Exploring the prominence of *Romeo and Juliet*'s characters using weighted centrality measures

Víctor Hugo Masías
Department of Management Control and Information Systems, Universidad de Chile, Chile

Paula Baldwin
Institute of Literature, Universidad de Los Andes, Chile

Sigifredo Laengle
Department of Management Control and Information Systems, Universidad de Chile, Chile

Augusto Vargas
Departamento de Diseño y Manufactura (DIMA), Universidad Técnica Federico Santa María, Chile

Fernando A. Crespo
Universidad Bernardo OHiggins, Centro de Desarrollo y Transferencia Tecnológica (CEDYTEC), Dirección de Investigación, y Facultad de Ingeniería y Administración, Chile

Correspondence:
Víctor Hugo Masías, Diagonal Paraguay 257, Torre 15, Oficina 2001, Piso 21, Santiago, Chile.
E-mail:
vmasias@fen.uchile.cl

Abstract

Why are Romeo and Juliet prominent characters in Shakespeare's play of the same name? Contrary to what common sense might suggest, the academic literature does not provide a unique answer to this question. Indeed, there is little agreement on who the main character is and which elements of a script contribute to establishing a character's leading role. The objective of this article is to explore and compare the prominence of characters in *Romeo and Juliet* by using social network analysis. To this end, we calculate the centralities of several characters in *Romeo and Juliet* using a method based on Social Network Analysis. Comparing the scores generated by this analysis, we found that Romeo's centrality is more stable than Juliet's while hers is lower and supported by the 'strength of the bonds' she develops with other characters. Thus, the comparison of different centrality rankings and clusters provides new knowledge about the plays of Shakespeare. We show that the 'strength' of the relationships affects the prominence of the characters. This finding opens new directions for analyzing Shakespeare's scripts and determining who the main character is using weighted centrality measures. Finally, we discuss some theoretical and practical implications of the method used in this study.

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1 Introduction

Shakespeare's plays remain a source of endless questioning. For example, how many protagonists do they have? In the academic literature we find a certain consensus that there is generally one main character, sometimes two, but rarely more (Koch, 2009; Partridge, 1971). However, there is little agreement on which elements of a script contribute to establishing a character's leading role.

In this article, after a brief bibliographical review we identify some answers to the question: What elements of the script aid in establishing the characters of *Romeo and Juliet* as prominent characters? On the one hand, we found the conventional proposal that Romeo and Juliet are indeed the main characters. For example, Hazen suggests that in Shakespeare's tragedies, the main character is the one who is unsuccessful in what he or she tries to do. This author argues that Romeo and Juliet are both the main characters of the play because they 'are frustrated in their goal of being together and end up dead at the conclusion of the play' (Hazen, 2004, p. 83). Along the same lines, Draughon suggests that the plot in *Romeo and Juliet* revolves around the conflict of whether or not they can be together, so much so that every decision they take points to that purpose (Draughon, 2003). According to this author, both Romeo and Juliet are main characters in that 'for Romeo and Juliet the goal is each other; but both risk being disowned by their parents and Juliet, being a woman, risks being made prisoner' (Draughon, 2003, p. 76). Also, Gallaway notes that 'in love stories and a few other kind of stories, the double protagonist is not uncommon. In *Romeo and Juliet*, to name only one example, it is really impossible to insist that either Romeo or Juliet is the protagonist' (Gallaway, 1950, p. 63).

Some critics, however, take a different view, arguing that Romeo is the only main character of the play. Ballon suggests that when his students ask who the main character in *Romeo and Juliet* is, he replies that there is only one: Romeo (Ballon, 2004). This is due to the fact that Romeo has '[A] specific goal which moves the story forward' (Ballon, 2004, p. 38): the notion that 'Romeo wants Juliet's love' (Ballon, 2004, p. 52). This idea can be contrasted with Partridge's opinion that female characters are more prominent, suggesting that 'it is only in the more romantic tragedies, *Romeo and Juliet* and *Antony and Cleopatra*, that the woman occupies a place as important as a man's' (Partridge, 1971, pp. 25–6). Similarly, Ely Fansler emphasizes that 'Juliet is not the antagonist of Romeo. She is a protagonist and has her own antagonist (her father); as Romeo is a protagonist and has his antagonists (the Prince, Tybalt, and Paris)' (Fansler, 1914, p. 113). Finally, Cartwright argues that 'Feminist critics have tended to elevate Juliet' (Cartwright, 2010, p. 66), and others point out that 'Some scholars and directors like to argue that the play is really all about Juliet. Romeo's around, true, but it's Juliet who undergoes the most dramatic transformation. She starts the play as a little girl and ends as a woman, and the audience gets to see her change every step of the way' (Shmoop University, 2010, p. 146).

What is particularly interesting on this issue is that there are several opinions as to which elements help establish the characters of Romeo and Juliet as main characters. Moreover, one does not have to take a position on the arguments by the above-cited authors to realize that they have their own reading of the play with independent and different perspectives of *Romeo and Juliet*. However, even when the name of a character is in the title, it is difficult to infer or justify which are the main ones or the protagonists in Shakespeare's plays. Boal says that 'the protagonist does not coincide necessarily with the main character. In *Macbeth* it can be Macduff; in *Coriolanus* it can be one of the commoners; in *Romeo and Juliet* it could be Mercutious if it were not for his premature death; in *King Lear* it could be the jester' (Boal, 2000, p. 181). From our point of view, all of this provides an insight into the necessity of having a theoretical and methodological framework to analyze and assess the unique aspects of a script that establish a character as the main character or protagonist.

In this context, we have taken a new path to explore the elements that contribute to the prominence of certain characters in a play. This study proposes an analysis of the degree of prominence of Romeo and Juliet based on a mathematical technique known as Social Network Analysis (SNA).

Under this approach, dramatic characters are represented by nodes and the relationships between them by edges. We opted to use this conceptual framework because previous studies have successfully analyzed and characterized the interaction of Shakespeare's characters (Carroll, 2008; Stiller and Hudson, 2005; Stiller *et al.*, 2003; Masías *et al.*, 2015; Nalisnick and Baird, 2013; Voloshinov and Gozhanskaya, 2008). However, none of them address the topic of prominence of a character using the concept of centrality.

Through SNA we attempt to offer a different method for approaching Shakespeare's dramatic texts, including the information about the 'structure of the script' itself: the conversational turn-taking sequences. To show how this might be possible, we explored the prominence of Romeo and Juliet using the concept of centrality. The analysis focuses on assessing and measuring 'how central' and prominent a node is according to its position in the social network (Wasserman and Faust, 1994). The concept of centrality to identify central individuals in human communication networks was introduced decades ago by Bavelas (1950), and since then, several different centrality measures have been developed, all with the same purpose: to 'quantify an intuitive feeling that in most networks some vertices or edges are more central than others' (Koschützki *et al.*, 2005, p. 16).

The objective of the present article is to explore and compare the prominence of characters in *Romeo and Juliet* using SNA. To achieve this, we undertook two different tasks. First, we determine the centrality of the characters in *Romeo and Juliet* by measuring three centrality indicators (see Subsection 3.3) and by assessing whether the 'number of bonds', 'strength of the bonds', or both, contribute to establishing the characters in the play as main (i.e. central) characters. Second, we compare the different conditions under which the characters of Romeo and Juliet achieve more or less centrality by creating different rankings with nodal centrality measures. By means of this comparative analysis we explore whether the concept of centrality contributes to expanding the discussion about the elements of the script that determine the prominence of certain characters in this tragedy. From this perspective we also understand that an empirical measure does not necessarily exclude the development of an alternative approach.

The rest of the study is organized as follows. First, we present a review of the literature analyzing Shakespeare's plays using SNA. Second, we introduce the concept of centrality and describe how the relationships between the characters contribute to positioning them as central figures in the network of dramatic characters. Third, we explain the method and the practical definition of centrality measures, and then describe the strategy used to compare the data. Fourth, we report the findings regarding the degree of centrality Romeo and Juliet have by means of rankings. Fifth, we discuss the results and conclude according to the proposed objectives of study.

2 Literature Review

In this section we discuss existing research using SNA to study Shakespeare's plays (Subsection 2.1). Additionally, we define some conceptual elements regarding the centrality of a character (Subsection 2.2).

2.1 The study of Shakespeare's plays from the SNA approach

SNA, or sociometry, is both a theory and an analytical method that emphasizes the importance of social networks and the individuals constituting them (Burt *et al.*, 1983; Scott, 1991; Wasserman and Faust, 1994). The SNA approach was first proposed by Moreno (1934) for the purpose of studying different types of social configurations. It consists of analyzing social behavior by representing individuals (sometimes called 'the actors') as nodes and the social relationships among them as links or bonds (Wasserman and Faust, 1994). The SNA research program is well-defined and its scope is wide (Marin and Wellman, 2011), providing the techniques for studying different social dimensions from structural to behavioral (Burt, 1982; Knoke and Kuklinski, 1982; Rogers and Kincaid, 1981).

Since the early 1990s, several studies applying SNA theory and method to Shakespeare's plays have been published (Masías *et al.*, 2015; Matthews

and Barrett, 2005; Stiller *et al.*, 2003; Voloshinov and Gozhanskaya, 2008). These studies consider drama from an evolutionary point of view and suggest that the way in which relationships among characters are organized is crucial for the 'audience' to understand a play (Csermely, 2006). In this sense, we consider Shakespeare as a key example because the organization of his scripts appears to take into account the social relationships among characters. This may contribute to the 'audience's' understanding and interpretation of these social relationships.

There are three main studies that use this interpretative framework.[1] In the first analysis (Stiller *et al.*, 2003), the authors study the properties in Shakespeare's plays and compare them with the size of groups reported in naturalistic observations (social group sizes observed in ethnographic contexts). For example, they found that Shakespeare's plays present: (1) low connectivity, i.e. not all characters are directly connected; (2) characters are connected by a distance lower than 2, i.e. a character does not need more than one character to reach other characters; (3) interaction occurs by means of cliques consisting of four or less characters; and (4) the number of characters in the plays are remarkably similar to those that compose natural human groups.

In the second study (Stiller and Hudson, 2005), the authors carried out an analysis based on the data used in Stiller *et al.* (2003). This time, they compared the size of cliques in Shakespeare's plays with those found in natural human groups. Among their main findings are that Shakespeare's plays (1) show properties similar to those in small world networks, i.e. each character is linked only by a few intermediate nodes, and (2) there is no significant difference between the observed support clique sizes. Likewise, this second study argued that Shakespeare's plays (3) incorporate keystone characters.[2] For example, in *Romeo and Juliet*, the authors suggested there were four keystone characters, namely, Romeo, Benvolio, Friar Lawrence, and the Nurse, who allow the flow of information from scene to scene.

In a third study, researchers compared the social networks in plays by Chekhov, Shakespeare, and Shaw, finding real human communication situations (Voloshinov and Gozhanskaya, 2008). More specifically, they compared Russian and English plays, and also the number of characters in the Russian and English plays with the number of individuals found in real and artificial social networks. Their findings were two-fold. First, by comparison with Chekhov and Shaw, Shakespeare's plays show (1) greater connectivity between dramatic characters, (2) higher average path length between characters, and (3) a greater tendency toward the formation of clusters (Voloshinov and Gozhanskaya, 2008). Second, and similar to Stiller and Hudson (2005), there are regularities between the number of characters in the plays of Shakespeare, Chekhov, and Shaw, and the number of individuals in natural social networks.[3]

To summarize, we can say that the aforementioned studies have based their research in the theory and method of SNA so as to reach different objectives: exploring the properties in Shakespeare's plays by using different social networks' measures, comparing data generated by applying those measures to Shakespeare's plays with data obtained from real social networks, and comparing the results of this application of SNA with those obtained from applying it to plays by other playwrights. These studies have contributed to the common purpose of recognizing, in Shakespeare's plays, social configurations and regularities that make them similar to the connections we find in human social networks. This finding is very interesting from a literary and cultural perspective given the universality of Shakespeare's portrayal of Western man and his human relationships.

2.2 Centrality as an attribute of prominence in *Romeo and Juliet*

Centrality is a key concept in SNA (Sabidussi, 1966; Wasserman and Faust, 1994). As noted above, Bravelas was the first researcher to use this concept of human communication networks (Bavelas, 1950) and since then several other centrality indexes have been developed for quantifying the centralities in different types of networks (Bonacich, 1972, 1987; Freeman, 1977). At present there is some consensus about the 'strength' and 'number of bonds' a node should have to reach a central point in a social network. Understanding these aspects and developing

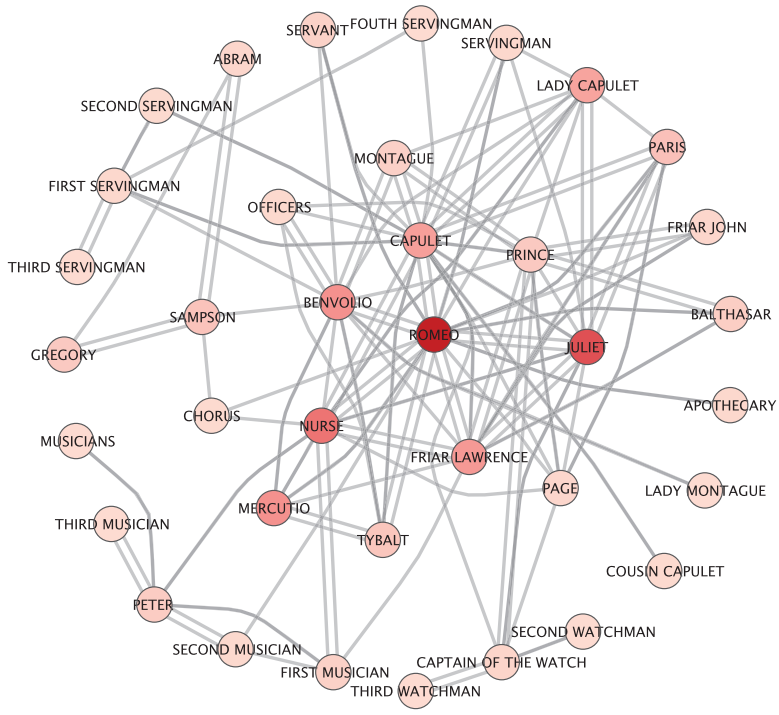

Fig. 1 Turn-taking of *Romeo and Juliet* scaled to the number of bonds. The brighter the node, the more links it has to other nodes

centrality indicators that incorporate them have been crucial for assessing the importance of a node, and in our case, it is also important for comparing Romeo and Juliet's prominence. As it has been suggested by Opsahl *et al.*, 2010 'One can view the number of ties as more important than the weights, so that the presence of many ties with any weight might be considered more important than the total sum of tie weights. However, ties with large weights might be considered to have a greater impact than ties with only small weights' (Opsahl *et al.*, 2010, p. 246). Within this interpretative framework, we suggest that Romeo and Juliet's conversational turn-taking sequences aid in exploring their prominence. In other words, and from a sociometric perspective, we can obtain two sets of data from the script which, theoretically, contribute to establishing Romeo and Juliet as protagonists. The first data set is the relationship each character establishes with every other character, i.e. the 'number of bonds' established among characters throughout the scenes of the play. The second data set is the 'number of times' each such relationship occurs, i.e. the 'strength' of the aforementioned bonds. These two data are graphed in Figs 1 and 2.

The Fig. 1 graph was created on the basis of the conversational 'turn-taking' sequences and 'number of bonds' among characters in *Romeo and Juliet*. In the graph, the intensity of a node's color represents its number of links. Thus, the brighter the node's red, the more links it has to other nodes. For example, Romeo and Juliet have a higher 'number of bonds' than the characters who are located in the outer perimeter of the diagram. But some of the characters, such as the Nurse, Mercutio, Capulet and Benvolio, also have a significant 'number of bonds' connecting them with other characters. Thus, the play can be understood as a 'conversational network'[4] in which each character maintains a certain number of bonds that contribute to a greater or lesser amount of centrality in the play.

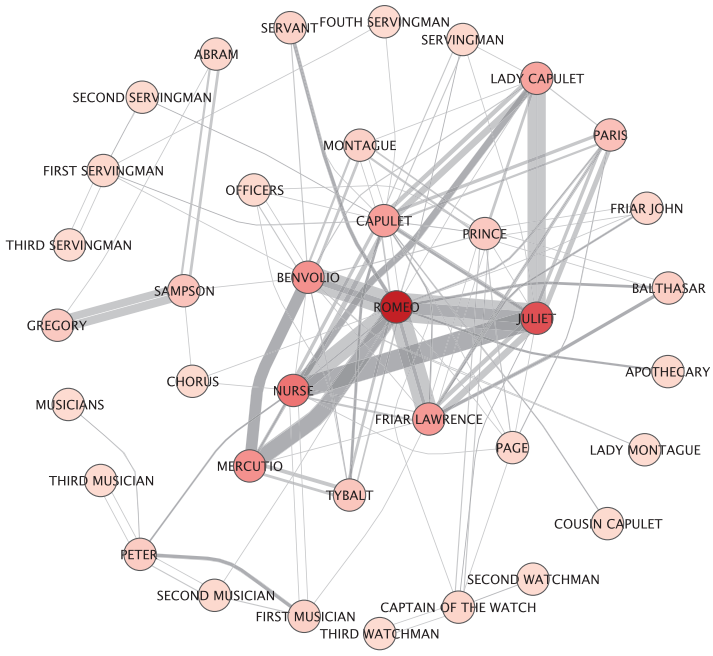

Fig. 2 Turn-taking of *Romeo and Juliet* scaled to the strengths of bonds. The thicker the link, the stronger the linkage between the nodes it joins

The Fig. 2 graph, on the other hand, shows the conversational turn-taking sequences of the same subset of dramatic characters. It differs from Fig. 1 in that this graph weighs the 'strength of such bonds' developed in the conversational flow. This strength is represented in the graph by the link's thickness. The thicker the link, the stronger the linkage between the nodes it joins. This attribute is significant from a sociometric point of view since, as Grannoveter argues, the 'strength' of a bond consists of a 'combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie' (Granovetter, 1973, p. 1361). As can be seen in Fig. 2, Romeo and Juliet's relationship is represented by a red bond. But other characters also develop strong links. We can therefore conceive of *Romeo and Juliet* as a 'conversational network' in which each character specializes in developing strong or weak bonds with the rest of the characters, which contributes to increasing or decreasing their centralities.

Thus, the sociograms in Figs 1 and 2 show both the 'number of bonds' a given character has with the other characters and the 'strength of those bonds', which contribute to establishing both Romeo and Juliet as the main characters in the play. In the following section, we explain the method and strategy used to measure centrality and compare prominence in the play.

3 Material and Methods

The method we adopted for this investigation was the single-case study. The idea of exploring the prominence or importance of characters in a text using graph theory has been previously applied to the analysis of novels and films, using information regarding the division into scenes and acts to construct importance weight factors (for example, see Tsai *et al.*, 2013; Weng *et al.*, 2009;). In the case of Shakespeare's plays, this division was introduced subsequent to their original publication. As Dobson notes, 'Of the original quartos of Shakespeare's plays, none is divided into numbered scenes (although in Q1 *Romeo and Juliet* a printer's

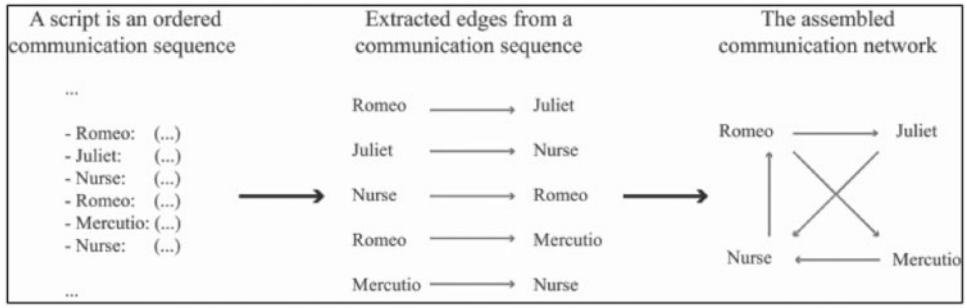

Fig. 3 Schematic diagram showing how to create a character network from the turn-taking communication sequence. This encoding of the script captures both the number of bonds among the characters and the strength of those bonds by using the who-talked-after-whom heuristic

ornament occasionally appears where new scenes begin' (Dobson and Wells, 2001, p. 1). It is also known that the plays were presented by adult theatre companies as continuous performances. We therefore designed a methodological strategy that enabled us to weight the prominence of Romeo and Juliet independently of the many different arguments regarding the division of the text into scenes and acts.[5] In this section we describe the method and strategies used to compare the prominence of Romeo and Juliet.

3.1 Data

The data used for this study was taken from the script of *Romeo and Juliet* as edited by Baltimore Evans (Shakespeare, 2003). This particular play was chosen due to the fact that it is the most popular and well-known of Shakespeare's romantic tragedies. Moreover, according to Dobson and Wells, this play is not only considered to be 'the greatest love story ever told' (Dobson and Wells, 2001, p. 397) but has also been the object of considerable study in the social sciences. A variety of analyses have been published in different perspectives and interpretative frameworks ranging from Kristeva (1987); Derrida (1992) to Gibbons (1980); Levenson (1987); Callaghan (2003); Reynolds and Segal (2005); Harris (2010), to mention but a few. Authors such as Leggatt (2005) and Dillon (2007) have also contributed to the play's analysis by establishing that it belongs to the genre of tragedy.

3.2 Coding the conversational turn-taking sequences

In the view of the present authors, a script can be seen as a conversational turn-taking sequence or communication flow. Turn-taking is a key concept in the analysis of natural conversations (Hawes *et al.*, 2009; O'Connell *et al.*, 1990). Therefore, to include and compare most of the characters in *Romeo and Juliet*, we reconstructed the script network using the 'who-talked-after-whom' heuristic (Moon *et al.*, 2006). This heuristic has been employed to extract sequences of human communication in digital settings such as the communication between participants in an online multi-player computer game involving more than three million registered players (Moon *et al.*, 2006). The heuristic can also be applied to extract social networks on any digital communication platform where the communication between the participants has a sequential order, such as Facebook, Twitter or WhatsApp. In all of these communication types, there is a communication flow structured by turn-taking sequences.

In *Romeo and Juliet*, the conversational flow is realized as 'turn-taking' sequences. The 'who-talked-after-whom' heuristic captures the structure of the script from the sequence of speaking turns of each character (see Fig. 3). To organize the sociometric data, we entered the coded script into a directed and valued square adjacency matrix in which each row was assigned the same set of characters. The actors use this information to establish the

order in which they speak. Turn-taking is a part of the structure and systematic organization of the script and is independent of the characters' text-based attributes and the multiple translated versions of the Shakespeare's plays. However, no analysis has been done of the relationship between the information provided by this underlying structure and its influence on the prominence of the characters. Other heuristics[6] for coding the works of Shakespeare may be found in Stiller *et al.* (2003) or Mutton (2004). Rydberg-Cox (2011) uses another type of coding heuristic to reconstruct the social networks in Greek tragedies. The concept of turn-taking enables us to study the plays of Shakespeare as digital or electronic social networks. With this encoding, we attempt to emphasize the importance of turn-taking when the characters speak. As a professional dramatist, Shakespeare organized his scripts so that a company of actors knew how to perform the play, i.e. (1) which character speaks which lines, and (2) which character speaks after whom. Most studies of Shakespeare focus on (1). Our own experience has taught us (1) how important it is for actors to remember their turns to speak as well as their lines. However, in our view it is not the case that 'you can always tell who is not a main character by the fact that Shakespeare did not put any great words into their mouth' (Freehof, 1972, p. 125). On the contrary, we believe that (2) characterizing the structure of a script is just as important, but less explored.

In fact, who must speak after whom, that is, the order of turn-taking, is important not only for an actor who needs to learn how to coordinate his movements and speech with the rest of the cast, but also for the 'audience', because without this information it is impossible to create an attuned flow of understandable interactions. Considering that these are two sides of the same coin, we hope to analyze the information present in both (1) and (2) in a future study.

3.3 Weighted centrality measures

The choice of centrality indicators is not random. For example, in SNA studies centrality is usually measured by using indicators of degree, closeness, and betweenness (Freeman, 1977). These measures (see Table A1 in Appendix) allow us to explore different ways in which a character may be central according to the interaction flow defined by the script. As an example, degree centrality can be used to identify the 'number' of direct contacts that are linked to a character, either with betweenness centrality measures that help identify which character mediates the relationships among other characters or with closeness centrality measures that identify the extent to which a character is in proximity to other characters.

From the coding of who spoke after whom, we can measure centrality and weight it as a function of the intensity of each interaction sequence. The degree centrality of a node measures the number of neighbors adjacent to it. However, if a character *A* has two different neighbors, one before his or her speaking turn and the other after it, on only one occasion in the entire script, he or she has a lower degree centrality than a character *B* who has the same two neighbors as *A* but on multiple occasions. To measure the number of a character's neighbors and weight it according to the intensity of his or her interaction with them, we used the $\alpha\omega$-weighted degree centrality measure (Opsahl *et al.*, 2010). The betweenness centrality measures how central a node is as a function of the number of shortest paths from all vertices to all others that pass through that node. However, the intensity of the relationships can make a node more central. For example, if character *B* has an intermediate position between the speaking turns of *A* and *C* on a single occasion in the whole play, *B*'s level of centrality will be lower than if he or she had such an intermediate position on multiple occasions. To measure the degree to which a node is intermediate and weight it according to the intensity of the interaction with the nodes it is intermediate between, we used the $\alpha\omega$-weighted betweenness centrality measure (Opsahl *et al.*, 2010). Finally, the closeness centrality measure of a node measures how close it is to all the other nodes in the network. However, the intensity or strength of its relationship may make it closer to certain of the others. For example, if two characters have the same degree of closeness but one of them has multiple instances of interaction with those close by, it will have greater weighted closeness

than the other one. To measure the closeness of a node and weight it according to the intensity of the interaction with close by or distant characters, we use the $\alpha\omega$-weighted closeness centrality measure (Opsahl *et al.*, 2010).

To incorporate the strength or intensity of a link, we modify its value using a parameter denoted α that allows us to calculate the centrality measures using a greater amount of information than can be included with the original measures. Thus, different value of α are used to vary the weight or intensity of bonds. To our knowledge, these centrality measures have not been previously used in analyses of the centrality of Shakespeare's characters.

To measure these same aspects considering the influence they may have in the weight or intensity of bonds, we used indexes of $\alpha\omega$-weighted degree, $\alpha\omega$-weighted betweenness and $\alpha\omega$-weighted closeness as proposed by Opsahl *et al.* (2010).[7] These indexes enabled us to measure centrality and degree of node importance depending either on the 'number' or the 'strength of the bonds', or both measures at the same time. For readers familiar with graph theory, the mathematical notation for the $\alpha\omega$-weighted centrality measures is harmonized with that used for the standard centrality measures in Appendix A1.

3.4 Cluster analysis

3.4.1 *Comparative data analysis using K-means clustering*

The analysis strategy consisted of comparing different rankings of the characters in the play. To compare the importance of the 'number of bonds', their 'strength', or both aspects at the same time, we evaluated the centrality of Romeo and Juliet by using three different criteria for the value of α. The first one weighted the centrality indexes exclusively in terms of the 'number of bonds', generating a value of 0.0; the second one weighted centrality by the 'number of bonds' and their 'strength', producing a value of 0.5; and the third one weighted centrality based exclusively on the 'strength of the bonds', yielding a value of 1.0 (Opsahl *et al.*, 2010). Thus, we ordered the ranking by each centrality value and compared the increase or decrease, if any, of the nodal positions in the play. We also explored whether the concept of centrality could be used to construct a typology of characters. Partridge, for example, argued that Shakespeare 'makes events largely dependent on character. The typical Shakespearean tragedy, though presenting a considerable number of persons, concentrates pre-eminently on one, the "hero," or at most on two, the "hero" and the "heroine"' (Koch, 2009, pp. 25–6). Similarly, Stephen Koch commented that '[t]here is usually only one protagonist in a given story. Sometimes there are two: Consider Romeo and Juliet. On rare occasions there may be more' (Koch, 2009, p. 79). In addition, it has been suggested in existing works that '[a]s a rule of thumb, major characters usually have a lot to say and appear frequently throughout the play, while minor characters have less presence or appear only marginally' (Lethbridge and Mildorf, 2003, p. 1). From our point of view (as humanistic individuals and as part of the audience), we think that Romeo and Juliet are the 'tragic heroes' par excellence, but there are also 'major' and 'minor' characters in the play. To explore this issue further, we performed a series of cluster analyses on the values that were obtained for the characters for $\alpha\omega$-degree, $\alpha\omega$-betweenness, and $\alpha\omega$-closeness to different values of α. The algorithm we used was the *K*-means algorithm (Wu *et al.*, 2008), which is a clustering technique that partitions a set n into K groups, each observation belonging to the group whose mean it is closest to.

3.4.2 *Validation of the number of clusters*

To validate the number of clusters generated by the *K*-means algorithm, we calculate a solution using $K=2$, $K=3$, and $K=4$ with α parameter values of 0.0, 0.5, and 1.0 for the $\alpha\omega$-weighted centrality measures. To evaluate the number of appropriate clusters for our data, assume that S_K is the sum of the cluster distortions when the number of clusters is K, N_d is the number of data set attributes (i.e. the number of $\alpha\omega$-weighted centrality measures), and α_K is a weight factor. We validate the number of clusters using the evaluation function $f(K)$ defined in Pham *et al.* (2005) (see Equation (1)) as follows:

$$f(K) = \begin{cases} 1 & \text{if } K = 1 \\ \dfrac{S_K}{\alpha_K S_{K-1}} & \text{if } S_{K-1} \neq 0 \text{ for all } K > 1, \\ 1 & \text{if } S_{K-1} = 0 \text{ for all } K > 1 \end{cases} \quad (1)$$

where

$$\alpha_K = \begin{cases} 1 - \dfrac{3}{4N_d} & \text{if } K = 2 \text{ and } N_d > 1 \\ \alpha_{K-1} + \dfrac{1 - \alpha_{K-1}}{6} & \text{if } K > 2 \text{ and } N_d > 1 \end{cases}$$

Thus, values of K that yield low values for $f(K)$ can be regarded as giving well-defined clusters (Pham *et al.*, 2005). Using this function, we validated that of the three K values tested, the most efficient solution was obtained for $K = 3$ regardless of the α value given that in each case, the index $f(K)$ falls to its minimum (see Table A2 in Appendix). It was also observed that one cluster concentrated the greatest quantity of characters and when the value of K was increased, the smallest classes tended to subdivide, but not the class with the highest number of elements. This is another result implying that the solution $K = 3$ is a valid choice for the case under study. A three-group solution therefore seems reasonable: the 'tragic heroes' (i.e. Romeo and Juliet as characters with high centrality/prominence), the 'major characters' (i.e. characters with medium centrality/prominence), and the 'minor characters' (i.e. characters with low centrality/prominence).

3.5 Software

We used the 'tnet' package to compute the weighted centrality measures. Additional information and examples for this R package can be found at http://toreopsahl.com/2010/04/21/article-node-centrality-in-weighted-networks-generalizing-degree-and-shortest-paths/

4 Results

In this section, we present the results of the centrality analysis for the different values of α (Subsection 4.1). To summarize these results, we also describe the position obtained by the characters in the cluster analysis (Subsection 4.2).

4.1 Nodal centrality report

We begin by discussing the centrality rankings using $\alpha\omega$-weighted degree, $\alpha\omega$-weighted betweenness, and $\alpha\omega$-weighted closeness.

4.1.1 *Ranking using $\alpha\omega$-weighted degree centrality*

The ranking using $\alpha\omega$-weighted degree centrality for the various characters is shown in Table 1 for the different α values.

As can be seen, the character of Romeo obtained the highest ranking (1st when $\alpha = 0$, 1st when $\alpha = 0.5$, and 1st when $\alpha = 1$). This outcome supports Ballon's theory (Ballon, 2004) as regards SNA. However, when the value of α was increased, Juliet was the second highest ranked (5th when $\alpha = 0$, 2nd when $\alpha = 0.5$, and 2nd when $\alpha = 0.5$).

4.1.2 *Ranking using $\alpha\omega$-weighted betweenness centrality*

The ranking using $\alpha\omega$-weighted betweenness centrality for the various characters is shown in Table 2 for the different α values.

In this case, the Capulet was the highest ranked character (1st when $\alpha = 0$), and Nurse was in second place (2nd when $\alpha = 0.5$). However, when the value of α is increased, Romeo took the top spot (3rd when $\alpha = 0.0$, 1st when $\alpha = 0.5$, and 1st when $\alpha = 1.0$). Finally, Juliet's character improved its score when the value increased (to 12th when $\alpha = 0.0$, 5th when $\alpha = 0.5$, and 2nd when $\alpha = 1.0$).

4.1.3 *Ranking using $\alpha\omega$-weighted closeness centrality*

The ranking using $\alpha\omega$-weighted closeness centrality for the various characters is shown in Table 3 for the different α values.

Here, the character of the Nurse was ranked at the top (1st when $\alpha = 0.0$), but when the value of α was increased, Romeo scored high (2nd when $\alpha = 0.0$, 2nd when $\alpha = 0.5$, and 2nd when $\alpha = 1.0$). Similarly, Juliet's character moved up when the value increased (4th when $\alpha = 0.0$, 1st when $\alpha = 0.5$, and 1st when $\alpha = 1.0$).

4.2 Cluster analysis report

The results of the cluster analysis are ordered in Table 4 by the values obtained for $\alpha\omega$-weighted degree, $\alpha\omega$-weighted betweenness, and $\alpha\omega$-weighted closeness centrality for different values of α. The first analysis grouped the characters using $\alpha = 0.0$, the second analysis used $\alpha = 0.5$, and the third used

Table 1 Ranking of characters by $\alpha\omega$-weighted degree scores with different values of α

Character	$\alpha = 0.0$	Character	$\alpha = 0.5$	Character	$\alpha = 1.0$
Romeo	15.0	Romeo	49.4	Romeo	163.0
Capulet	14.0	Juliet	32.6	Juliet	118.0
Nurse	11.0	Nurse	31.3	Nurse	89.0
Friar Lawrence	11.0	Capulet	26.2	Benvolio	62.0
Prince	9.0	Friar Lawrence	24.4	Mercutio	62.0
Juliet	9.0	Benvolio	22.3	Friar Lawrence	54.0
Benvolio	8.0	Mercutio	15.7	Capulet	49.0
Paris	6.0	Lady Capulet	13.6	Lady Capulet	46.0
Tybalt	5.0	Paris	11.5	Paris	22.0
Peter	5.0	Prince	11.2	Sampson	20.0
Captain of The Watch	5.0	Tybalt	9.2	Tybalt	17.0
Lady Capulet	4.0	Peter	8.1	Gregory	15.0
Montague	4.0	Sampson	7.7	Prince	14.0
Mercutio	4.0	Montague	6.3	Peter	13.0
First Servingman	4.0	Balthasar	6.0	Balthasar	12.0
Page	4.0	Captain of The Watch	5.5	Montague	10.0
Sampson	3.0	Gregory	5.5	First Musician	9.0
Officers	3.0	First Musician	5.2	Servant	8.0
Servingman	3.0	Page	4.5	Captain of The Watch	6.0
First Musician	3.0	First Servingman	4.0	Page	5.0
Balthasar	3.0	Servant	4.0	Friar John	5.0
Chorus	2.0	Servingman	3.5	Abram	5.0
Gregory	2.0	Friar John	3.2	First Servingman	4.0
Servant	2.0	Officers	3.0	Servingman	4.0
Second Servingman	2.0	Second Musician	2.4	Apothecary	4.0
Second Musician	2.0	Abram	2.2	Officers	3.0
Friar John	2.0	Chorus	2.0	Second Musician	3.0
Abram	1.0	Second Servingman	2.0	Chorus	2.0
Lady Montague	1.0	Apothecary	2.0	Second Servingman	2.0
Third Servingman	1.0	Cousin Capulet	1.4	Cousin Capulet	2.0
Fourth Servingman	1.0	Lady Montague	1.0	Lady Montague	1.0
Cousin Capulet	1.0	Third Servingman	1.0	Third Servingman	1.0
Musicians	1.0	Fourth Servingman	1.0	Fourth Servingman	1.0
Third Musician	1.0	Musicians	1.0	Musicians	1.0
Apothecary	1.0	Third Musician	1.0	Third Musician	1.0
Second Watchman	1.0	Second Watchman	1.0	Second Watchman	1.0
Third Watchman	1.0	Third Watchman	1.0	Third Watchman	1.0

$\alpha = 1.0$. The mean values of each cluster and the distance matrices between clusters are reported in Table A4 in Appendix.

In all three analyses, the characters are classified into three clusters: cluster *A*, for characters with high centrality/prominence; cluster *B*, for characters with medium centrality/prominence; and cluster *C*, for characters with low centrality/prominence. The characters marked in light blue do not change clusters when the value of α increases. The results for the first cluster show that Romeo, the Nurse, and Capulet are part of cluster *A* while Juliet appears with other major characters in cluster *B*. In the second analysis, Romeo is the only one in cluster *A* while Juliet again appears with other major characters in cluster *B*. In the third analysis a solution is reached where only Romeo and Juliet are members of cluster *A* whereas the Nurse, Capulet, Lady Capulet, Benvolio, and Peter are classified in cluster *B*. Finally, in all three cluster analyses there is a set of minor characters that are classified almost identically in cluster *C*. Therefore, these analyses show once again the stability of Romeo's centrality under different conditions, whereas Juliet achieves greater centrality when her

Table 2 Ranking of characters by $\alpha\omega$-weighted betweenness scores with different values of α

Character	$\alpha = 0.0$	Character	$\alpha = 0.5$	Character	$\alpha = 1.0$
Capulet	393.5	Romeo	567.0	Romeo	661.0
Nurse	364.4	Nurse	392.0	Juliet	493.0
Romeo	292.1	Capulet	320.5	Nurse	428.0
Benvolio	234.9	Benvolio	294.0	Benvolio	386.0
Peter	151.2	Juliet	291.0	Capulet	303.5
Sampson	139.7	Peter	227.0	Peter	267.0
Captain of The Watch	138.5	Sampson	138.0	Lady Capulet	209.0
First Servingman	111.4	Captain of The Watch	138.0	Prince	145.5
Chorus	99.0	First Servingman	104.0	Sampson	138.0
Prince	94.3	Chorus	99.0	Captain of The Watch	138.0
Friar Lawrence	83.0	Friar Lawrence	68.0	First Servingman	104.0
Juliet	75.8	Lady Capulet	26.0	Chorus	99.0
Lady Capulet	38.0	Prince	25.5	Montague	73.0
First Musician	27.6	Paris	22.0	Friar Lawrence	71.0
Page	25.3	Mercutio	21.0	First Musician	35.0
Tybalt	18.9	First Musician	4.0	Paris	32.0
Mercutio	17.6	Page	0.0	Mercutio	28.0
Second Musician	10.5	Tybalt	0.0	Page	0.0
Montague	8.1	Second Musician	0.0	Tybalt	0.0
Officers	7.2	Montague	0.0	Second Musician	0.0
Paris	4.5	Officers	0.0	Officers	0.0
Servant	1.7	Servant	0.0	Servant	0.0
Balthasar	1.2	Balthasar	0.0	Balthasar	0.0
Friar John	0.8	Friar John	0.0	Friar John	0.0
Gregory	0.0	Gregory	0.0	Gregory	0.0
Abram	0.0	Abram	0.0	Abram	0.0
Servingman	0.0	Servingman	0.0	Servingman	0.0
Apothecary	0.0	Apothecary	0.0	Apothecary	0.0
Second Servingman	0.0	Second Servingman	0.0	Second Servingman	0.0
Cousin Capulet	0.0	Cousin Capulet	0.0	Cousin Capulet	0.0
Lady Montague	0.0	Lady Montague	0.0	Lady Montague	0.0
Third Servingman	0.0	Third Servingman	0.0	Third Servingman	0.0
Fourth Servingman	0.0	Fourth Servingman	0.0	Fourth Servingman	0.0
Musicians	0.0	Musicians	0.0	Musicians	0.0
Third Musician	0.0	Third Musician	0.0	Third Musician	0.0
Second Watchman	0.0	Second Watchman	0.0	Second Watchman	0.0
Third Watchman	0.0	Third Watchman	0.0	Third Watchman	0.0

bond 'strength' with other characters is included. These results demonstrate the importance of the strength of bonds in the conversational flow. But they also show how difficult it is to find a single answer as to who is the main character. Note, however, that both Romeo and Juliet achieve high centrality/prominence when $\alpha = 1.0$. As we mentioned in the introduction, there is a broad consensus that in Shakespeare's plays there is generally one main character, sometimes two, but rarely more (Koch, 2009: Partridge, 1971). Therefore, the typology consisting of tragic heroes (i.e. characters with high centrality/prominence), major characters (i.e. characters with medium centrality/prominence), and minor characters (i.e. characters with low centrality/prominence) seems to have some initial support.

5 Discussion

In this discussion we explore and compare the characters of Romeo and Juliet using different measures

Table 3 Ranking of different characters by $\alpha\omega$-weighted closeness scores (10^{-3}) with different values of α

Character	$\alpha = 0.0$	Character	$\alpha = 0.5$	Character	$\alpha = 1.0$
Nurse	14.93	Juliet	12.66	Juliet	6.41
Romeo	14.49	Romeo	12.66	Romeo	6.37
Capulet	14.49	Nurse	12.58	Nurse	6.34
Friar Lawrence	13.89	Lady Capulet	11.59	Benvolio	6.21
Juliet	13.33	Benvolio	11.56	Lady Capulet	6.19
Prince	12.35	Capulet	11.48	Mercutio	6.16
Lady Capulet	12.05	Mercutio	11.32	Friar Lawrence	6.07
Mercutio	11.63	Friar Lawrence	11.19	Capulet	5.98
Benvolio	11.49	Paris	10.26	Paris	5.68
Paris	11.49	Tybalt	9.77	Servant	5.30
Captain of The Watch	11.11	Balthasar	9.39	Tybalt	5.25
Montague	11.11	Servant	9.38	Balthasar	5.17
Page	10.99	Peter	9.13	Montague	5.14
Tybalt	10.99	Montague	9.05	Apothecary	4.90
Officers	10.99	Apothecary	8.87	Peter	4.85
Chorus	10.64	Prince	8.55	Friar John	4.73
Peter	10.53	Friar John	8.26	Prince	4.37
Second Musician	10.53	Captain of The Watch	7.76	First Musician	4.23
Balthasar	10.53	Servingman	7.65	Servingman	3.83
Servingman	10.53	Chorus	7.52	Cousin Capulet	3.83
First Musician	10.31	Page	7.51	Page	3.82
Servant	10.31	Cousin Capulet	7.42	Second Musician	3.34
First Servingman	10.10	First Musician	7.36	Captain of The Watch	3.24
Friar John	9.90	Second Musician	7.34	Sampson	3.22
Second Servingman	9.90	Sampson	7.25	Chorus	3.20
Fourth Servingman	9.71	Officers	7.15	Gregory	3.09
Apothecary	9.62	First Servingman	6.90	First Servingman	3.04
Cousin Capulet	9.62	Second Servingman	6.72	Second Servingman	2.95
Sampson	9.17	Fourth Servingman	6.55	Officers	2.94
Lady Montague	8.20	Lady Montague	6.49	Abram	2.88
Second Watchman	8.00	Gregory	6.41	Lady Montague	2.86
Third Watchman	8.00	Abram	5.95	Fourth Servingman	2.85
Musicians	7.69	Musicians	5.65	Musicians	2.53
Third Musician	7.69	Third Musician	5.65	Third Musician	2.53
Third Servingman	7.46	Second Watchman	5.09	Second Watchman	2.01
Gregory	6.99	Third Watchman	5.09	Third Watchman	2.01
Abram	6.94	Third Servingman	4.71	Third Servingman	1.93

of nodal centrality. Why are Romeo and Juliet prominent characters? In our introduction we referred to the different arguments holding that Romeo is the only main character of the play (Ballon, 2004), that Juliet's character is as important as Romeo's (Partridge, 1971), or that both Romeo and Juliet are the main characters (Hazen, 2004). No study or proposal denies Romeo's prominence; it is when Juliet is posited as the main character that critics tend to disagree and opinions diverge. Our findings here may explain why Romeo's prominence is not as questioned as Juliet's. Comparing centrality rankings on the assumption that both the 'number of bonds' and their 'strength' contribute to high centrality, we found that the way in which Romeo and Juliet become central characters is different. This analysis revealed that Romeo's centrality is more stable than Juliet's in all of the indexes we calculated. We also found, however, that under certain conditions Juliet's character obtained a high degree of centrality.

In addition, our results point up an aspect that might explain why Romeo's prominence is not questioned whereas Juliet's prominence is: because

Table 4 Cluster analysis (K = 3) results by α value

Cluster analysis ($\alpha = 0.0$)		Cluster analysis ($\alpha = 0.5$)		Cluster analysis ($\alpha = 1.0$)	
A	Capulet	*A*	Romeo	*A*	Juliet
A	Nurse	*B*	Benvolio	*A*	Romeo
A	Romeo	*B*	Capulet	*B*	Benvolio
B	Benvolio	*B*	Juliet	*B*	Capulet
B	Captain of The Watch	*B*	Nurse	*B*	Lady Capulet
B	Chorus	*B*	Peter	*B*	Nurse
B	First Servingman	*C*	Abram	*B*	Peter
B	Friar Lawrence	*C*	Apothecary	*C*	Abram
B	Juliet	*C*	Balthasar	*C*	Apothecary
B	Peter	*C*	Captain of The Watch	*C*	Balthasar
B	Prince	*C*	Chorus	*C*	Captain of The Watch
B	Sampson	*C*	Cousin Capulet	*C*	Chorus
C	Abram	*C*	First Musician	*C*	Cousin Capulet
C	Apothecary	*C*	First Servingman	*C*	First Musician
C	Balthasar	*C*	Fourth Servingman	*C*	First Servingman
C	Cousin Capulet	*C*	Friar John	*C*	Fourth Servingman
C	First Musician	*C*	Friar Lawrence	*C*	Friar John
C	Fourth Servingman	*C*	Gregory	*C*	Friar Lawrence
C	Friar John	*C*	Lady Capulet	*C*	Gregory
C	Gregory	*C*	Lady Montague	*C*	Lady Montague
C	Lady Capulet	*C*	Mercutio	*C*	Mercutio
C	Lady Montague	*C*	Montague	*C*	Montague
C	Mercutio	*C*	Musicians	*C*	Musicians
C	Montague	*C*	Officers	*C*	Officers
C	Musicians	*C*	Page	*C*	Page
C	Officers	*C*	Paris	*C*	Paris
C	Page	*C*	Prince	*C*	Prince
C	Paris	*C*	Sampson	*C*	Sampson
C	Second Musician	*C*	Second Musician	*C*	Second Musician
C	Second Servingman	*C*	Second Servingman	*C*	Second Servingman
C	Second Watchman	*C*	Second Watchman	*C*	Second Watchman
C	Servant	*C*	Servant	*C*	Servant
C	Servingman	*C*	Servingman	*C*	Servingman
C	Third Musician	*C*	Third Musician	*C*	Third Musician
C	Third Servingman	*C*	Third Servingman	*C*	Third Servingman
C	Third Watchman	*C*	Third Watchman	*C*	Third Watchman
C	Tybalt	*C*	Tybalt	*C*	Tybalt

A indicates characters with high centrality/prominence, *B* indicates those with medium centrality/prominence, and *C* indicates those with low centrality/prominence.

his centrality is higher and more stable whereas hers is less stable. Furthermore, when information about the weight of the relationships was introduced, the cluster analysis showed both Romeo's stability in the characters' cluster with a high centrality and Juliet's change in this cluster. To a certain extent, Juliet inherits more centrality due to the 'strength of the bonds' she has with characters who possess high centrality. Measures not included in this report, such as Authority and Hub centrality (Kleinberg, 1999), may give clear indications of Juliet's centrality; for now, we conclude that the concept of centrality contributes significantly to the exploration and comparison of the two characters' prominence.

As just hinted at above, our comparative analysis also showed that Juliet's position rapidly changes when we add the 'strength of the bond' to the 'number' of links. Given that Shakespeare's plays imitate social reality, this result is consistent with women's social context at the time. A woman was

supposed to take less part in social relations; it was not considered proper for a woman to be eloquent. Indeed, popular writers in the early modern period considered female speech as highly dangerous (Vives, 1991; Xenophon, 1994). Modern scholars such as Patricia Parker also refer to the public nature of rhetoric in contrast to the role of women within the private sphere (Parker, 1987). In general, female characters in Shakespeare's plays seem to obey this social structure; however, their silences do not lack 'strength' (Baldwin Lind, 2015). In this perspective, Romeo and Juliet are prominent because they both obtained high centralities, but the way in which they achieve centrality transforms them into two very different main characters.

Our centrality analysis demonstrated that some of the other characters in the play also have high centralities. This adds a new insight to the whole issue. For example, how prominent are the characters of the Nurse, Mercutio, or Benvolio in the dramatic constellation of characters? This question is relevant because, as Boal suggested in *Romeo and Juliet*, Mercutio could conceivably be the main character given that the 'audience' creates an empathic bond with him. However, Arroyo argues that Mercutio is not a main character, but rather a foil character to Romeo because he 'is a character closely related to the protagonist' (Arroyo, 1987, p. 95). At the same time, Bloom notes in *William Shakespeare: The Invention of the Human* that the Nurse and Mercutio are the audience's favorites and Gleed observes that 'if Mercutio represents one of the most ferociously male figures in the text, the Nurse offers a vivid portrait of female hyper-sexuality' (Gleed, 1998, p. 78). All of this leads us to rethink the importance of the centrality of other characters for the structure of the social plot in *Romeo and Juliet*.

As for Capulet, his centrality is noticeably high when measured in $\alpha\omega$-weighted betweenness. This centrality presents him as an intermediate character and creates a distance in communication, which makes sense given the plot of the play. His character complicates communication because he is opposed to Romeo and Juliet's love, and he comes between them and hinders their relationship. Moreover, in the academic literature there is an interpretative perspective which highlights the importance of Capulet as a character that should be seen in the midst of the patriarchal plot (Goldstein, 1996). From this point of view, if we consider *Romeo and Juliet* as a play written under the patriarchal paradigm, it seems only natural to conceive that Shakespeare gave prominence to a character as Capulet because he is the character who fulfils the role of mediator between the Capulets and the Montagues in general, and between Romeo and Juliet in particular.

The concept of centrality might also help to assess the centrality of other major characters. For example, it was noted that the Nurse has the highest ranking for $\alpha\omega$-weighted closeness, thus situating her as an essential character to the others, especially Juliet. Benvolio's high ranking for $\alpha\omega$-weighted betweenness centrality is also noticeable as he is a character who unsuccessfully tries to mediate and pacify the violent situation between the two families, and his centrality could be characterized as that of a communication mediator. Finally, Mercutio has smaller centrality levels in comparison with Nurse and Benvolio but his $\alpha\omega$-weighted centrality closeness is still high considering that his interaction with the other characters ends in the third act when he is killed by Tybalt.

The results of our research have certain limitations that should be kept in mind. There is a clear difference between the centrality of a given character and the value he or she is given by the 'audience'. Though the present authors believe that the centrality of a character is key to understanding prominence, an in-depth study of the audience's appreciation of the character is also required. In other words, the relationships of these characters have to be read within the context of the play itself. The social network approach must incorporate the eye of the beholder in the assessment of a character's prominence. Above all, as Stiller and Hudson suggest, 'the success of an audience's interaction with a dramatic performance ultimately depends on the accurate mimesis of natural human social groups within the diegetic world' (Stiller and Hudson, 2005, p. 60). Finally, the underlying assumptions in the 'who-talked-after-whom' heuristic fail to take into account non-speaking roles.

For example, if a king or queen is always accompanied by attendants who never speak (as is common in Shakespearean drama), the heuristic does not recognize their intrinsic social closeness. Future research could measure this play from a multiplex or multilayer perspective, using not only the who-talked-after-whom heuristic but also the heuristics used by Stiller *et al.* (2003), Mutton (2004), Rydberg-Cox (2011), or Rochat (2014). Thus, the comparison of different 'layers' of social networks can provide us with new knowledge about Shakespeare's plays. In this study, what we have demonstrated is that the strength of relationships between characters in a play has a strong influence on their prominence. Therefore, indicators of social networks that measure this factor should definitely be included in future studies.

The existence of different coding systems is an advantage for the study of Shakespeare's plays. For our purposes these systems can be divided into two types: those that code based on explicit elements in the script such as something said by a character, and those based on the structural aspects of the script. These latter aspects we call 'deep structure', in direct allusion to the Chomskian tradition. We use a heuristic aimed at mapping this deep structure in the plays, which can be identified by tracing the relationships inherent in the characters' turn-taking, that is, who speaks after whom. This factor is independent of the characters' text-based attributes or multiple translated versions of the Shakespeare's plays. This layer of information can be compared and complemented with a layer of 'surface structure' and the information so generated can be analyzed using algorithms for multilayer networks. In this sense, the different coding systems provide different but complementary information.

However, a clear advantage of coding the script using the who-talked-after-whom heuristic (Moon *et al.*, 2006) is that we can measure the interaction sequence of the characters objectively and independently of the textual content whereas the other heuristics used in previous studies of Shakespeare's plays are subject to the coder's subjective interpretation or fine-tuning parameters. A future study could include the information gleaned from different network layers and analyze the protagonism of the characters using information captured by other coding systems. Various algorithms developed mainly by physicists and computer scientists to analyze complex networks could be applied here (see De Domenico *et al.*, 2013; Kivelä *et al.*, 2014).

Further work should be undertaken to confirm the results and findings of this investigation for other cases. For example, a study could be conducted to measure and compare our findings with some other play by Shakespeare such as *Antony and Cleopatra*. This tragedy is similar to *Romeo and Juliet* in that there are two main characters. The research could focus on confirming whether Antony's prominence is as stable as we found Romeo's to be, or whether Cleopatra's prominence is also based on the 'strength' of her links as with Juliet's. This play would be an important case for further analysis and would enrich the discussion as to which elements of a script contribute to developing centrality. Confirmation of this notion of centrality would allow us to better understand Shakespeare's style in the interaction of his characters and position them in terms of their respective level of prominence.

The theoretical and methodological approach used in this study, as in the suggestions for future research, could also be extended to other authors, playwrights, and plays. We hope that the present analysis has contributed to the study of prominence of characters in Shakespeare's plays using the method of SNA.

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Appendix

A.1 Formal definitions of weighted centrality measures

Social and other networks are conveniently described as a graph $G = (V, E)$, where V is the

Table A1 Notation and definition of centrality measures

Centrality measure	Notation	Definition	Reference
			Local measures
Degree	$C_D(v)$	$\sum_{e_v \in E} a(e_v)$	(Diestel, 2005)
ω–weighted degree	$C_D^{\omega}(v)$	$\sum_{e_v \in E} \omega(e_v)$	(Opsahl *et al.*, 2010)
$\alpha\omega$–weighted degree	$C_D^{\alpha\omega}(v)$	$C_D(v)^{(1-\alpha)} C_D^{\omega}(v)^{\alpha}, \alpha > 0$	(Opsahl *et al.*, 2010)
			Distance measures
Betweenness	$C_B(v)$	$\sum_{s \neq v \neq t \in V} \frac{\sigma(s,t\|v)}{\sigma(s,t)}$	(Freeman, 1977)
ω–weighted betweenness	$C_B^{\omega}(v)$	$\sum_{s \neq v \neq t \in V} \frac{\sigma^{\omega}(s,t\|v)}{\sigma^{\omega}(s,t)}$	(Opsahl *et al.*, 2010)
$\alpha\omega$–weighted betweenness	$C_B^{\alpha\omega}(v)$	$\sum_{s \neq v \neq t \in V} \frac{\sigma^{\alpha\omega}(s,t\|v)}{\sigma^{\alpha\omega}(s,t)}$	(Opsahl *et al.*, 2010)
Closeness	$C_C(v)$	$\frac{1}{\sum_{t \in V} \delta(v,t)}$	(Beauchamp, 1965; Sabidussi, 1966)
ω–weighted closeness	$C_C^{\omega}(v)$	$\frac{1}{\sum_{t \in V} \delta^{\omega}(v,t)}$	(Opsahl *et al.*, 2010)
$\alpha\omega$–weighted closeness	$C_C^{\alpha\omega}(v)$	$\frac{1}{\sum_{t \in V} \delta^{\alpha\omega}(v,t)}$	(Opsahl *et al.*, 2010)

Those that are $\alpha\omega$–weighted generalize the metrics weighted only by ω (i.e. if $\alpha = 1$) as well as those that are not weighted (i.e. if $\omega = 1$).

Table A2 Validation of the *K*–number

K	Maximum K/N ratio (%)	α_K	S_K	f(K)
	$\alpha = 0.0$			
2	89.19	0.75	145758.65	1.00
3	72.97	0.79	40300.76	**0.35**
4	67.57	0.83	26303.79	0.79
	$\alpha = 0.5$			
2	83.78	0.75	362572.56	1.00
3	83.78	0.79	82935.01	**0.29**
4	78.38	0.83	59230.05	0.86
	$\alpha = 1.0$			
2	89.19	0.75	489052.50	1.00
3	81.08	0.79	167549.25	**0.43**
4	72.97	0.83	80209.50	0.58

Table A3 Cluster analysis tables

$\alpha\omega$–weighted measure	Cluster *A*	*B*	*C*
Center values ($\alpha = 0.0$)			
Degree	13.33	6.22	2.36
Betweenness	350.00	125.30	6.45
Closeness (10^{-3})	1.46	11.40	9.60
Total elements	3	9	25
Center values ($\alpha = 0.5$)			
Degree	13.33	6.22	2.36
Betweenness	350.00	125.30	6.45
Closeness ($\cdot 10^{-3}$)	4.60	11.40	9.60
Total elements	3	9	25
Center values ($\alpha = 1.0$)			
Degree	140.50	51.80	9.83
Betweenness	577.00	318.70	28.78
Closeness ($\cdot 10^{-3}$)	6.44	5.90	3.80
Total elements	2	5	30

set of vertices representing actors and E the set of edges representing the links between the actors. For simplicity we assume that all graphs are directed and connected, though they may have loops or multiple edges.

Let $a(e)$ be a function representing the existence of an edge $e \text{in} E$. If $a(e) = 1$, then there exists an edge $e \in E$; if $a(e) = 0$, no edge exists. Also let ω be a ω-**weight function** on the edges, where $\omega(e) > 0$ for weighted graphs. These weights are used to measure the 'strength' of the links. An edge having a vertex $v \in V$ is denoted e_v.

Define a **path** from $s \in V \text{to} t \in V$ as an alternating sequence of vertices and edges beginning with vertex s and ending with t such that each edge connects its previous vertex with its following one. We use $\delta(v, t)$ to denote the **distance** between vertices s and t, i.e. the minimum length of all paths

Table A4 Distance between cluster centers

Cluster	*A*	*B*	*C*
$\alpha = 0.0$			
A	–	224.82	343.73
B	224.82	–	118.91
C	343.73	118.91	–
$\alpha = 0.5$			
A	–	263.33	547.96
B	263.33	–	284.70
C	547.96	284.70	–
$\alpha = 1.0$			
A	–	273.11	563.57
B	273.11	–	292.94
C	563.57	292.94	–

connecting s and t. By definition, $\delta(s, s) = 0$ for every $s \in V$ and $\delta(s, t) = \delta(t, s)$ for $s, t \in V$.

The length of an edge e is defined as $\frac{1}{\omega(e)^{\alpha}}$, with $\alpha \geq 0$ (Opsahl *et al.*, 2010). In the special case where $\alpha = 0$, the length is 1. We call this edge length measure **$\alpha\omega$-weighted length**. Also, define the **$\alpha\omega$-weighted distance** $\delta^{\alpha\omega}(s, t)$ between any pair of vertices $s, t \in V$ based on the $\alpha\omega$–weighted length (Opsahl *et al.*, 2010). A particular case is $\alpha = 1$, which obtains the **ω-weighted length** $\delta^{\omega}(s, t)$ from the **$\alpha\omega$-weighted distance** $\delta^{\alpha\omega}(s, t)$.

Let $\sigma(s, t) = \sigma(t, s)$ denote the number of shortest paths from $s \in V$to$t \in V$, where $\sigma(s, s) = 1$ by convention. Let $\sigma(s, t|v)$ be the number of shortest paths from s to t where$v \in V$ lies on the path. Then define $\sigma^{\alpha\omega}(s, t), \sigma^{\alpha\omega}(s, t|v)$ using the definition of **$\alpha\omega$-weighted distance** (Opsahl *et al.*, 2010). In the case where $\alpha = 1$, we obtain $\sigma^{\omega}(s, t)$ and $\sigma^{\omega}(s, t|v)$, respectively.

As can be seen above, the definitions including the term $\alpha\omega$ generalize the definitions weighted only with ω when $\alpha = 1$, and generalize the unweighted terms when $\omega(e) = a(e) = 1$. Therefore, the definitions proposed by Opsahl *et al.* (2010) can be considered a useful generalization of the standard measures of degree, closeness, and betweenness. The centrality measures are defined in Table A1.

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Notes

1 These studies have analyzed Shakespeare's plays using three social networks, namely, connectivity, mean path distance—sometimes called degrees of separation—and cluster coefficient (Stiller and Hudson, 2005; Stiller *et al.*, 2003; Voloshinov and Gozhanskaya, 2008).

2 The keystone characters are those who allow 'the maintenance of the plot and flow of information from scene to scene' (Stiller and Hudson, 2005, p. 70). This term considers an ecosystemic metaphor. According to Csermely '[t]he keystone species is an important hub of an ecosystem whose removal triggers many secondary extinctions and may cause the fragmentation of the whole network' (Csermely, 2006, p. 331).

3 To be read as similar in comparison to the human groups reported in Dunbar and Spoors (1995) and Kudo and Dunbar (2001).

4 For an introduction to the theory of conversational networks, see Woelfel *et al.* (1993). However, the analysis of conversational networks is not based on a unified theory or methodology. Rather, studies of such networks use social network theory to help find responses to various questions, hypotheses, or theories arising in the digital humanities and social media research. For example, Elson *et al.* (2010) use social network theory to automate the extraction of conversation networks in 19th-century British novels. Another case is the work of Hassan *et al.* (2012), which applies linguistic techniques to online discussion posts to automatically construct a signed social network. Finally, Park *et al.* (2013) extract a social network from literary texts as part of an investigation into the common structure of literature regardless of written languages.

5 The evidence accumulated by T.W. Baldwin suggests that Shakespeare learned the five-act structure of plays from studying Terence with Donatus's commentary, as well as Plautus's and Lyly's dramaturgical form (Baldwin, 1947). However, in his career as dramatist he also realized that sometimes there was a clash between this theory and early modern theatre practices, and that a number of plays did not fit into that form. According to Eric Rasmussen, 'division into scenes was a structural element of early English plays—a new scene began whenever the stage was clear and the action not continuous—but division into acts was a later convention, perhaps adopted from classical drama' (Michael Dobson, 2001, p. 1). On the basis of research into act and scene division in Shakespeare's plays by writers such as G. K. Hunter (1976), J. Dover Wilson (1927), W. T. Jewkes (1958), and Emrys Jones (1985), and particularly by Gary Taylor and Jowett (1993), Peter Holland argues that 'continuous performance was the norm for adult companies working in the public theatres until around 1609, that thereafter they gradually adopted the procedure of music intervals that had been customary in the private theatres prior to that date and that there was no practice of continuous performance a decade after that date' (Holland, 2001, p. 38). Some years before, Taylor's insightful research had challenged Baldwin's and Hunter's idea that from the beginning, Elizabethan plays were written to be performed with pauses between the acts. He also expanded Jewkes findings upon an earlier survey by W. W. Greg (1928), thus providing evidence to conclude that 'during 1591–1607, of 75 extant plays written

for adult companies, none has act–division except for the five by Jonson. [...] During 1609–1616, over half the plays written for adult companies have act–divisions, which appear more frequently' (Taylor and Jowett, 1993, p. 4–25). Lukas Erne contributes to this debate, pointing out that because the 'performance of plays by adult companies in public outdoor theatres appears to have been uninterrupted, [...] divisions in theatrical manuscripts [were] unnecessary. Performances by boys' companies at the more elite indoor venues, however, were interrupted by act breaks, which is reflected in the printed versions of plays designed for indoor performance' (Erne, 2013, p. 112). In any case, the norm of continuous performance and the absence of these intervals or divisions in manuscripts and playbooks does not imply that Elizabethan playwrights, and therefore Shakespeare, did not organize the structure of plays according to the five–act arrangement or that the early modern dramatists had no perception or sense of this dramaturgical pattern. Moreover, scenes in Shakespeare's plays are understood as units of action during which one set of characters enters, indicated in early editions by the stage direction 'Enter', and others who leave the stage, indicated by 'Exit' or 'Exeunt'. Though modern editions nearly always divide Shakespeare's plays into acts, among the playbooks—original quartos—published during his lifetime, none is divided into numbered scenes. In the case of *Romeo and Juliet*, we know of two different versions of the play that were published during Shakespeare's lifetime: the second quarto of 1599, the basis for most modern editions, and the first quarto of 1597. In the latter version, which is shorter, a printer's ornament is inserted between scenes or scenic movements, which according to Erne is a way of filling additional space resulting from the use of small type (Erne, 2011, p. 39–41). Only 7 years after Shakespeare's death, his works were published in the First Folio of 1623 in which nineteen of the plays were divided into acts and scenes and another ten were divided into acts. In other words, this structural pattern was not used consistently. Nicholas Rowe's edition (Shakespeare, 1709) of Shakespeare's works was the first to divide all of the plays into numbered acts and scenes.

6 The word *heuristics* derives from the Greek *heurisken*, which means to find or to discover. In general, '[...] a heuristic procedure is a collection of rules or steps that guide one to a solution that may or may not be the best (optimal) solution' (Laguna and Martí, 2013, p. 76). There are several reasons for employing heuristics: '(1) The problem is such that no exact solution method is known for it, (2) known exact solution methods are computationally expensive and, therefore, they are able to solve only small instances of the problem, (3) the flexibility of the heuristic approach enables the incorporation of realistic problem features that otherwise would be difficult to model, and (4) an heuristic method is used within an exact procedure to generate an initial solution or to guide the search' (Laguna and Martí, 2013, pp. 698–9).

7 See https://toreopsahl.com/tnet/weighted-networks/node-centrality/