The small world of Shakespeare's plays

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THE SMALL WORLD OF SHAKESPEARE'S PLAYS

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Drama, at least according to the Aristotelian view, is effective inasmuch as it successfully mirrors real aspects of human behavior. This leads to the hypothesis that successful dramas will portray fictional social networks that have the same properties as those typical of human beings across ages and cultures. We outline a methodology for investigating this hypothesis and use it to examine ten of Shakespeare's plays. The cliques and groups portrayed in the plays correspond closely to those which have been observed in spontaneous human interaction, including in hunter-gatherer societies, and the networks of the plays exhibit "small world" properties of the type which have been observed in many human-made and natural systems.

KEY WORDS: **Drama; Group size; Humans; Shakespeare; Small world networks; Social networks**

In *Hamlet,* Prince Hamlet tells the actors that the purpose of a play is "as 'twere, to hold the mirror up to Nature." He is thus espousing the Aristotelian view that drama functions by *mimesis,* the accurate simulation of

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reality (Hutton 1982). The idea that drama, to be successful, must reflect reality, at least in some key respects, is intuitively compelling and forms the basis of much critical practice. However, there has been little by way of development of methodology for systematically comparing the fictional worlds created in dramas with real social interactions.

In this paper we use the mathematical analysis of networks as a basis for exploring the dramatic world of ten plays by William Shakespeare. We have chosen this author not because we believe he will prove unique or exceptional in the parameters under study, but because he is the most performed dramatist in history, with many of his plays finding favor in cultures and ages far removed from the locations of their plots or the cultural context of their original enactments (Bate 1997; Kott 1974). Thus, for the assay of a methodology and the formulation of initial generalizations about dramatic worlds, Shakespeare is a good place to start.

There is already a developing body of work using knowledge of the evolved mind to understand features of literary productions and other art forms (Carroll 1995, 1999; Dissenyake 1992; Storey 1996). Carroll, for example, relates the plots of stories to the pursuit of fundamental biological goals that people have evolved to find important, and Dissenyake explains aesthetic preferences in terms of visual features of the environment of evolutionary adaptedness. Such analyses could be extended to the content of plays, including Shakespearean plays. However, the dramatic mode differs from other modes in that it involves a direct simulation of a human social group. Thus, as well questions of content, there are questions of structure. What size social group is typically depicted? What are its composition and social structure? How do they relate to ethnographic generalizations about the kind of social groups in which human beings live, or which were typical of the environments in which they evolved?

Dramas depend on the human capacity for social cognition—being able to follow how everyone relates to everyone else—and the relationships must be apprehended in real time. Moreover, comprehension of plot is dependent on comprehension of relationship. Graesser et al. (1999) have shown that the process of tracking the changing mental states of characters in a story depends on apprehending their social relationships to key protagonists. For example, if we learn that Sir Toby Belch in *Twelfth Night* hates Malvolio and wants to humiliate him, then we can infer by default that Feste, Fabian, and Aguecheek will want this too, since they form Belch's social clique. As long as the playwright constructs a social structure that we can clearly track, much other inference necessary to the dramatic effect of the story can be assumed to be filled in from the general psychology of alliances, kinship, and social groups. It may be that the dramas that work best are those that depict social groups and relationships maximally similar to the kind that human social-cognitive capacities evolved to track in real life. Thus, there may be upper limits on the number of characters or complexity of relationships that an audience can follow. Since the plays under study here have all been widely performed for several hundred years, we can assume that they operate within any such limits.

We first outline our method of analysis of the plays, which involves treating the play as a sociologist or anthropologist would a real social group: as a network, with the people (characters) represented as nodes, and a link recorded between any two nodes that interact (in our case, on stage). We then consider two key aspects of human groupings—social group sizes and network connectivity within these groups. We review what is known of naturally occurring groups, including those of hunter-gatherers, and present comparison data from the plays.

METHODS

The analysis of the each play was carried out using the printed text, by tabulating the speaking characters present on the stage at each time slice through the play. A new time slice was deemed to begin whenever a character was stated or could be inferred to have left the stage. The scene size is the number of speaking characters present during the time slice. The total number of speaking characters for each play was simply the tally of different characters occurring in the set of time slices (which differed slightly from the dramatis personae of the play in that some characters named in the dramatis personae do not speak, and some speaking characters are identified in the dramatis personae as Lords, Gentlemen, etc.).

The network structure calculations were obtained by treating each speaking character as a node, and deeming two characters to be linked if there was at least one time slice of the play in which both were present (that is, if two characters spoke to each other or were in each other's presence, then they have a link). We calculated the connectance (C) of the network of each play. This is the proportion of possible links between characters that are in fact realized, and in a network containing S nodes and L observed links C is given by L/S^2 (Dunne et al. 2002; Williams et al. 2002). This parameter ranges from 0 for a group of completely unlinked nodes to 1 for a fully connected set in which each character interacts with each other character.

We also calculated the characteristic path length (D), or "degrees of separation." For each pair of characters, the number of links in the shortest possible route connecting the two is found. D is the mean of these path lengths for all pairs of characters in the network (for a formal statement, see Montoya and Sole 2002:406). Finally, we calculated the cluster coefficient (T) for each play. This coefficient is the probability that two nodes each linked to a third will also be linked themselves (for a formal definition, see Montoya and Sole 2002:406). This parameter reflects the extent to which the network is subdivided into densely interconnected subparts. In a randomly connected network, the cluster coefficient (T) is equal to the connectance (C).

RESULTS

Group Size

Human beings live in complex social groups whose overall composition varies with ecology and technological development. Typically they involve several levels of structure nested inside each other. Hill and Dunbar (2003) have argued that social groups based on close personal acquaintance are limited to about 150 individuals. Hunter-gatherer bands are about this size, and within contemporary society such groupings recur in settings as diverse as Christmas card lists, military companies, church congregations, and research specialisms in science. Nested within these groups are closer-knit units that are organized in an inclusively hierarchical fashion into relatively stable groupings of 3–5, 12–15, and 35–50 individuals (Hill and Dunbar 2003). These constitute, respectively, the number of individuals with whom one has an emotionally supportive relationship (support clique), the number of key friends whom one contacts at least once a month (social network), and, at least in hunter-gatherer societies, the overnight camp (Birdsell 1968; Dunbar 1993; Layton 1986; Riches 1995). In spontaneous interaction, social groups of any size usually fragment into smaller conversational cliques. Such cliques are typically of 4 or fewer individuals, only exceeding this limit in infrequent formal contexts (Dunbar et al. 1994).

Shakespeare's plays all depict a social group of several dozen characters, but these characters do not all appear simultaneously. Rather, they are presented interacting in subgroups in different scenes. We compared the total number of speaking characters in the sample plays with social group sizes observed in a wide variety of ethnographic contexts (Table 1). All the naturally occurring observations fall with the range of the ten plays, and within two standard deviations of their mean. The plays and real data could thus have been drawn from the same distribution. We also compared the average number of speaking characters in a scene at any one time with real data on conversation cliques (Figure 1). For the scenes, as for real conversations, the vast majority consist of four or fewer individuals. The modal size is three in both cases, and the mean for the plays of 3.48 falls within the range of 3–3.5 derived from observational studies (Dunbar

Table 1. Naturally Occurring Human Group Sizes and the Total Number of Speaking Characters in Ten Shakespearean Plays

Source	*Number*
Hunter-gatherer camps (Birdsell 1968)	25
Hunter-gatherer camps (Dunbar 1993)	37.7
Australian aboriginal camps (Layton 1986)	25.82
British social networks (Hill and Dunbar 2003)	35
Mean for real groups	*30.9*
Hamlet	33
King Lear	28
A Midsummer Night's Dream	23
Othello	22
Richard III	47
Romeo & Juliet	35
Tempest	19
Titus Andronicus	24
Troilus & Cressida	29
Twelfth Night	18
Mean for plays	*27.8*

et al. 1994). The only difference is that the dramatic scenes are characterized by a larger tail where the characters are numerous (mainly made up of formal contexts like court and council scenes).

Network Structure

The networks of interactions created by human beings have often been shown to depart significantly from random graphs, and to have "small world properties" (Bernard et al. 1988; Liljeros et al. 2001; Newman 2001; Strogatz 2001; Watts 1999). This means that they combine a short pathway linking any two individuals in the network ("few degrees of separation") with high local clustering (if A and B and B and C are linked, A and C are likely to be linked too). In addition, some networks, such as those of Internet web pages, have been shown to follow a scale-free distribution where the number of links per person follows a power law, with many individuals with a few links and a few individuals with many (Barabasi et al. 2000; Broder 2000). This is hypothesized to occur because nodes that are already richly linked are better at recruiting additional linkages.

Table 2 shows that in Shakespearean plays not all characters are directly connected, but there are rarely more than two degrees of separation, a regularity that has recently also been observed for ecological webs (Dunne et al. 2002; Montoya and Sole 2002; Williams et al. 2002). As the number of characters in a play increases, the mean path length (D) increases (log-log

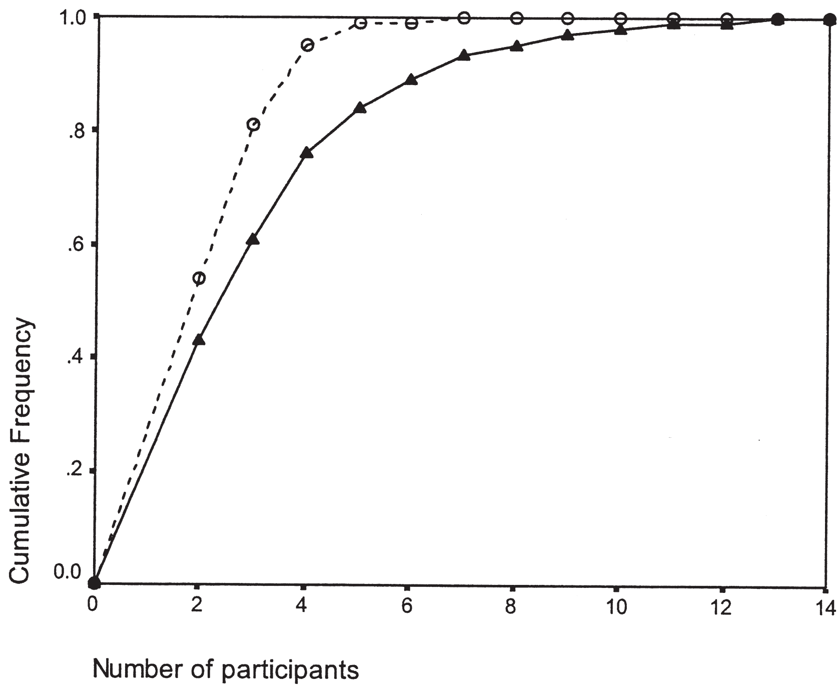

Figure 1. Distribution of scene sizes (solid line) in the plays compared with the distribution of sizes of spontaneously forming conversational groups (broken line; from Dunbar, Duncan, and Nettle 1994).

Table 2. Average Connectivity (C: the proportion of possible links realized), Distance (D: degrees of separation), and Cluster Coefficient (T: the probability that two links of any node are themselves linked) for Characters in Ten Shakespearean Plays

Play	*C*	*D*	*T*
Hamlet	0.25	1.8	0.82
King Lear	0.39	1.76	0.76
A Midsummer Night's Dream	0.51	1.57	0.87
Othello	0.50	1.55	0.72
Richard III	0.21	1.98	0.70
Romeo & Juliet	0.34	1.8	0.80
Tempest	0.72	1.38	0.93
Titus Andronicus	0.55	1.45	0.84
Troilus & Cressida	0.29	1.69	0.87
Twelfth Night	0.69	1.23	0.79

correlation, $r = 0.94$, df = 9, $p < 0.001$) and the overall connectance (C) decreases ($r = -0.94$, df = 9, $p < 0.001$), while the size of scene cliques is unaffected ($r = -0.54$, df = 9, ns). This suggests that when Shakespeare's story requires more characters to be incorporated, he does so by adding more scenes with different cliques rather than increasing the number of characters in a scene or clique. This means that plays, just like social networks, become more fragmented as the number of individuals increases, and this fragmentation may set upper bounds on their size. This fragmentation can be seen in Figure 2, which shows the proportion of pairs of characters who have no direct interaction as a function of the total number of characters. Increasing the number of characters further would lead to stories that might be difficult to follow owing to the preponderance of non-relationships between the characters depicted.

In a randomly connected graph, the average cluster coefficient will be equal to the overall connectivity. For the plays, the average cluster coefficient (T) significantly exceeds the overall connectivity in every case (Table 2). This means that characters in the plays are more cliquishly connected than would be expected by chance. As noted above with regard to the World-Wide Web, it has been shown that in naturally occurring small-world networks the distribution of links to nodes follows a power law,

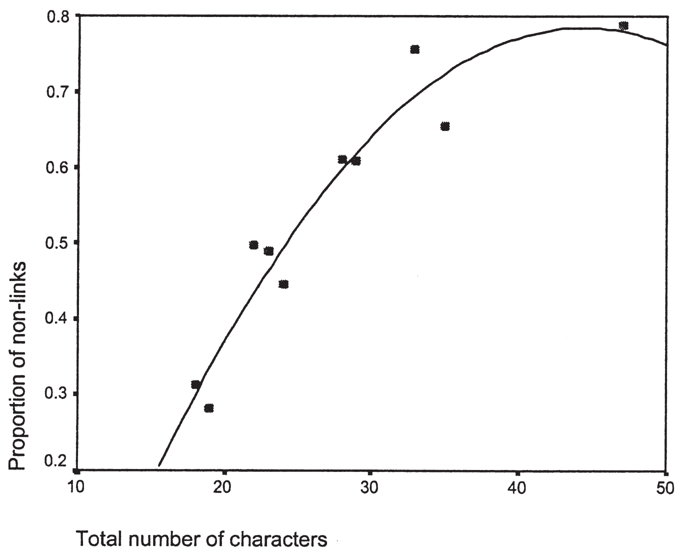

Figure 2. Proportion of characters having no direct contact, as a function of total number of characters for the ten plays.

with some nodes rich in links and many having very few. This is a departure from a randomly connected graph, which would follow a Poisson distribution. The distribution of links to characters for the ten plays, excluding *The Tempest* and *Twelfth Night*, which have very small numbers of characters, is shown in Figure 3. There are consistent departures from the Poisson model for all the plays, with more dispersion among the characters than would be predicted by the random graph, more characters with very few links, and more with a large number. The distribution is not best modelled by a power law, however. For *Hamlet* and *Richard III*, the distribution is best fitted by an exponential function ($r^2 = 0.98$ in both cases), and for the other six plays, the distribution is uniform ($r^2 = 0.91$–0.99).

DISCUSSION

Our analyses have shown that Shakespearean dramas are structured in a very specific way that mirrors patterns observed in real human interactions. Characters are connected by a small number of degrees of separation, generally no more than 2. Nonetheless, social connections are highly clustered, as in real human behavior. Onstage interactions generally consist of cliques of four or fewer individuals, as in real human conversations. This limit is inflexible and maintained even as the total number of characters in the story increases. Thus, increasing the total number of characters necessitates increasing the number of different cliques, so the drama becomes less richly connected with increasing overall size. This sets an upper limit on the total number of characters in one play—30 to 40—that is remarkably similar to those observed in hunter-gatherer societies, and in people's social contacts in contemporary society. The reasons for the size regularities may be parallel in the two cases; as the size increases, the connectance decreases to the point that the network fissions (groups) or becomes incoherent (plays). Plays with fewer than this limiting number of characters cause essentially no problems in terms of keeping track of all the relationships involved, since our social cognitive capacities have evolved in contexts where simultaneously interacting groups of this size, albeit divided into smaller cliques, were the norm.

Our results provide new tools for understanding some of the reasons plays provoke the reactions that they do. In *Richard III*, stage practice has often been to amalgamate minor characters such as Tyrell, Ratcliffe, and the murderers to reduce the overall network size. Our analysis suggests that such a play could be straining the size and coherence that an audience would accept as a believable interacting group. The "well-made" quality of comedies such as *Twelfth Night* and *Midsummer Night's Dream* is often commented on, and *The Tempest* is seen as coming closest of all of Shake-

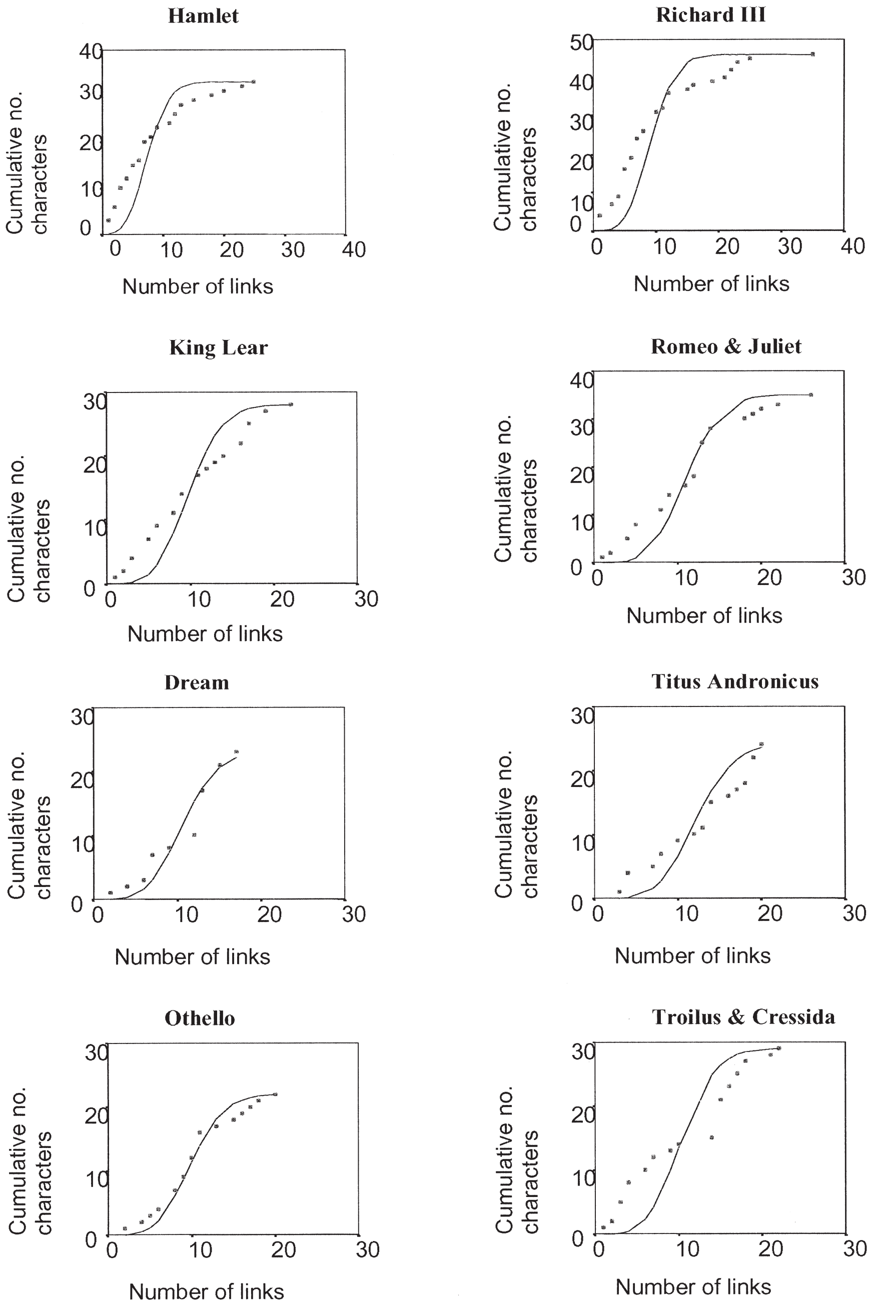

Figure 3. Cumulative distribution of links per character (dots) as compared to a Poisson random model based on the mean number of links (line) for eight of the ten plays. The plays all show greater dispersion (more characters with very few or very many links) than the Poisson model.

speare's plays to complete unity of time, place, and action (Kott 1974). This is reflected in our analysis by the high connectance and short path distance in these particular plays.

The results suggest that the forms drama can take are not unconstrained; rather theymight prove to be limited by regularities in human cognition and behavior. Future studies can be carried out using this method with dramatic material from other authors, times, and cultures, since it is quite plausible that constraints on dramatic form will be universal. Furthermore, it should be possible to study experimentally whether varying the network size and connectivity of characters affects the ability of audience members to comprehend the overlying plot. The widespread popularity of certain artistic forms might be due not just to their social relevance in terms of plot but also to the way their structure mirrors deep principles of human social organization.

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REFERENCES

Barabasi, A.-L., R. Albert, and H. Jong
2000 Scale-Free Characteristics of Random Networks: The Topology of the World-Wide Web. *Physica A* 281:69–77.
Bate, J.
1997 *The Genius of Shakespeare.* London: Macmillan.
Bernard, H. R., P. D. Killworth, M. J. Evans, C. McCarty, and G. A. Shelley
1988 Studying Social Relations Cross-Culturally. *Ethnology* 27:155–179.
Birdsell, J. B.
1968 Some Predictions for the Pleistocene Based on Equilibrium Systems among Recent Hunter-gatherers. In *Man the Hunter.* I. DeVore, ed. Pp. 229–240. New York: Aldine.

Broder, A.
2000 Graph Structure in the Web. *Computer Networks* 33:309–320.
Carroll, J.
1995 *Evolution and Literary Theory.* Columbia: University of Missouri Press.
1999 The Deep Structure of Literary Representations. *Evolution and Human Behavior* 20:159–173.
Dissenyake, E.
1992 Homo aestheticus: *Where Art Comes From and Why.* New York: The Free Press.
Dunbar, R. I. M.
1993 Coevolution of Neocortical Size, Group Size and Language in Humans. *Behavioral and Brain Sciences* 16:681–735.
Dunbar, R. I. M., N. Duncan, and D. Nettle
1994 Size and Structure of Freely Forming Conversational Groups. *Human Nature* 6: 67–78.
Dunne, J. A., R. J. Williams, and N. D. Martinez
2002 Food-Web Structure and Network Theory: The Role of Connectance and Size. *Proceedings of the National Academy of Sciences of the USA* 99:12917–12922.
Graesser, A. C., C. Bowers, B. Olde, K. White, and N. K. Person
1999 Who Knows What? Propagation of Knowledge among Agents in a Literary Storyworld. *Poetics* 26:143–175.
Hill, R. A., and R. I. M. Dunbar
2003 Social Network Size in Humans. *Human Nature* 14:53–72.
Hutton, J., ed.
1982 *Aristotle's Poetics.* New York: Norton.
Kott, J.
1974 *Shakespeare our Contemporary.* New York: Norton.
Layton, R.
1986 Political and Territorial Structures among Hunter-gatherers. *Man* 21:18–33.
Liljeros, F., R. Christopher, C. R. Edling, L. A. Nunes Amaral, H. Eugen Stanley, and Y. Aberg
2001 The Web of Human Sexual Contacts. *Nature* 411:907–908.
Montoya, J. M., and R. V. Sole
2002 Small World Patterns in Food Webs. *Journal of Theoretical Biology* 214:405–412.
Newman, M. E. J.
2001 The Structure of Scientific Collaboration Networks. *Proceedings of the National Academy of Sciences of the USA* 98:404–409.
Riches, D.
1995 Hunter-gatherer Structural Transformations. *Journal of the Royal Anthropological Institute* 4:679–701.
Storey, R.
1995 *Mimesis and the Human Animal.* Evanston, Illinois: Northwestern University Press.
Strogatz, S. H.
2001 Exploring Complex Networks. *Nature* 410:268–276.

Watts, D. J.
1999 *Small Worlds.* Princeton: Princeton University Press.
Williams, R. J., E. L. Berlow, J. A. Dunne, A.-L. Barabasi, and N. D. Martinez
2002 Two Degrees of Separation in Complex Food Webs. *Proceedings of the National Academy of Sciences of the USA* 99:12913–12916.