Cognitive and Network Constraints in Real Life and Literature

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Abstract Storytelling has played a major role in human evolution as a mechanism for engineering social cohesion. In large measure, this is because a shared worldview is an important basis for the formation not just of friendships but, more generally, of social communities. Storytelling thus provides the mechanism for the transmission of shared cultural icons and shared histories within a community. That being so, the effectiveness with which stories do their job is likely to be related to the storyteller's ability to make challenging yet realistic stories without overtaxing the listeners' abilities to comprehend the narrative. I summarise some of the constraints likely to act on this both in terms of community size and organisation and in terms of cognition, and explore their implications for storytelling.

Storytelling, in its many different forms, has played a central role in human evolution. Although we might distinguish, in this respect, fictional storytelling round the campfire from myths and religion, and from science (understanding the world), all of these involve someone offering an account of some virtual world that we do not directly experience. At some level or other, all of them have important advantages in that they allow individuals to acquire an understanding of how and why the world is as it is, and hence offer an important knowledge base for controlling their world. In addition, however, the first three provide particularly important benefits in terms of community cohesion. The stories that we know and love because we heard them so often at our mother's knee or, later, round the campfire, the myths that detail our origins as a community and why we share a common heritage, or the religious framework that we all sign up to—all mark us out as members of a particular community. Our shared understanding of why we are different from "that lot over the hill", our shared belief in a particular social or religious convention, identify us out as members of a specific community, and this

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helps to bond us as a group. Indeed, it turns out that these same features are the ones that determine the strength of our individual friendships (Curry and Dunbar 2013).

My main concern here, however, is not so much with the functional benefits that derive from storytelling in these many different forms, but rather with the psychological underpinnings that make them possible. Storytelling is possible at all only because we are willing to sit and listen to someone else (almost always in the singular) telling us something. We learn from that experience, and gradually build up a matrix of shared knowledge. That shared knowledge allows us to increase the efficiency of speech because we do not have to spell out everything on every occasion. Instead, we assume that we all understand the background, and this allows most of our conversations to consist of passing allusions and to be extraordinarily telegraphic as a result—full of circumlocutions and half-articulated assertions, unfinished sentences and obscure metaphors. I know that you can fill in the missing gaps because we share a common framework within which all this will make perfect sense—and complete nonsense to those who aren't members of our community, further allowing us to draw a clear line between us and them.

Our ability to understand story telling has, hitherto, been limited by lack of adequate tools to explore some of the underlying complexity in the psychological processes involved in storytelling. My claim will be that new developments in psychological theory and statistical analysis (notably network analysis methods) offer opportunities for novel insights beyond those that more conventional literary methods allow.

There are a number of important psychological constraints on what is possible in the context of storytelling. These have to do with the three separate features of our psychology. One is that our stories, or at least our fictional stories, should not be too far removed from real life. This can take a number of different forms, each of which is important in itself. The closer a story mirrors real life the more persuasive it is likely to be. We can tolerate some slippage, in that slight exaggerations of real life seem to be especially engaging, but the slippage cannot be too large or it all becomes implausible. This is essentially the idea of minimally counterintuitive concepts, originally developed in the cognitive science of religion: we are more likely to believe that our heroes can break the laws of physics (e.g. walk on water or pass through walls), but not by too much or it becomes implausible. And, of course, what our heroes can do we mere mortals cannot because we are subject to the full force of everyday physics. So things that are slight exaggerations push buttons for us, but there is a fine balance between the plausible and the implausible.

There is a second way in which the constraints of everyday reality are important, and this is in terms of how stories are structured, especially in respect of their network structure. If this deviates from the natural structure of everyday social networks, the story is likely to become incomprehensible because it overloads our ability to keep track of who is doing what with whom. Network methods may be able to provide us with novel insights into story structure because they reduce some of this natural complexity to simpler, more easily understood indices. Applications of network analysis methods to literature have been few and far between, but the approach has considerable potential because these methods have the capacity to provide insights into the structure of stories in ways that typically cannot be done by the more conventional methods of literary criticism.

The third class of cognitive constraint concerns the role of mentalising in our ability to create and understand exciting storylines. Mentalising, or mindreading, is the ability to understand what another individual believes about the world. The concept of mindreading has its origins in philosophy of mind, where the ability to understand one's own and others' intentions was seen as an important feature of the human condition (the so-called *intentional stance*: Dennett 1978). Formalised as "having a theory of mind" (or simply "theory of mind" for short), it identified the fact that I have a belief about your mindstate (your beliefs or intentions) as being central to many of our social interactions. These mindstates are associated with the use of intentional words—the class of words like "believe", "suppose", "intend", "wonder", and "think" that refer to the mind doing what we might think of as "serious work". Acquiring theory of mind (i.e. the ability to recognise that someone else has a belief about the world, and in particular one that may be different from my own belief) is something that happens quite early on in childhood (typically around the age of 5 years).

The capacity to mentalise is in fact recursive, potentially infinitely so (Dennett 1978), in the sense that A can *believe* that B *supposes* that C *wonders* whether D *intends* . . . and so on for as long as one might wish (with the individual intentionality terms italicised). Although this sequence could go on forever, in practice there appears to be a natural limit at five minds (including your own as the reader) imposed by the capacities of the human mind. Each of these belief states is defined as a level (or order) of intentionality. Understanding my own mind is equated with first order intentionality; understanding someone else's mindstate is second order; and the example I gave above is fifth order (with your mind as reader as the anchor: when you read it, you *realise* that A *believes* . . . .etc). Not only does this place a limit on the complexity of the sentences we can construct, but also, seemingly, on the number of different individuals one can have in a conversation.

I will consider each of these approaches in turn, and, on the basis of the examples I offer, try to provide some evidence that investing more heavily in all three will pay dividends.

Reality-Mining in Literature

Let me first illustrate how reality intrudes into storytelling, at least when those stories purport to tell us about events in the real world. Purely mythical stories are usually prefaced with some cues that they concern people or events that happen outside the confines of everyday experience. In contrast, stories that that are about everyday events or even real historical events must abide by the conventional experiences of that realm. The Icelandic family sagas, mostly composed in the late twelfth and early thirteenth centuries, detail genuine historical events, but, as is inevitable with early historical documents, with a variable degree of elaboration and exaggeration. The opportunity for exaggeration notwithstanding, the authors of these histories write with remarkable consistency in ensuring that their stories fit with what we would expect from real life. Hamilton's (1964) theory of kin selection, for example, is one of the central pillars of modern evolutionary theory and states that individuals will behave in such as way as to favour their relatives over unrelated individuals, unless the benefits to the actor of doing so favour the unrelated individual. In an analysis of two major sagas, *Njalssaga* and the *Orkneyingasaga*, we found that the murders reported in the sagas followed this pattern: when the benefits of the murder were low (following a spontaneous fight after an insult or a drunken brawl) close relatives were much less likely to be murdered than unrelated individuals, but when the benefit from the death was significant (acquisition of land, or inheriting an earlship) close relatives were not spared (Fig. 1).

Kinship is important in human affairs because kin are the one group of people who will come to one's aid come what may. This is a simple consequence of Hamilton's theory of kin selection: evolution drives a willingness to behave altruistically towards kin in a way that does not happen towards non-kin (a claim supported by considerable empirical evidence: see, for example, Madsen et al. 2007 and references therein). Kin provide an important source of support in dangerous contexts, such as when one is under attack or wants to attack others. One example of that is provided by evidence from the sagas that individuals were willing to commit murder only when they had more kin available to come to their support than their victims did (Fig. 2). They were seemingly not prepared to risk murdering someone if that individual had a large number of relatives in Iceland, because relatives were entitled to pursue revenge strategies or make claims against the murderer.

These twoexamples provide some evidence that storytellers cannot stretch the bounds of real world plausibility, even if that would suit the purposes of the story

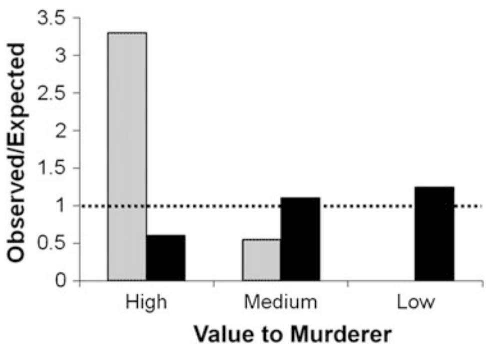

Fig. 1 Relative frequency with which individuals murdered others as a function of whether they were kin (related as paternal cousins or closer) (*hatched bars*) or not (*black bars*) and the benefit obtained by the murderer. Relative frequency is the observed number of murders divided by the number one would expect if murderers were distributed at random across the population. High benefit includes acquisition of land or titles; low benefit refers to murders arising from trivial altercations like insults or drunken brawls. Redrawn from Dunbar et al. (1995a)

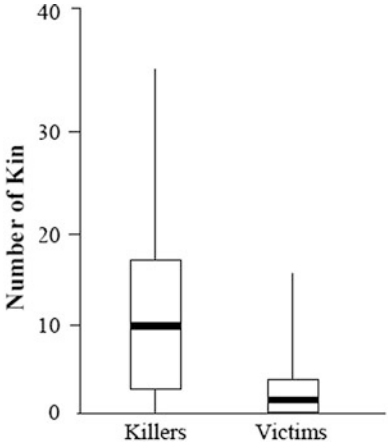

Fig. 2 Number of kin for murderers and their victims in three Icelandic sagas (*Njal's Saga*, *Egil's Saga* and the *Laxdaela Saga*). The *thick black line* gives the median; the *box* gives the distribution of the 50 % of values closest to the median; and the *whiskers* the distribution of 95 % of the data. *Source*: Palmstierna et al. (2016)

they want to tell. They have to stick within what is plausible and reasonable if they are to carry their audience with them.

Natural Network Structure

Human social networks have a very distinctive structure. If you rank all the members of your network in a linear sequence based on the emotional intensity of your relationship with them, they naturally fall into distinct sets that comprise, successively, 5, 10, 35 and 100 individuals. When these are progressively added together, they comprise a natural series that has a very distinct scaling ratio of three: in other words, each circle is about three times larger than the circle inside it (5, 15, 50, 150). This pattern reappears in many different social contexts, ranging from personal offline (Hill and Dunbar 2003; Zhou et al. 2005) and online social networks (Passarella et al. 2012; Arnabaldi et al. 2013) to the natural organisation of hunter gatherer societies (Hamilton et al. 2007) and the community structure of online gaming worlds (Fuchs et al. 2014).[1] In part, this distinctive structure is created by how we divide our available time among the various members of our social networks (Sutcliffe et al. 2012a, b). These structural constraints have important implications for the way personal social networks are structured, since they place limits on, for example, indices like the connectivity of the individuals in a network.

Another important constraint on the size of natural human groups is the limit on conversation group sizes. These turn out to have a very consistent upper limit at four individuals (Dunbar et al. 1995b; Dezecache and Dunbar 2012). It seems that we

[1]Editors' note: See, also, the Chapter "Analyses of a Virtual World" by Holovatch, Mryglod, Szell and Thurner.

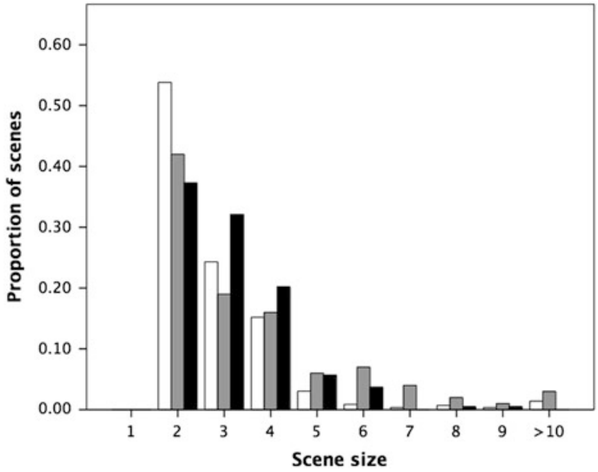

Fig. 3 Proportion of scenes of different size in 12 'hyperlink' genre films (*white bars*), 10 Shakespeare's plays (*grey bars*) and natural conversations (*black bars*). *Sources*: Krems and Dunbar (2013), Stiller et al. (2004) and Dezecache and Dunbar (2012), respectively

are unable to maintain a coherent conversation with more than four people for any length of time: a conversation that acquires a fifth person very quickly breaks up into two sub-conversations, often with constantly revolving membership as individuals switch from one conversation to another. It is not clear what imposes this limit, but it may have to do with the number of different mindstates we can keep track of at any one time (Krems et al. 2016).

Figure 3 plots the distribution of conversation sizes in 193 natural conversations, 10 of Shakespeare's plays and 12 'hyperlink' genre films. (Hyperlink films are a genre of films that seek to break through the natural limits on communication such that individuals' behaviour can influence each other even though they are in different times and places. They include films like *Crash*, *Babel*, *Love Actually*, *Traffic*, etc.) For the plays and films, a conversation is defined as a scene, with a new 'scene' starting whenever a character left or joined an existing conversation. These three very different kinds of data have virtually identical patterns. In all three cases, 85 % of conversations contained four or fewer individuals (or characters), and 90 % contain five or fewer. It seems that neither Shakespeare nor modern scriptwriters are willing to break the patterns seen in natural conversations. I suggest that this is because, if even if they could do it themselves, they would rapidly lose their audiences.

Figure 4 plots the clustering coefficient for the hyperlink film sample, along with the mean values for the 10 Shakespeare plays, a set of 10 contemporary romantic genre films (examples include *A League of Their Own*, *First Wives Club*, *Pride and Prejudice*, *Sex and the City* and *The Sisterhood of the Traveling Pants*), and the plays of the Russian playwright Anton Chekov and the Irish playwright George Bernard Shaw. The clustering coefficient is the probability that if A is linked to B and B

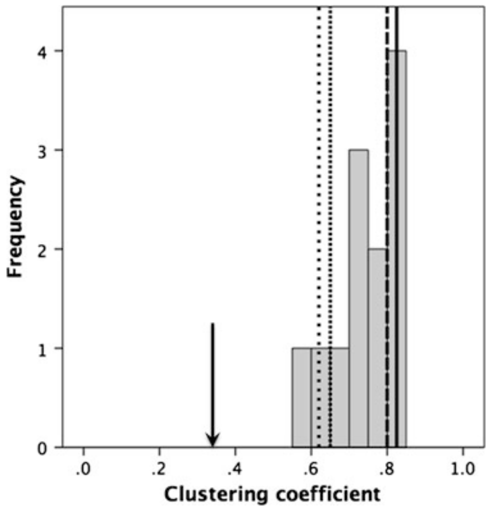

Fig. 4 Frequency of clustering coefficients in 12 individual hyperlink films (*bars*). Also plotted on the graph are the mean values for 10 Shakespeare plays (*solid vertical line*), 10 romantic genre films (*dashed line*), Chekov's plays (*fine dots*) and the plays of George Bernard Shaw (*spaced dots*). The *arrow* marks the equivalent frequency in real life networks. *Source*: Krems and Dunbar (2013)

is linked to C (i.e. have appeared together in the same conversation/scene), then A and C will also be linked. In real world networks, this kind of triad, in which all three connections are positive, are particularly common, and account for about a third of all relationship triads in both real life (Leskovec et al. 2010) and online gaming environments (Szell et al. 2010). Note the high proportion of such triads in the drama samples (far higher in fact than in normal everyday networks, demarcated by the arrow), and the broad similarity between the five different genre of drama. Nonetheless, both Chekov and Shaw have relatively low values compared to the other three, though still well above the norm for everyday networks. This suggests that these two nineteenth century dramatists typically used a more diffuse network structure than did either Shakespeare or contemporary film scriptwriters. Whether this reflects the particular subject matter of their plays, or the structural design they imposed on the action in their plays, remains to be determined.

This broad similarity does not, however, extend to all network indices. Figure 5 plots the density of ties (the number of direct connections that each character has) in these same films and plays. Hyperlink films clearly differ strikingly from the other genre in having a much lower proportion of directly connected characters (characters that appear together in conversations), despite the fact that they don't differ that much in total cast size from, at least, the Shakespeare plays. Chekov and Shaw plays have a particularly high density, mainly because they have relatively small cast lists compared to the other genres.

The effect of cast size on density is illustrated in Fig. 6a for the Shakespeare plays. Essentially, density declines as the number of characters increases (Pearson correlation $r = -0.877$, $p = 0.001$, indicating a very strong negative relationship). In part, of course, this is simply a consequence of the fact that 'conversation' group size and degree (the number of individuals each character is directly connected to) remain constant despite increases in cast size. There is some suggestion that this

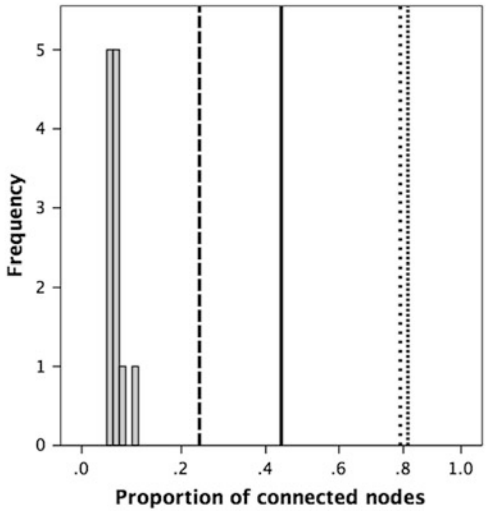

Fig. 5 Frequency distribution of the density (proportion of connected nodes) in hyperlink genre films. Also plotted on the graph are the mean values for 10 Shakespeare plays (*solid line*), 10 romantic genre films (*dashed line*), Chekov's plays (*fine dots*) and the plays of George Bernard Shaw (*long dots*). Note the log scale of the X-axis. *Source*: Krems and Dunbar (2013)

index reaches a lower asymptote at a value of around 0.2 when cast size exceeds 45. Figure 6b plots the average path length (the number of connections that separate any two characters in the play) for these same plays. Average path length rises with cast size ($r = 0.918$, $p < 0.001$), with a possible tendency towards an asymptotic value somewhere around 2.0 when cast size is 50 or so. In contrast, the clustering coefficient (Fig. 6c) seems to behave rather differently. While there is a weak, non-significant negative relationship with cast size (the bigger the cast list, the less likely triads are to be fully connected: $r = -0.499$, $p = 0.124$), the distribution seems to have a rather obvious upper bound (denoted by the dashed line). In other words, there is an upper limit beyond which it is not possible to go, but any value below that limit is possible. That limit is independent of cast size and the three classes of plays do not differ in this respect. In fact, the regression line for this upper bound has a standardised slope coefficient of $b = -0.981$, which is close enough to $b = -1$ to suggest that the upper limit on clustering coefficient is a constant function of cast size. This likely suggests a constraint imposed by the limit on conversation group size and the typical time frame of plays: you can only include so many conversations in a play of a given length (in this case, about 2.5 h) and so some triads just have to be left to the audience's imagination.

The distributions in Fig. 6a, b could be interpreted as being asymptotic, but another interpretation is possible. Relative to the pattern observed in the other plays, our one example of a history (*Richard III*) has a disproportionately low frequency of connected dyads and a rather higher mean path length (i.e. relatively longer path lengths between dyads) than one might expect. It is not clear whether this is a feature of histories as a genre or simply due to the natural behaviour of networks when their size gets large (irrespective of genre)—or just an oddity of this particular play, which is known to be difficult to stage because of its large cast. One potential problem that a playwright faces with histories is that they have less control over the number of

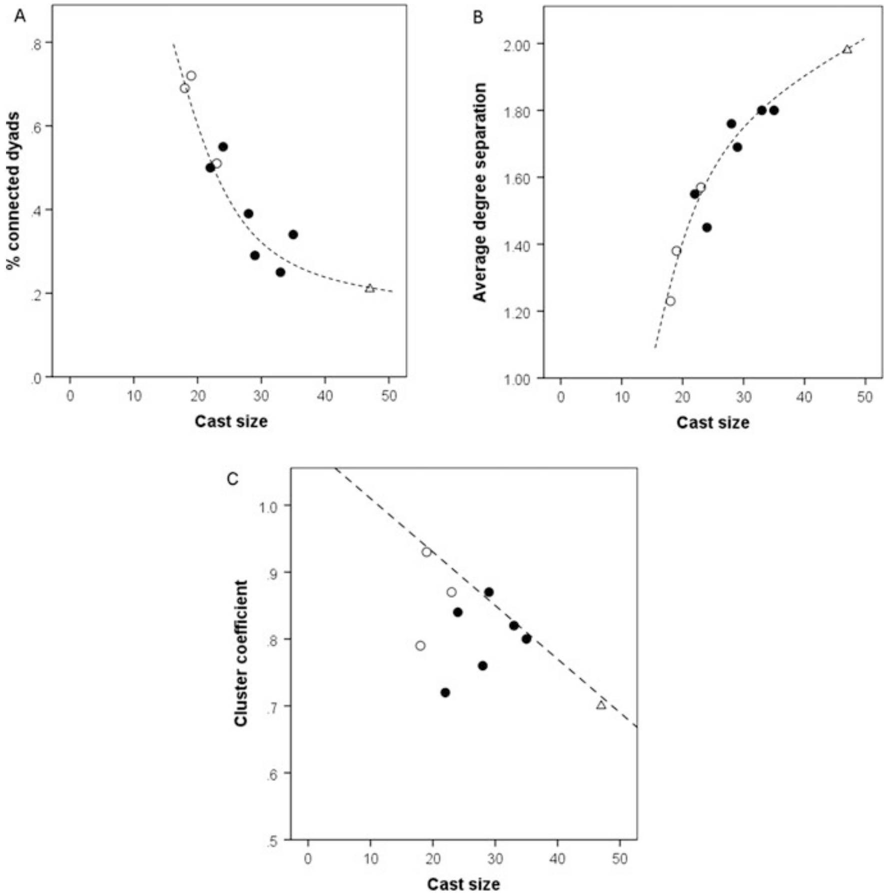

Fig. 6 For each of the 10 Shakespeare plays, differentiated between tragedies (*solid symbols*), comedies (*open symbols*) and the one history in the sample (*Richard III*) (*triangle*), I plot (**a**) density (proportion of all dyads that are actually connected, i.e. appear in a conversation together), (**b**) average path length (the mean number of links required to get from any one character to any other) and (**c**) the clustering coefficient (the proportion of all triads in which all three members are connected). In (**c**), the data suggest that there is an upper bound (shown by the *dashed line*) beyond which values cannot go. *Source*: Stiller et al. (2004)

characters and their interactions: the actual events may necessitate the inclusion of a larger number of characters than can is ideal for the audience to handle, and in real life they may have interacted more than would be desirable for a structurally simple script. *Richard III* is commonly viewed as difficult to stage, and directors often combine characters to reduce some of the complexity. In terms of size, its cast of 47 primary characters is certainly pushing the limit on one of the natural grouping layers of human social networks (the 50-layer). If the relationships in Fig. 6a, b are actually linear, a cast of 47 ought to have a density that is close to 0 and an average path length of about 2. Since being in a fully connected triad without ever actually meeting in a scene would be rather challenging, some twisting of the plot structure might be necessary to accommodate so many characters.

Mentalising Constraints

Mentalising, the capacity to understand the mindstates of other individuals, is one of the core cognitive abilities that distinguish humans from other animals. In the present context, mentalising, or mindreading as it is sometimes known, is what allows us to engage in a fictional world, to imagine a world that is distinct from the world we actually inhabit—one where we can engage in the activities and even mindstates of fictional characters within that virtual world. Without this capacity, we would be limited to a literalist interface with the world we live in, much as is the case for all other animals. This ability to step back from the world we experience directly and imagine a virtual one depends on our being able to separate reality from 'virtuality'. Just how important this is is highlighted by the case of autistic individuals, who lack theory of mind (the first step on the recursive process of mentalising). Without theory of mind (second order intentionality), autists take the world exactly as they find it and have difficulty imagining alternatives, or even imagining that the world could have been different to the way it appears to be. As a result, they have difficulty understanding metaphors, and instead take the meanings of sentences to be exactly what the words they contain literally mean (Happé 1994). While much work has been done on theory of mind, in fact this is a competence that children acquire as early as 5 years of age. Adults can do significantly better than 5-year-olds, and we have shown in a number of studies (Kinderman et al. 1998; Stiller and Dunbar 2007) that the typical upper limit for normal adults is fifth order intentionality, with only modest and diminishing numbers of people being able to manage sixth order or better (Fig. 7).

If we consider the mental work that someone has to do at a play, the magnitude of the task becomes clear. Think about what is involved when we watch Shakespeare's *Othello*. Here, at least as far as the plot of the play is concerned, we have to believe that Iago *intends* that Othello *believes* that Desdemona *loves* Cassio, and in the limit that her love is reciprocated by Cassio (i.e. Cassio also *loves* Desdemona). What makes the difference here is the last intentional state (Cassio's reciprocating Desdemona's love). Without that, we have a fairly boring narrative story: Desdemona has the 'hots' for Cassio, but in the absence of any action on Cassio's part this isn't very exciting and Othello shouldn't have cared less. What makes Shakespeare's story grip us is that Othello is led to believe that Desdemona's mindstate (being in love with Cassio) is reciprocated by Cassio, because now there is every chance that they might actually run away together (thus publicly embarrassing Othello, never mind causing him emotional pain) or, worse still, arrange for Othello to be bumped off so that Cassio could take his place as the General of the Venetian army.

The significance of this is that the audience has to handle four separate mindstates simultaneously, and, since they can only do that by having a mindstate of their own to do this with, this means that they have to work at their natural limit at fifth order intentionality. In other words, in a play like *Othello* with four main protagonists, the typical audience member is being pushed to their cognitive limits in terms of mentalising. But to be able to do that, the dramatist (in this case, Shakespeare) has to be able to work at one level higher (sixth order). In other words, while 65 % of the population will be able to appreciate the play because they can work at the requisite intentionality level, only about 35 % of the population have the cognitive ability (at least in terms of mentalising) to actually write the play.

One obvious prediction from this might be that an audience member's ability to enjoy a play (or, equivalently, a reader's ability to enjoy a novel) is determined by how far the author can push the audience. In other words, for someone with fifth order mentalising competence, a story that requires fourth or fifth order mentalising on their part is likely to be rated as more engaging or exciting than one that requires only second or third order mentalising, whereas a story that requires sixth or seventh order mentalising is likely to be seen as difficult and less enjoyable. Similarly, someone with third order mentalising competences might enjoy a third order story, but find fourth, fifth and sixth order stories increasingly more difficult to get to grips with, and hence less enjoyable. Carney et al. (2014) tested this using short (1000-word) story vignettes from two different genres (a spy story and a story about romantic relationships) written at third or fifth order intentionality. Subjects found fifth order spy stories less engaging than third order spy stories, but they rated fifth order romantic stories as more enjoyable than third order ones. Thus, familiarity (or, alternatively, closeness to everyday experience) may influence our ability to follow the twists and turns in a plot. In similar vein, subjects rating jokes told by

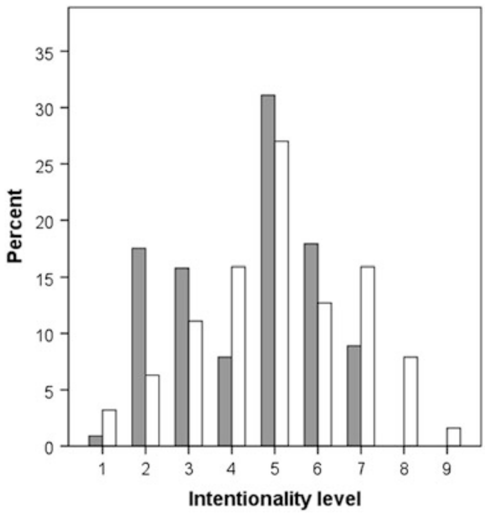

Fig. 7 Distribution of mentalising competences (indexed as the highest level at which individuals successfully passed these tasks) in two different studies: Kinderman et al. (1998) (*grey bars*) and Stiller and Dunbar (2007) (*white bars*). Kinderman et al. only tested subjects up to sixth order intentionality, and a proportion of these subjects would have passed at higher levels; for illustrative purposes, those passing at this level have been partitioned in a 2:1 ratio between 6th and 7th orders

famous comedians found higher mentalising order jokes more enjoyable than less demanding jokes (Launay and Dunbar 2016).

In composing his plays, Shakespeare seems to have paid very close attention to the demands he was placing on his audiences. In an analysis of the mentalising states involved in the same 10 Shakespeare plays and a sample of natural conversations on a University campus, Krems et al. (2016) found that the number of people involved in a conversation (hence the number of intentionality levels involved) was one whole mindstate level lower when the conversation involved an absent party's mindstate than when it involved either factual events offstage or the mindstate of one of the people involved on stage in the conversation. What is quite remarkable is how closely Shakespeare followed the natural rhythms of conversation, adjusting naturally for features that are really quite subtle.

Conclusions

I have offered three ways in which we might gain novel insights into storytelling in its many different forms by exploiting powerful theoretical frameworks on offer in psychology and evolutionary biology, combined with novel statistical methods like network analysis. These have so far been relatively underused in the humanities, but their potential to offer insights is considerable when handled with appropriate care and informed application. Here, I have done no more than point the way with some simple, but hopefully informative, examples. These examples should not be taken as indicating the limits of such applications. Rather, they are intended to provide encouragement and point the way ahead.

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