble 2008).

Material culture in cognitive evolution

The lack of direct evidence for hominin brains and the relative paucity of the fossil record make the role of material culture in the process of cognitive evolution one of the most pressing issues for research. Many animal species use material objects for various purposes, and all great apes can use and indeed make tools in captivity (see e.g. reviews in Berthelet & Chavaillon 1993). Even in the wild the tool kits of some great apes are so group-specific and persistent over time that they can justifiably be termed ‘material cultures’ (e.g. McGrew 1992; van Schaik et al 2003). It would seem, then, that the cognitive capacities for learning and behavioural flexibility are part of our primate heritage. However, as yet even the best primate stone tool knapper – the chimpanzee Kanzi – has never produced anything as complex even as mode 1 technology (the Oldowan, the very first recognisable stone tool industry known from 2.6mya; Schick & Toth 1995, 139; Schick et al. 1999). By the time mode 2 technology appears in the archaeological record in the shape of the Acheulean handaxe (associated with *Homo erectus*), the high standard of technical – and perhaps not incidentally, aesthetic – skill involved, together with the persistence of the technology for more than a million years across much of the Old World makes it clear that the scale of material engagement even at this early stage of hominisation is beyond that available to other primate species.

The specific cognitive mechanisms necessary for manufacturing these different forms of stone tool remain a topic for much debate (e.g. Coolidge & Wynn 2005). However, research is now beginning to focus on the social implications of the cumulative cultural transmission they imply, including the role of teaching and pedagogy (e.g. Ingold 1999; Tomasello 1999; Matsuzawa 2007; Coward 2008; Thornton & Raihani 2008) and the contribution of derived forms of theory of mind which allow the appreciation of goals rather than simply actions (e.g. Gallese 2006).

However, perhaps the distinguishing characteristic of human material engagement is the extent to which the objects which humans manufacture and use are integrated into our social relations. The idea of distributed personhood – the notion that personhood is neither discrete nor bounded and synonymous with a body but spills out through one's relationships with others such that it makes more sense to speak of 'dividuals' than 'individuals' – has become more widely accepted recently (Marriott 1976; Strathern

1988, 1998; Bird-David 1999; Thomas 2002 e.g. 34; Jones 2003). In this paradigm, the accumulation, fragmentation and movement of things acts to enchain people across time and space (Chapman 2000; Gamble this volume; Coward & Gamble 2008): the classic ethnographic examples are that of the Melanesian Kula ring (Malinowski 1920, 1922) and the Ju/'hoansi (Kalahari) *hxaro* exchange system (e.g. Layton & O'Hara this volume), where the circulation of objects links people together across space and over time. During this process the objects themselves acquire biographies and identities of their own (Hoskins 1998; Gosden and Marshall 1999) and become incorporated into our social lives in very similar ways to our fellow humans as different ('more than human'; Whatmore 2002, 161) kinds of nodes in our very heterogeneous social networks. Such practices date to very early in the process of hominisation: there is evidence for the purposeful movement of material objects even in the very earliest sites from the Lower Pleistocene in Africa (Schick & Toth 1995, 213; Coward & Gamble in press; references in Roberts this volume). Over the course of hominisation, such practices become *part of* cognition and social interaction rather than merely aids or prompts (Coward & Gamble 2008) – the defining characteristic of *extended*, rather than merely *embedded*, cognition (Rowlands this volume).

Material culture and networks

Viewed from such a perspective, the archaeological record is not a passive by-product of social relationships: rather, it *is* social relationships (Gamble 1999, 2007; Barrett, 2000

[1988]; Knappett 2005). The patterning of material culture is a direct result of the social relationships between individuals and groups in which these objects were caught up.

Archaeologists have long been comfortable dealing with populations, assemblages and distributions, with diffusion viewed in terms of the spread of traits across a homogeneous population and geography, analogous to the transmission of disease (e.g. Ammerman & Cavalli-Sforza 1973). Such approaches have more recently been complemented by consideration of ‘mosaic’ patterns of social and material culture change across space and over time (see e.g. papers in Douglas-Price 2000; Clark 2001; Simek 2001, 201; Asouti 2006). As long ago as 1952 Hägerstrand’s Monte Carlo simulations demonstrated the significance of contextual factors on processes of diffusion, emphasising for example how communication and the regularity and quality of interpersonal contact channel the spread of traits (cited McGlade & McGlade 1989). Research since has highlighted the simple fact that the spread and timing of traits is situation-specific and highly contextual (see review and references in McGlade & McGlade 1989, 285-7; also Coward & Grove submitted). In short, it is simply not possible to address the distribution of material culture (or, indeed, disease; see e.g. Lindenbaum 1978) without tackling the individual relationships that lie at the heart of the processes governing their spread. To this end, Dodds and Watts (2005) have recently suggested that a natural progression would be to consider diffusion models for a *networked* population of individuals, echoing Katherine Wright’s recent call for a focus on networks rather than regions or cultures in archaeology (2008).

The burgeoning literature on the structure, properties and significance of social networks has a great deal to offer archaeology. A network perspective provides a much more realistic picture, not only of *objective* sociality, but also potentially of individuals' *subjective* experience of their worlds. Hägerstrand's time-geography, for example, described human activity as a web of individual paths in time-space:

> This space-time region contains the social system and is the setting of everyday life. As time flows, organisms and objects of different life-space describe paths which together form a large and complex web, where paths are born, move around (some more, some less) and die, combining all the time into different constellations (Carlstein 1982, 40).

Furthermore, individual paths are not isolated: what Hägerstrand calls 'stations' (sites, dwellings, resources etc.) form 'pillars' in time-space, while there may be 'channels' of transport and communication etc. which serve to link individual paths together in space-time. The diagrams illustrated in Carlstein 1982 (figs 2.1-7, 40-4) are simply networks viewed from a three-dimensional perspective that, although unfamiliar, serves to remind us of our embeddedness in the social and physical world: not a two-dimensional quantitative 'surface to be occupied' but 'a world to be inhabited' and experienced in terms of movement along paths and track (Ingold 2000, 155). One of the strengths of such a network perspective is that it allows – in fact, *demands* – a heterogeneous way of thinking about social relations. Humans, animals, plant species, things and places are all tangled up in the same network, as in Actor-Network Theory (see e.g. Law 1999; Latour 1996; Whatmore 2002, 2006). The world is always shared with others whose paths meet, avoid, branch off from, run parallel to or merge with one another over the course of their lives: ‘Putting together all the trails of all the different beings that have inhabited a country – human, animal and plant, ordinary and extraordinary – the result would be a dense mass of intersecting pathways’ (Ingold 2000, 144).

The classic anthropological example is that of Australian Aboriginal groups, who perceive the entire country in terms of networks of places linked by paths of movement (e.g. Munn 1973, 215): however, such network (or relational, or rhizomatic) modes of thought are not solely applicable to hunter-gatherers in contrast to the ‘genealogical’ (substantive, objective etc.) cognitive style of agriculturalists (Deleuze & Guattari 1988, 18). As Ingold has argued, the latter arises out of the former and exists alongside and complementary to it in the particular context of agricultural groups (Ingold 2000, 133-4), while Actor-Network Theory is consistently and successfully applied to modern western societies (e.g. Latour 1996; Jacobs 2006).

Another strength of a network approach is that the networks being investigated are simultaneously bottom-up and top-down. Individual actors are part of the network and so are influenced by their associations with other nodes – but at the same time the network is created by them, so it can never be static or completely deterministic (Callon 1987). There is thus no tension between the structuring role of large-scale cultural and geographical patterning and decision-making and performance on the part of the individual; indeed, as Latour has pointed out, the idea is to bypass the whole structure/agency debate altogether, as actors and networks become two faces of the same phenomenon (1999, 18).

Prehistoric social networks

Studies of prehistoric social networks are not entirely new; however, they have mainly been applied to island contexts so far – the Pacific islands were studied by Irwin (1983), Hunt (1988) and Hage and Harary (1996), and the Bronze Age Aegean Archipelago by Broodbank (2000) and Evans et al (in press). These studies have certainly demonstrated the robustness of the methodology and its potential in prehistoric contexts – however, all of these examples have focused primarily on the *geographical* aspect of these island networks. However, the entanglement of social interaction and material culture into a heterogeneous relational network means that similar methodologies can be used to investigate the material components of prehistoric networks and inform on how the wider networks of interaction of which they are a part change over time.

The datasets

The datasets discussed here are based on a database initially compiled by Sue Colledge as part of the AHRB-funded project 'The Origin and Spread of Neolithic Plant Economies in the Near East and Europe' (Colledge et al. 2004[i]) and significantly extended by the author. The database contains 780 individual levels from 591 sites dated to the Epipalaeolithic and Early Neolithic (PPNA & PPNB) from the Near East (including Israel, Jordan, Saudi Arabia, Egypt [the Sinai Peninsula], Iran, Iaq and Southeastern Turkey [South of the Taurus Mountains]). These tables are linked to a database of ^{14}C dates for sites in the Near East as well as to tables recording the finds recovered from those sites. Seven different varieties of material culture are recorded: art (defined as representations of various forms); burial data; items engraved with (non-representational) designs of various kinds; structural and architectural features; ground stone; hearths; lithics; ochre; ornaments and jewellery; shells and worked bone (Figure 1). Some artefacts are recorded in more than one table – for example, engraved grooved polishers are recorded in both the ground stone and the engraved items tables.

FIGURE 1 ABOUT HERE

Data were gleaned from the widest possible variety of sources. Where possible original definitive reports were used, but many sites have been reported to date only in interim reports (more recent reports beings prioritised over earlier). A number of region- and theme-specific reviews were also extremely useful, including those by Bar-Yosef (1970); Aurenche (1981a-c); Wright (1992a-b); Hours et al. (1994); Sayej (2004); Kozlowski & Aurenche (2005) as well as online databases such as the TAY project[ii] (), CANEW[iii] and the CONTEXT radiocarbon database (Böhner & Schyle 2002-2006[iv]).

In the analyses presented here only sites with radiocarbon dates were included; dates were calibrated using OxCal v4[v], with all dates in this paper being calibrated in years BC. Dated sites were divided into datasets of non-mutually-exclusive 1,000-year intervals from 21,000 – 6,000 cal BC on the basis of the range of dates within 1 standard deviation from the mean calibrated date; most sites therefore appear in more than one consecutive interval. For example, a date of 8658+/-101bp from Jericho II (P-381) is calibrated to between 8170 and 7524 at 68% probability and therefore appears in both the 9-8kyrs cal BC and 8-7kyrs cal BC time intervals.

Dates were not audited, although those explicitly considered problematic by excavators were removed from the analysis, as were dates with errors of more than 1,000 radiocarbon years which would otherwise have dominated the datasets. Only two sites stood out as problematic during the compilation of these datasets: Nemrik 9, believed to date to the PPNA, has a total of 81 radiocarbon dates ranging from >40,000 (Gd-5237) to 3990+/-510cal BC (Gd-4194), thus covering most of the time periods analysed here. However, the dates cluster around 10,500bp, and the excavators consider it probable that the site dates to between 10,500bp (~10,800-10,165 cal BC) and 8,400 bp (~7,592-7,195 cal BC; Kozlowski 1989, 25-6), and therefore Nemrik appears in these analyses only in intervals between 11 and 7kyrs cal BC. The second site, Salibiya IX, has yielded two dates of 20,050+/-230 and 12,470+/-620 cal BC, and is variously assigned to either the Khiamian (PPNA) and/or the Late Natufian or a mixture between the two. Given these uncertainties, the site was not included in these initial analyses. The sites included in each dataset are listed in table 1.

TABLE 1 ABOUT HERE

One final concern was that higher levels of mobility earlier in the record might create ‘noise’ in these datasets (Chapman pers comm.); therefore, sites yielding solely lithic material culture were excluded from these initial analyses. Obviously, however, this is an issue that will be investigated more closely in future.

For analysis by social network techniques (using UCINET 6; Borgatti et al 2002), datasets need to be in the format of an adjacency matrix with as many rows/columns as there are actors in the dataset under investigation. In social network analysis ‘actors’ need not be individuals but are discrete social units at a variety of levels of analysis ranging from the individual to the corporate and national: in this analysis, discrete levels of sites from the Epipalaeolithic and early Neolithic Near East at which various kinds of material culture have been recovered become nodes in the networks. Scores in the cells of the matrix record information about the relational ties between each pair of sites; the range and variety of ties that may be investigated is extensive but routinely includes transfers of material resources (see e.g. Wasserman & Faust 1994, 18 for further discussion).

In this study, the material culture inventories from the sites/levels in each 1,000-year timeslice were used as material proxies for social interactions between those sites. In the case of a single discrete and transportable object such as a particular kind of ground stone implement – a pestle in Figures 2a & 2b – the object might have been directly physically transferred between sites through processes of transport, trade, exchange etc. More generally, the idea behind the practices associated with different objects may have been shared purely in the sense of being held in common: two sites with even rather different specific forms of ground stone still clearly share the kinds of practice that are associated with that kind of technology, specifically subsistence strategies prioritising the grinding of vegetable foods.

FIGURES 2A AND 2B ABOUT HERE

The distribution of particular forms of material culture between sites thus becomes a material reflection of some form of social relationship (in its widest sense) between those sites. Further, the range of different forms become the heterogeneous relationships connecting sites into multiple, heterogeneous interlinked networks. For example, the co-occurrence of ground stone pestles at different sites is recorded as a relation between those sites (regardless, in this analysis, of the *number* of pestles found), as is the co-occurrence of dentalium beads, female figurines, internal hearths etc. The result is a matrix in which the total number of different forms of material culture shared between any each pair of sites is treated as the strength of the relationship between them.

This use of valued relations is potentially somewhat problematic in that many formal methods of social network analysis are defined primarily for binary or dichotomous relations, where a relation is either present or absent. However, given the sheer quantity of different forms of material culture that formed part of this study, when dichotomised many of the social networks studied here simply collapsed to form maximally connected ('complete') networks where virtually all nodes were connected to virtually all others. Many applications of social network analysis to anthropological and archaeological situations avoid this problem by connecting nodes only to a specified number of their closest neighbours (often three; see e.g. Irwin 1983, 35-6; Hunt 1988, 137; Broodbank 2000, 180), and this will certainly be a feature of future analyses. However, for the purposes of the current paper it was deemed important to maximize the data, and relations are therefore valued: the specific implications of this are discussed in more detail at the appropriate points below.

Results

Mean distances between sites in each dataset generally increase over time (Figure 3; distance is measured here as geodesic distance, which simply equates to the value of the relations in the shortest path between every pair of sites). At the same time, the proportion of sites connected directly declines (figure 3; values range 0-1). However, a permutation-based ANOVA (see Hanneman & Riddle 2005 for discussion of why standard statistical tests should not be applied to network data, in which individual observations are not necessarily independent) found these variations between datasets were not statistically significant (10,000 permutations, 15 degrees of freedom: f-statistic 1.1640; r^2 0.045; $p = 0.0863$). This increase in distance may well be a function of the general increase in the size of the datasets over time (see table 1).

A corollary of this increase in distance is that individual sites become differentially connected over time. In general, the more ties an actor/site has, the more power they (may) have; autonomy makes an actor less dependent on any specific other actor, and hence more powerful. The number/value of an individual actor/site's ties (degree centrality) is thus a good measure of their 'centrality' in a network and hence (potentially) their power, and the variability in that measure over the network is a measure of how uniformly (or otherwise) power is distributed between sites. Network centralization measures (UCINET 6's routine for computing network centralization had to be adapted for valued data[vi]) track this variability by expressing the degree of variability in degree centrality outlined above as a percentage of the maximum possible variability in a network of the same size[vii] (Wasserman & Faust 1994; Hanneman & Riddle 2005). As figure 4 demonstrates, the trend in measures of network centralization is generally upward from 16-15,000 cal BC (the middle/late Epipalaeolithic, specifically late Kebaran/early Geometric Kebaran).

TABLE 1 ABOUT HERE

At the same time, however, the mean strength of the ties between sites (Figure 5) increases over time. A permutation-based ANOVA revealed highly significant statistical differences among the datasets (10,000 permutations, 15 degrees of freedom: f-statistic =

22.9658, r^2 = 0.484, p = 0.0001). Post hoc permutation-based t-tests (all at 10,000 permutations) using the 7-6kyr cal BC dataset as the dependent variable demonstrated that there were no significant differences between this dataset and those dating 12-7kyrs cal BC: tested against the 13-12kyrs cal BC p = 0.0446 and against all preceding datasets p = 0.0001.

Overall density of networks – the proportion of the maximum possible strength of ties that is realised – also, generally speaking, increases between 21,000 and 6,000 cal BC (Figure 6): a permutation-based ANOVA was highly significant (10,000 permutations, 15 degrees of freedom: f-statistic = 11.9362; r^2 = 0.328; p = 0.0001). Post hoc permutation-based t-tests (all at 10,000 permutations) found no significant differences between the 7-6kyrs cal BC datasets and those dating 11-7kyrs cal BC but significant differences with those dating to before 11kyrs cal BC (10-9kyrs, p = 0.0444; 13-12kyrs cal BC, p = 0.0134; 14-13kyrs cal BC, p = 0.0002; all preceding datasets p = 0.0001).

FIGURES 3-6 ABOUT HERE

The cause of this increase would appear to be the sheer diversity of forms of material of the later sites: when normalised for the number of different kinds of material culture contributing (using UCINET's 'marginal' normalising routine), the later datasets are indeed generally less dense and the strength of ties (degree) declines over time (Figures 7 & 8).

FIGURES 7 AND 8 ABOUT HERE

Discussion

The material component of social networks will of course only ever give a partial view of the wider social networks in which they are embedded: in addition to the perennial issues of differential preservation of different kinds of object, variable investigation, excavation and publication in different countries and regions etc, there may be many forms of relationship between groups, sites and individuals that do not have material correlates. Furthermore, the data presented here are restricted to the minority of sites that have been robustly dated, resulting in some very small datasets (particularly early on in the sequence).

In addition, a wide variety of different kinds of correspondences in material culture are treated together here which may in reality hide a similarly disparate repertoire of behavioural strategies, such as the physical trade of individual items; the movement of individuals with particular kinds of knowledge relating to manufacturing and technological traditions (perhaps through marriage networks); the spread of ideas, motifs etc. independent of any physical movement of items or people, and so on. Each of these practices may be associated with rather different kinds of networks and/or forms of material culture with their own distinctive properties, costs and benefits. However, it seems unlikely that such a fine-grained teasing apart of the individual factors involved in prehistoric material culture networks will ever be completely possible. The uncertainties in dating (each dataset here covers 1,000 years and thus many generations), coupled with the aforementioned sampling issues necessitates a broad view of the problem; clearly the networks presented here potentially subsume many more specialized sub-networks within them. However, that in itself will contribute to the patterns of increasing fragmentation, within-network distinctiveness and variability that are demonstrated here.

In short, the material networks investigated here represent *minimum* or maximally parsimonious starting points for investigating how the social networks of the Near East develop over the course of the Epipalaeolithic and early Neolithic. This makes it all the more interesting that several statistically significant trends have emerged: over time networks grow in size and become more dense, the mean strength of ties between sites (degree) becomes stronger while variability in the distribution of those ties (network centralization) increases, and connectivity between sites (distance) declines (although this last is not statistically significant).

There are therefore some very interesting comparisons to be made between the patterns demonstrated by these networks and those known from modern human and primate social networks; in general, larger social groups are less dense than smaller (see references in Lehmann et al this volume; Hanneman & Riddle 2005; Wasserman & Faust 1994).

The constraints on network size discussed by Roberts (this volume) may be significant here, and include:

1) Cognitive constraints on keeping track of dynamic patterns of interactions with different others (furthermore, increasingly *individualised* others with more divergent behaviours; Read this volume) as well as their interactions with one another, and

2) Time and energy constraints: relationships require continual maintenance if they are not to 'decay'. Competing demands on time and emotional intensity

> inevitably means that as the number of individuals in each hierarchical level (support, sympathy, band or active network) of the network increases, the level of emotional intimacy and frequency/intensity of interaction necessarily decreases.

As a result, it would seem that there may be an absolute limit to the number of friends and acquaintances any individual can maintain at different hierarchical layers. Various means of off-setting these costs and constraints have been suggested, most famously the expansion of the neocortex documented among primates and humans, which it would seem has allowed us to steadily increase the size of our social groups over time to the observed level of ~150 (‘Dunbar’s number’; Aiello & Dunbar 1993; Dunbar 2003, 1996, 1993). However, many modern humans live in much greater aggregations than this: indeed, since 2008 humans as a species have been a majority city-living species (UNFPA 2007). At the same time, however, it would seem that Dunbar’s number has remained a highly significant building block for the social groups of historical western humans and even *Homo urbanus* (e.g. Dunbar 1993, tables 1 and 2 684-686). Nor is there any evidence for further enlargement of the neocortex among city-dwellers, or of an increased ability to deal cognitively with ever-higher levels of intentionality.

In short, some additional strategies must be off-setting these costs and maximising the benefits of networks. Other papers in this volume have discussed some of these, including:

1) Categorical modes of thought, which simplify the cognitive load of social surveillance (see e.g. Read this volume regarding kin systems).

2) Specialised roles and individualisation: e.g. Roberts (this volume) discusses the role of ‘kinkeepers’ in acting as hubs for social surveillance of extended kin and the dissemination of relevant information to interested parties, thus lightening the demands on their time. Interestingly, ‘kinkeepers’ tend to be older females; there is some evidence to suggest that males and females maintain slightly different roles within social networks that reflect the different costs and benefits applicable to the different sexes but that also complement each other in terms of maintaining more extended social networks. Of course, more than gender distinguishes between individuals along more continua than gender; age and personality differences and increasing individualization (Read this volume) may also contribute to the complexity of overall social networks through greater variability between individual ego-networks (see e.g. Coward & Grove submitted for discussion).

3) Extended cognition: Rowlands (2003 e.g. 166; this volume) has argued that in ‘off-loading’ some aspects of cognition to the external world individuals can lighten their personal cognitive loads (the ‘Barking Dog’ principle; see Gamble this volume). Language may be one such strategy, allowing the enhanced sharing of ideas and information (see discussion in Gamble this volume). The *structure* of the networks of which individual relationships are a

> part may also lighten the cognitive load of maintaining them, as the positioning of any one dyadic relationship between two individuals may be variably held in place by its entanglement in the other relationships surrounding it (Roberts this volume).

The use of material culture is also highly pertinent here: as discussed above, the incorporation of non-human *things* into social networks allows for their other-than-human qualities – notably, in the case of material culture, the qualities of *durability*, *persistence* and *divisibility* (from humans; from other associated items of material culture and in and of themselves through practices of fragmentation; Chapman 2000, see Gamble 1998; this volume) – to be co-opted (or exapted) for the purposes of constructing and maintaining ever-greater social networks. As argued above, the use of material culture in this way would seem to date back to very early in the process of hominisation (see also Gamble and Roberts, this volume and *contra* the arguments for a late advent of material engagement discussed earlier).

All of these strategies would seem to be relevant for the analysis presented here: as noted above, the main reason that these Epipalaeolithic and early Neolithic networks increase in density over time is the sheer number of different forms of material culture contributing to those networks. When networks are normalised to compensate for this, density behaves as would be expected by decreasing as networks increase in size over time. Off-loading the cognitive costs of maintaining large social networks by extending social networks to include material culture may therefore be a crucial factor in the shift to village life that occurred during the Epipalaeolithic and early Neolithic of the Near East.

Ethnographic evidence suggests that in small-scale mobile societies, social networks tend to be open and ephemeral, with patterns of social interaction primarily organized around kinship and close physical proximity: 'Within a small group of individuals such as a hunter-gatherer residential groups ... there are fairly direct and unambiguous links between each individual' (Whitelaw 1991, 182). Daily hunter-gatherer life generally occurs in full view, with most time spent within range of intimate and personal distance of one another (Wilson 1988). Knowledge of one another is therefore multiplex, personal and biographical, and the social networks involved are what Hillier and Hanson refer to as 'dense encounter sets' (1984, 27): interactions occur repeatedly between the same individuals, who by virtue of their common enmeshment within the same matrix of relationships, will share (at least to some degree) a common way of life (Lofland 1973).

Of course, even in larger and/or less mobile groups there will be groups of kin or individuals whose closeness results in frequent intimate and personal interactions and mutual knowledge. However, these clusters of strongly-related individuals must maintain relations with other such clusters in their wider community unless the group as a whole is to fission – an option that obviously becomes less feasible almost by definition as groups become more sedentary. Furthermore as groups increase in size it is inevitable that any one individual will encounter any other less frequently; larger societies are inherently less dense 'encounter sets' than smaller (Hillier & Hanson 1984, 27) with concomitant increases in the cognitive, temporal and energetic costs outlined above. Sociologists have noted that one strategy which may off-set some of these costs by reducing the potential 'overload' of information is the simplification of some relationships (Lofland 1973; Milgram 1977). Of course, there is always the potential to invest more in any relationship, but in large-scale societies any individual can only afford to have 'weak ties' with the majority of people he/she interacts with: categorical rather than biographical relationships (Granovetter 1973, 1983; Lofland 1973; Milgram 1977; see also Read this volume). It is these weak ties that are crucial for maintaining the links between dense kin- and proximity-based groups and that make the difference between fission or growth of social groups – however, alongside the cognitive ability to deal with categorical relationships discussed above, weak ties also require some cognitive mechanism for adjustment to the fracturing of co-presence and personal knowing (Lofland 1973; Whitelaw 1991, 158).

One such mechanism, and perhaps the most important for explaining how the networks of the Epipalaeolithic and early Neolithic can become larger, more fragmented and yet simultaneously denser, is the increasing incorporation into these networks of material culture. In small, dense groups the intimate and personal relations between strongly-associated individuals means that they 'share, to some degree, a particular understanding of the world' (Douglas 1973, 78; Coser 1975, 254; DeMarrais et al. 1996). As a result, communication codes in a variety of modes may be more restricted, such that 'more meanings are implicit and taken for granted as the speakers are so familiar with one another' (Bernstein cited Coser 1975, 254). However, while such dense and complex relations of course continue to exist in larger groups they do so alongside more simplified interactions, and the individuals participating in these do not have intimate personal knowledge of one another by which to judge their embodied performances. Communication in these more fragmented networks requires *elaborated* forms of communication (Bernstein cited Granovetter 1973, 1983). In these situations, there is generally a greater emphasis on spatial and environmental cues to define what Goffman (1959) calls ‘settings’ through the elaboration of material culture, effectively ‘distributing’ the information required for social cognition and effective performance into the physical and material world (Lofland 1973, 82-3; Rapoport 1981, 30; 1990, 16; Sanders 1990, 71) – hence the general association of greater degrees of formal segregation and organisation of space in larger societies and particularly among sedentary agriculturalists, despite some exceptions such as the Mongols (Kent 1990; see also Rapoport 1969; Donley-Reid 1990, Whitelaw 1991; 1994, 238). Perhaps, then, the changing material culture networks of the Epipalaeolithic and early Neolithic described above represent a gradual shift from ‘the tribal human confronting, with fear and suspicion, the infrequent stranger ... [to] ... the cosmopolitan human confronting, with ease and ability, the constant stranger’ (Lofland 1973, xi).

However, it is important to note that the two organising principles – kin and restricted communication/material culture codes and weakly-linked acquaintances and elaborated codes – are not mutually exclusive but present to some degree in all modern human societies. For example, among Central Australian Aboriginal groups, the emphasis between the two forms of integration varies both by season (relating to differences in resource structure and mobility) and, more fundamentally, by sex, with women more inclined to form close clusters and men to act as ‘weak links’ between these (Hillier & Hanson 1984, 236; see also Postmes et al. 2005). Interestingly, this pattern has also been noted among primate groups (e.g. Kudo & Dunbar 2001; see also Roberts' notes on 'kinkeepers', this volume). As Lofland concludes, '*The cosmopolitan did not lose the capacity for knowing other personally. But he gained the capacity for knowing others only categorically*' (1973, 177, italics in original; see also Read this volume).

In short, then, we should be cautious about heralding the changes in social networks suggested by the analysis presented here as revolutionary. They are more likely to relate to a shift of emphasis in the kinds of social strategies pursued and the kinds of resource utilised by individuals – adding those associated with weaker, categorical social relations to the repertoire of resources used in multiplex and personal relationships that are part of our primate heritage or that had developed during the process of hominisation (Coward & Gamble 2008).

In fact, very similar patterns have been documented in primate social networks. Lehmann et al (this volume) describe primate social networks becoming increasingly more fragmented (less dense and less well-connected) among species with larger neocortices (which is of course in turn highly correlated with group size; Dunbar 1992, 1993; Aiello and Dunbar 1993); Lehmann et al suggest that low levels of density and connectivity and greater fragmentation (more, more distinctive grooming 'clans' or densely-clustered sub-groups) can be used as an operational definition of social complexity. Furthermore, they find that it is neocortex size, rather than group size *per se*, which is more strongly related to density; primates with bigger brains tend to be those species who are better at finding cognitive strategies for linking up small, dense kin-based clusters with 'weak links'. Layton and O'Hara (this volume) further discuss some of the ecological characteristics that distinguish humans from other primates, suggesting that greater reliance on meat-eating among humans necessitates much lower population densities: larger group sizes, but spread over much greater areas. They suggest that this would have required mechanisms for sustaining reduced frequency of direct interaction with acquaintances than is the case for primates.

The overall direction of these developments, therefore, appears to be towards the so-called ‘small-world’ phenomenon, where path length (the distance between any two nodes) is small and ‘clustering’ (the tendency of the ‘nodes’ to form small, dense groups), is high; the formation of such networks is governed by the probability of nodes being connected outside of their immediate group – i.e. by the proportion of ‘weak’ connections between dense groups (Watts & Strogatz 1998; Newman 2000, 2001; Buchanan 2002; Watts 2003). The result of this process – where highly-connected individuals enjoy the so-called ‘six degrees of separation’ effect – is such a robust and efficient structure for a dynamic network that it has been identified in real-world situations ranging from power grids to ecological foodwebs to the neural network of the nematode worm *Caenorhabditis elegans* and, famously, the structure of the world wide web (see e.g. Buchanan 2002; Watts 2003 for discussion and references). Among humans – and primates more generally – the benefits of moving towards such a ‘small world’ social organization may be its efficiency in terms of time and energy (as well as cognitive effort), and its structural flexibility, simultaneously allowing for small groups of close (supportive) others and broader circles of overlapping but individualized (thus reducing competition) more distant others who allow navigation of the wider social world. These wider social networks may have fulfilled a variety of functions, perhaps most importantly reducing risk by tapping into a wider range of natural and social resources through trade, marriage etc.

Conclusion

The analyses presented here demonstrate some interesting trends in the material culture component of social networks over the course of the Epipalaeolithic and early Neolithic of the Near East between 21-6,000 years cal BC. Mean tie strength between sites increases over time and becomes more variable, connectivity decreases and overall density of networks increases. Interestingly, however, when networks are normalised for the variety of different forms of material culture contributing to them, density actually decreases over this period.

These developments echo those documented among primates more generally, as well as among modern human groups, and appear to represent new strategies for off-setting the increased costs associated with maintaining relationships among larger groups living firstly at lower population densities in the case of mobile hunter-gatherers (Layton & O'Hara this volume) and more recently at higher densities. Off-loading demanding cognitive tasks through such strategies as language (almost certainly in place by the speciation of *Homo sapiens*, *contra* Humphrey 2007) and the incorporation of material culture into social relations has allowed human social relationships to become ever more extended in space and time. However, there is nothing deterministic about this process: the specific format of social network varies locally between and even within different groups. The tension between early and late chronologies is therefore a blind alley. As Mellars pointed out in reference to the Neanderthal/modern human debate, ‘There seems to be an irresistible urge to polarize scientific debate into extreme positions. The truth is rarely that simple’ (1996, 8).

While there may certainly be inflections in the general trend in particular times and places (the so-called ‘creative explosion’ of the Last Glacial Maximum in Europe, the early Neolithic of the Near East?) the trajectory of hominisation appears to be towards greater social complexity measured in terms of the increasing ability to forge and maintain weak links between the small tightly-bonded groups that are our primate heritage.

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Figure 6: Density

Figures 7 and 8: Declining network density and degree when normalised for the number of contributing forms of material culture.

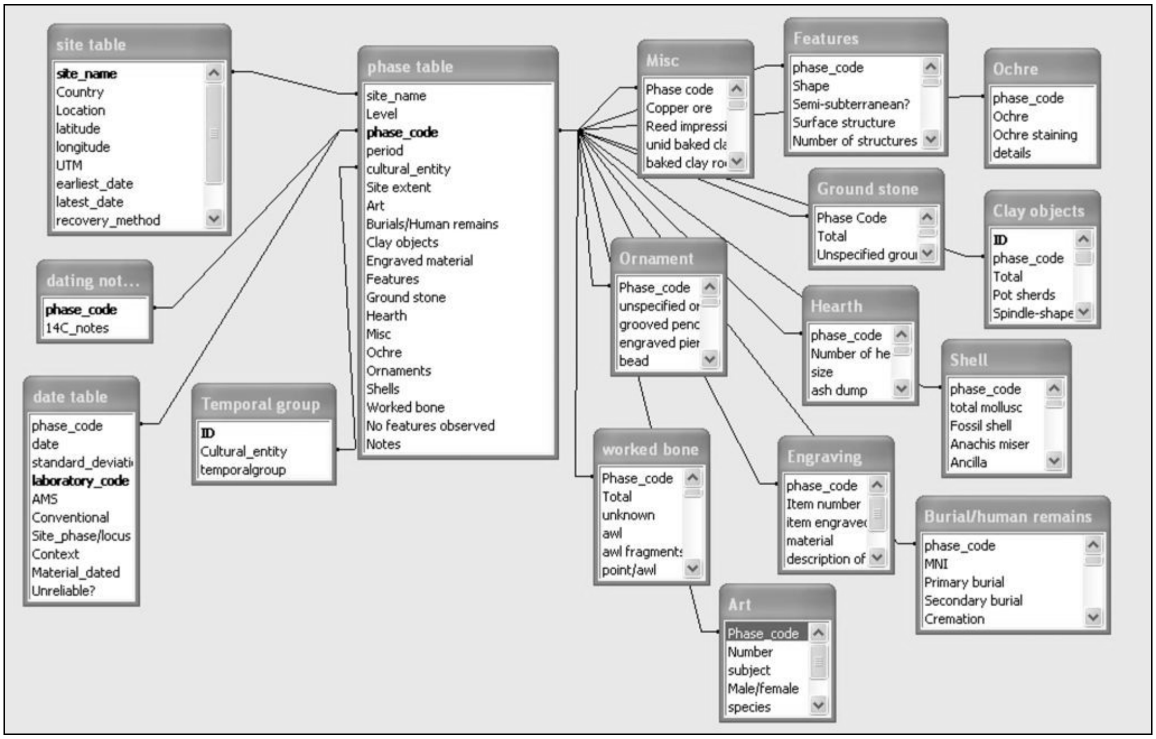
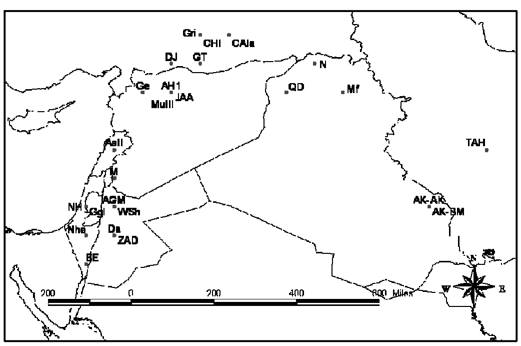
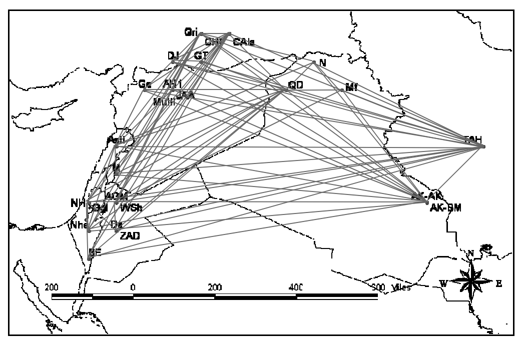


Figure 1: Structure of the database.





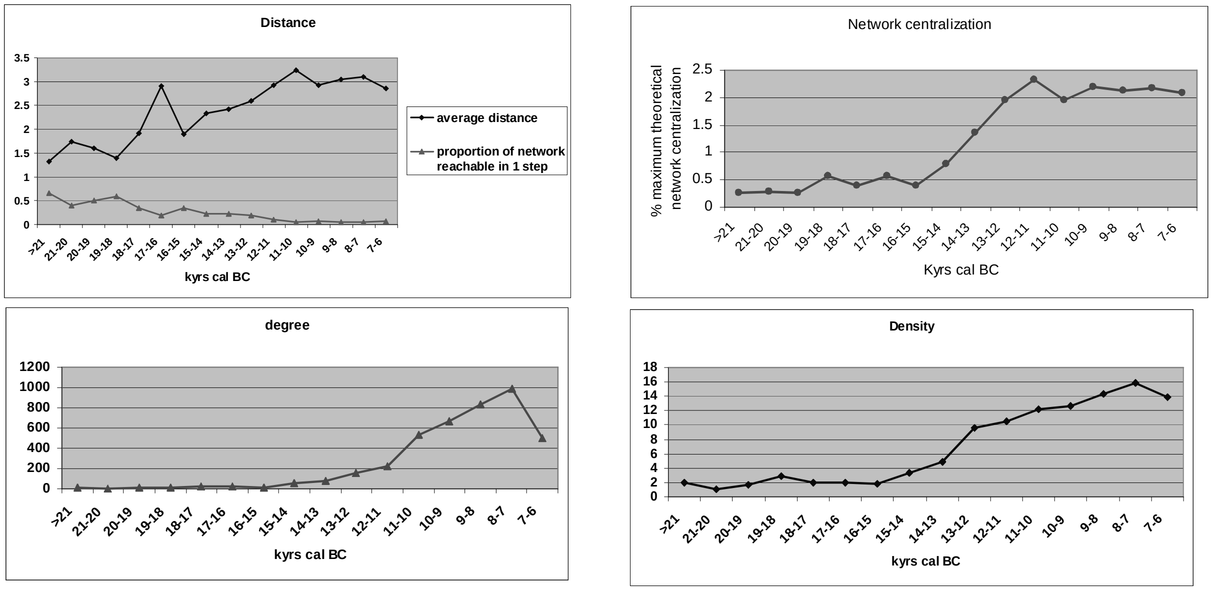
Figures 2a (left) and 2b (right): Presence of pestles in sites dated 9-8,000 cal BC: sites as nodes, co-occurrence of material culture as ties.

Kyrs cal BC	No. sites	Sites
>21	4	Ohalo II; Rakefet Cave XIII; Uwaynid 18 upper; Wadi Hammeh 26
21-20	6	Haon II level 3; Nahal Oren Terrace VIII, IX (Noy); Ohalo II; Rakefet Cave XIII; Uwaynid 18 upper; Wadi Hammeh 26
20-19	5	Haon II level 3; Nahal Oren Terrace VIII, IX (Noy); Ohalo II; Rakefet Cave; Wadi Hasa 1065 B-E
19-18	6	Haon II level 3; Nahal Oren Terrace VIII, IX (Noy); Ohalo II; Wadi Hammeh 31; Wadi Hasa 1065 B-E; Wadi Jilat upper phase A
18-17	13	Ein Gev I levels 3 & 4; Haon II level 3; Hamifgash IV; Kharaneh IV D; Mdamagh; Nahal Oren Terrace VIII, IX (Noy); Ohalo II; Rakefet Cave XIII; Urkhan e-Rubb IIa; Wadi Hammeh 31; Wadi Hasa 1065 B-E; Wadi Jilat 6 Upper phase A
17-16	11	Ein Gev I levels 3 & 4; Ishkaft Palegawra lower; Kharaneh IV D; Mdamagh; Mushabi XIV 1; Mushabi XVII; Nahal Oren Terrace VIII, IX (Noy); Urkhan e-Rubb IIa; Wadi Jilat 10; Wadi Jilat 6 Upper phase A
16-15	7	Ishkaft Palegawra lower; Kharaneh IV D; Mdamagh; Mushabi XIV 1; Mushabi XVII; Urkan e-Rubb IIa; Wadi Jilat 10
15-14	17	Ain Mallaha III, IV; Beidha natufian; El Wad B2; Ishkaft Palegawra lower; Wadi Judayid J2 C; Mdamagh; Mushabi I; Mushabi XIV 1; Mushabi XVII; Neve David; Nahal Zin D5; Urkan e-Rubb IIa; Wadi Jilat 10; Wadi Jilat 22 C & E; Wadi Jilat 8
14-13	18	Ain Mallaha III, IV; Beidha natufian; El Wad B2; Hayonim Cave B; Ishkaft Palegawra lower; Wadi Judayid J2 C; Mdamagh; Mushabi I; Mushabi V; Mushabi XIV 1; Mushabi XVI; Mushabi XVII; Neve David; Nahal Zin D5; Salibiya I; Wadi Jilat 10; Wadi Jilat 22 E; Wadi Jilat 8
13-12	17	‘Ain Ghazal MPPNB; Ain Mallaha III, IV; Beidha natufian; El Wad B2; Hayonim Cave B; Hayonim Terrace B, C/D; Wadi Judayid J2 C; Mushabi V; Mushabi XIV 1; Mushabi XVI; Neve David; Nahal Sekher 23; Qermez Dere; Salibiya I; Tor Hamar A-E1; Wadi Hammeh 27; Wadi Jilat 10
12-11	22	‘Ain Ghazal MPPNB; Tell Abu Hureyra 1; Ain Mallaha III, IV; Beidha natufian; El Wad B2; Hayonim Cave B; Hayonim Terrace B, C/D; Ishkaft Palegawra lower; Jarmo aceramic JI8-6, JAIII, IV, V; Wadi Judayid J2 C; Jericho Natufian; Kebara Cave B; Nahal Sekher 23; Qermez Dere; Rakefet Cave Natufian; Rosh Horesha; Saflulim; Salibiya I; Shinera IV; Wadi Hammeh 27; Zawi Chemi Shanidar B
11-10	45	‘Ain Ghazal MPPNB; Tell Abu Hureyra 1; Ali Kosh (Ali

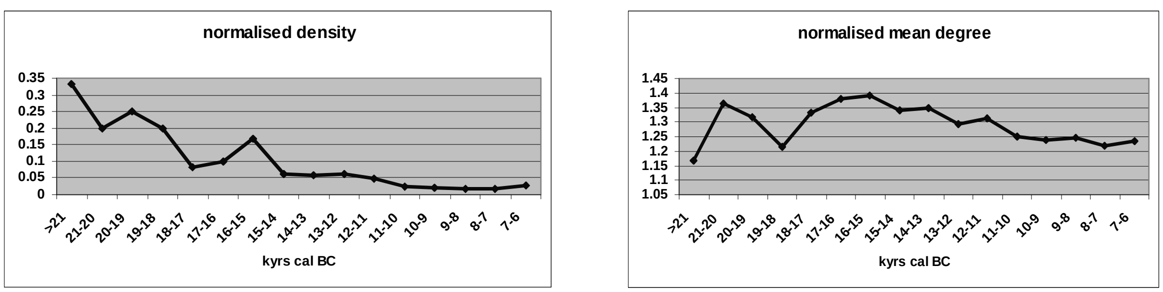
		Kosh, Bus Mordeh); Abu Madi 1 5-12; Ain Mallaha Ic & III/IV; Beidha natufian; Çayönü Ia (round buildings); Dhra PPNA; Dja'de; El Wad B1 & 2; Ganj Dareh Tepe E; Gilgal I; Hallan Çemi Tepesi; Hayonim Terrace B, C/D; Jarmo aceramic JI8-6, JAIII, IV, V; Wadi Judayid J2 C; Jericho Natufian; Kebara Cave B; Munhata; M'lefaat; Maaleh Ramon East; Maaleh Ramon West; Tell Mureybet IA & IB & II & III; Nemrik; Neve David; Netiv Hagdud; Nahal Oren Terrace V/VI (Noy); Qermez Dere; Rakefet Cave Natufian; Ramat Harif; Rosh Horesha; Saflulim; Salibiya I; Shanidar B1; Shunera IV; Wadi Shu'eib; Zawi Chemi Shanidar B
10-9	53	'Ain Ghazal MPPNB; Tell Abu Hureyra 1 & 2A; Ali Kosh (Ali Kosh, Bus Mordeh); Abu Madi 1 5-12 & 1-4; Ain Mallaha Iab & Ic & III/IV; Abu Salem; Beidha natufian; Çayönü Ia (round buildings); Cafer Höyük III; Dhra PPNA; Dja'de; El Wad B1; Ganj Dareh Tepe D-A & E; Gesher; Gilgal I; Hallan Çemi Tepesi; Halula I/II levels 1-20; Hayonim Terrace B, C/D; Iraq ed Dubb II; Jerf el Ahmar I/W, -1/-II/E; Jericho I & II & Natufian; Munhata; M'lefaat; Maaleh Ramon West; Tell Mureybet IA & II & III & IV; Nemrik; Nevali Çori; Netiv Hagdud; Nahal Hemar; Nahal Oren Terrace V/VI (Noy); Qermez Dere; Ramat Harif; Rosh Horesha; Shunera IV; Tepe Abdul Hosein; Wadi Shu'eib; Zahrat adh-Dhra; Zawi Chemi Shanidar B
9-8	59	'Ain Ghazal MPPNB; Tell Abu Hureyra 1 & 2A; Ali Kosh (Ali Kosh, Bus Mordeh); Abu Madi 1 5-12 & 1-4; Ain Mallaha Iab & Ic & III/IV; Asiab; Tell Aswad IA & IB & II; Beidha Neolithic; Çayönü Ia (round buildings) & IB (grill/channel buildings) & IC (cobble-paved buildings); Cafer Höyük I & II & III; Dhra PPNA; Dja'de; El Aoui Safa; El Kowm II; Ghwair 1; Ganj Dareh Tepe D-A & E; Gesher; Gilgal I; Tell Ghoraifé IA; Gritille A-D; Göbekli Tepe; Hallan Çemi Tepesi; Horvat Galil; Halula I/II levels 1-20; Jarmo acermaic JI8, JAIII/IV/V; Jerf el Ahmar VII-oE, IV-III/W & I/W, -1/-II/E; Jericho I & II; Munhata; M'lefaat; Motza; Tell Mureybet III & IV; Nemrik; Nevali Çori; Nahal Divshon; Netiv Hagdud; Nahal Hemar; Nahal Oren Terrace V/VI (Noy); Qermez Dere; Shunera IV; Tepe Abdul Hosein; Tepe Guran D-V; Wadi Jilat 26; Wadi Jilat 7 II; Wadi Shu'eib; Yiftah'el; Zahrat adh-Dhra
8-7	63	Ain Abu Nekheileh; 'Ain Ghazal LPPNB & MPPNB; Tell Abu Hureyra 1 & 2A & 2B; Ali Kosh (Ali Kosh, Bus Mordeh); Akarçay Tepe all PPNB; Asiab; Tell Aswad IB & II; Azraq 31; Beidha Neolithic; Bouqras; Çayönü Ia (round buildings) & IB (grill/channel buildings) & IC (cobble-paved buildings); Cafer Höyük I & II & III; Dja'de; El Kowm II;

		Er-Rahib; Es-Siffiya; Ghwair 1; Ganj Dareh Tepe D-A & E; Tell Ghoraifé IA & II; Gritille A-D; Göbekli Tepe; Horvat Galil; Halula I/II levels 1-20; Jarmo acermaic JI8, JAIII/IV/V; Jericho I & II; Kfar HaHoresh; Munhata; Motza; Tell Mureybet IV; Magzalia; Nemrik; Nevali Çori; Nahal Divshon; Nahal Hemar; Nahal Issaron C; Qdeir 1; Tell Ramad I; Tell Ras Shamra Vc1-3; Tepe Abdul Hosein; Tell Damishliyya 1-7; Tell es-Sinn; Tepe Guran D-V; Wadi Jilat 26; Wadi Jilat 7 II; Wadi Shu'eib; Yiftah'el
7-6	37	Ain Abu Nekheileh; 'Ain Ghazal MPPNB; Tell Abu Hureyra 2A & 2B; Ali Kosh (Ali Kosh, Bus Mordeh); Bouqras; Çayönü Id (cell plan/large room buildings); Cafer Höyük I; El Kowm I lower & II; Er-Rahib; Es-Siffiya; Ganj Dareh Tepe D-A; Tell Ghoraifé IA & II; Gritille A-D; Halula I/II levels 1-20; Jarmo acermaic JI8, JAIII/IV/V; Khirbet Hammam; Kfar HaHoresh; Laboureh A1, bottom of B; Munhata; Motza; Nahal Divshon; Nahal Hemar; Nahal Issaron C; Qdeir 1; Tell Ramad I; Tell Ras Shamra Vc1-3; Tepe Abdul Hosein; Tell Damishliyya 1-7; Tell es-Sinn; Tepe Guran D-V; Tell Sabi Abyad II; Tell Seker al-Aheimar; Wadi Shu'eib

Table 1: The datasets



Figures 3: Distance (top left); 4: Network centralization (top right); 5: Degree (bottom left); 6: Density (bottom right).



Figures 7 and 8: Declining network density and degree when normalised for the number of contributing forms of material culture.

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i http://ads.ahds.ac.uk/catalogue/collections/blurbs/452.cfm

ii http://www.tayproject.org/enghome.html

iii http://www.canew.org/

iv http://context-database.uni-koeln.de/site.php

v http://c14.arch.ox.ac.uk/embed.php?File=oxcal.html

vi ((r(g-1))-r)(g-1) where g=number of actors; r=number of relations

vii that of a 'star graph' whose degree centrality is given by (g-1)(g-2) where 'g' is the number of actors in the network