# The Rich-Get-Richer Phenomenon and language evolution: The case of the German present perfect

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This paper explores language evolution within a complex network framework and, in particular, the preferential attachment tendency, also known as the Rich-get-Richer phenomenon, in the development of the German present perfect. This process, which was first discovered in the World Wide Web where "the links are formed preferentially to pages that already have high popularity" (Easley & Kleinberg, 2010, p. 483), refers to the dynamics involved in the growth of complex scale-free networks (Barabási & Albert, 1999) and, in more general terms, to the development of complex adaptive systems that show a power law degree of distribution: when new connections are created, they connect to the few hubs in the network that already have a high number of links.

I argue that the same phenomenon can be found in the evolution of specific grammatical structures and I will provide evidence using written data from different time periods related to the history of German. Diachronic linguistics analyses show indeed that the evolution of the present perfect displays the same patterns observed in the World Wide Web; in the first attestations from the Old High German period just a few verbs could be combined with the auxiliary verbs. The lexicon's growth in Middle High German and the expansion of contexts in which the present perfect could be used increased the number of possible combinations. Today in New High German, every verb can be coupled with the auxiliary verbs.

In conclusion, this paper provides general support for the implementation of a network framework for the study of the dynamics involved in language change and evolution, as well as support for a Complexity Theory approach, which considers human languages as complex adaptive systems, as described by Hopper (1998), Larsen-Freeman and Cameron (2009) and Bybee (1994, 2003, 2006, 2007, 2010). *Keywords: networks; emergent grammar; complexity theory* 

## 1 Introduction

In recent years, the discovery of complex networks, such as small-world (Watt & Strogatz, 1998) and scale-free (Barabási & Albert, 1999) networks, has opened new possibilities for the representation of the complex connectedness of our society (Ke, 2007; Easly & Kleinberg, 2012). Understanding and studying

complex systems with networks can result in a more effective approach when dealing with complexity. Using a multidisciplinary approach, networks science today offers specific tools for the analysis and for the understanding of complex systems. Network science started to be applied also for the representation of languages themselves since human languages can be also considered as complex dynamic systems (The Five Graces Group, 2008; Larsen-Freeman & Cameron, 2009; Bybee, 2010; De Bot, 2009). To this extent, different scholars used networks for the representation of specific language aspects related to phonetic, phonology, morphology etc. (Ke, 2007; Ke, Gong & Wang, 2008; Chodhury & Mukherjee, 2009; Cong & Liu, 2014; Vitevitch, 2008). In his article, Perc (2012) analyzed the most common English words and phrases since the beginning of the sixteenth century, and showed that these words, regardless of the century considered, are more likely to retain their top rank. He refers to it as the linear preferential attachment, also known as the Rich-get-Richer Phenomenon, which indicates the tendency of new connections in a complex network to be formed with already highly connected nodes which will grow consequentially in connectivity. This process was first observed in the World Wide Web, where "the links are formed preferentially to pages that already have high popularity" (Easley & Kleinberg, 2010, p. 483). The phenomenon described above shows striking similarities to what happens in linguistics to grammatical structures that undergo bleaching or generalization, which is "the process by which specific features of meaning are lost, with an associated increase in the contexts in which that particular structure may be appropriately used" Bybee (2003, p. 605). This means that the loss of semantic force will also increase the elements the specific form can be combined with. Bybee (2003) shows this process using an example from the development of the modal verb "can" from the Old English era to the modern day. "Cunnan" increased in type frequency of co-occurring lexical items as a consequence of bleaching and, at the same time, the token frequency of units also increased dramatically till it reached the number of combinations that are possible today in Modern English with the verb "can".

The Rich-Get-Richer phenomenon seems to be not limited to the World Wide Web, but also can be observed in the different dynamics related to language evolution. Indeed, the historical development of the German present perfect resembles the development of the modal verb "can". The present perfect was at the beginning limited to a small number of verbs. Like "cunnan", it underwent "categorization", which is "the expansion of contexts in which a construction can occur" (Bybee, 2003, p. 12) and today, in Modern German, this tense can be combined with every available verb.

The goal of this work is to provide evidence of the preferential attachment tendency in the historical evolution of the German present perfect. In order to do this, I will be using written data from different historical periods: *The Lay of Nibelungen* (ca. 1200) and *The Sorrow of Young Werther* by Goethe (1774). For the texts' analysis I will use the free web-based text analysis software, Voyant, available at <u>http://voyant-tools.org</u>, which allows users to perform lexical analysis including the study of frequency and distribution data on any written document.

The organization of this study is as follows: The first part deals with Complexity Theory, Emergent Grammar and the Network framework and lays the theoretical foundation of this work, while the second part will be dedicated to the texts' analyses, with some introductory information about the software used for this research and the presentation of the results, and lastly, the final part will provide a short discussion.

## 2 Emergent grammar, Complexity Theory, and human languages

In an Emergent Grammar approach, as described by Hopper (1999), grammar is not the source of understanding and communication, but can be considered as a by-product of it, or a result of the interaction between speakers. Grammar is, in other words, epiphenomenal.

Complexity Theory shares with this framework the same view about languages: "When linguistic structure is viewed as emergent from the repeated application of underlying process, rather than given a priori or by design, then language can be seen as a complex adaptive system" (Bybee, 2010, p.2). This approach today offers a new theoretical framework in applied and historical linguistics, fostering a change in the way we should look at human languages; they are continuously evolving systems with emergent structures, developed through usage and repetition. "From a complexity theory perspective, a language, at any point in time, is the way it is because of the way it has been used" (Larsen-Freeman and Cameron, 2009, p. 80). In this perspective, human languages are viewed as complex adaptive systems which interact with their environment and change over time. Also, Larsen-Freeman and Cameron (2009), underline the dynamic nature of the human languages and consider linguistic patterns as "epiphenomena of interaction", emphasizing in this way the essential roles of the agents and their interactions with each other which is the guiding force of language change and evolution. This approach views human languages no longer as an autonomous set of grammar rules developed on their own and learned by speakers of a specific linguistic community, but rather as dynamic systems strictly related to their speakers and to their environment. The authors highlight that "the history of a language reflects the behavior of its speakers" (Larsen-Freeman and Cameron, 2009, p. 91), quoting Nettle's (1999) claim that "the structure of language has emerged from the kind of message speakers wish to convey and the kind of cognitive, perceptual, and articulatory mechanisms they have to convey them, either by biological evolution, cultural evolution, or more likely by some combination of the two" (Nettle, 1999, p. 13). Complexity theory draws attention to the strong connection between speakers and languages and how the first influences the second and vice versa. Larsen-Freeman and Cameron (2009) explain magisterially this phenomenon when they claim that "language emerges upwards in the sense that language-using patterns arise from individuals using the language interactively, adapting to another's resources. However, there is reciprocal causality, in that the language-using patterns themselves,

downwardly entrain emergent patterns" (Larsen-Freeman & Cameron, 2009, p. 80).

A Complexity theory approach means to also combine a synchronic with a diachronic approach, because "language change is not just a peripheral phenomenon that can be tacked on to a synchronic theory; synchrony and diachrony have to be viewed as an integrated whole" (Bybee, 2010, p. 105).

In this work, languages are also viewed as complex dynamic systems, and grammar structures are considered as a result of the interactions between speakers to convey ideas and thoughts since the aim of a language is communication, as also emphasized by The Five Grace Group in their position paper (2007): "language has a fundamentally social function. Processes of human interaction along with domain-general cognitive processes shape the structure and knowledge of language" (p. 1). Languages, therefore, "emerge from the verbal interaction among humans" (Lee, Mikesell, Joaquin, Mates & Schumann, 2009, p. 3) and their most fundamental features are biological adaptations for cooperative social interaction in general" (Tomasello, 1999, p. xi).

## 3 The Rich-get-Richer Phenomenon in languages

Since languages are complex adaptive systems (The Five Graces Group, 2008; Larsen-Freeman & Cameron, 2009; Bybee, 2003, 2006, 2010; De Bot, 2009), their representation can be carried on in a framework that better captures their complexity and dynamics. The implementation of networks for the study of languages requires a multidisciplinary approach, since it demands the implementation of mathematical models to the representation of linguistics phenomena. Different scholars are adopting a representation with networks in order to analyze different aspects of languages themselves, including phonetics, phonology, morphology, etc., (Ke, 2007; Ke, Gong & Wang, 2008; Chodhury & Mukherjee, 2009; Cong & Liu, 2014; Vitevitch, 2008). Network analysis allowed the visualization of language structures in a completely different and new way and made new findings possible, like the notions of key players, maximal connectivity (Borgatti, 2006), coreness (Carlson, Sonderegger & Bane, 2014) etc. These studies also allowed the discovery of specific processes involved in their growth over time, like the preferential attachment tendency. Perc (2012), in his article, focuses on the development of written English and demonstrates how the most popular words in a certain time period keep in maintaining their high positions in rank and even become more popular with time. Analyses of lexical co-occurrence also showed that these words increase in connectivity, or the number of elements that they can be combined with. Perc refers to this phenomenon as the linear preferential attachment, or the so-called Rich-get-Richer model. This phenomenon was discovered first in the World Wide Web where it was observed that new webpages have the tendency to be connected within the network with already highly connected pages. The preferential attachment seems to, therefore, be a common feature of complex systems, which affects the dynamics of their evolution. It applies to these particular hubs in the

networks with the most connections since their distribution, both in the World Wide Web and in Perc's analysis, follows a power law distribution which can be observed in both a synchronic and a diachronic perspective.

Perc (2012) provides evidence for the presence of the preferential attachment tendency in the dynamics of language change, as well as support for the implementation of network science and Complexity Theory for the study of these dynamics. His article also represents the starting point for this work which will demonstrate how the Rich-get-Richer model can be found in the diachronic representation of the linguistic development of specific grammar structures.

The next sections will be dedicated to the description of the preferential attachment tendency in the development of the German present perfect with the implement of written data from different time periods: *The Lay of The Nibelungs* (ca. 1200) and *The Sorrow of Young Werther* by Goethe (1774). The earlier work has a modest amount of perfect forms and it suited perfectly for the analysis described here since the preferential attachment refers to already relatively highly connected nodes and not to the nodes at their earliest stages of evolution. Both works will be used to illustrate this phenomenon and the focus will be on the *haben Perfekt*, (to have present perfect).

## 4 The German present perfect and the linear preferential attachment

The development of the German present perfect, formed by the combination of the two auxiliary verbs haben and sein plus the past participle of the verbs, is analyzed by Kuroda (1999) and Concu (2015) in their respective works: Die historische Entwicklung der Perfektkonstruktionen im Deutschen and The German Present Perfect as an Emergent Structure. While Concu (2015) is mainly focused on the cognitive processes that led to the formation of this periphrastic construction, Kuroda (1999) analyzes the growth of the number of tokens combined with the auxiliary verbs. Like the verb "can" in English, the German present perfect underwent categorization, the expansion of the contexts in which that particular structure can be used. From the almost 50 forms found in the Evangelienbuch (ca.865) and the 250 in Tristan (ca. 1210), the present perfect was then used 300 times in Fortunatus (1509) and 400 times in Die Wahlverwandtschaften (1809). The increased number of verbs used can also be considered as a process that resembles the preferential attachment observed with both the World Wide Web and the verb "can". Every new verb introduced in modern German will also be conjugated in the present perfect tense, like the brand new "chatten" which indicates the participation in a web chat. The categorization which affected this construction allowed the combination with a progressively larger number of verbs. In a network framework, this process can be seen as the growth of connectivity of the verb haben and sein which became two of the largest hubs in Modern High German. In both English and German, the preferential attachment tendency can be considered as responsible for the power law distribution that the words in the languages follow. "Can" in English and haben and sein in German (with all the conjugated forms) are among the most

common words in these two languages and maintain constantly their high ranks in modern days.

#### 4.1 The corpus

The corpus used in this study is composed of two literary texts from different time periods from German literature. These works are: The Lay of The Nibelungs (ca. 1200) by an unknown author and *The Sorrow of young Werther* (1774) by Goethe. The Lay of The Nibelungs is one of the most important literature monuments in Middle High German. It is a long heroic poem written between 1190 and 1200 and "it is handed down in thirty manuscript, partly complete and partly incomplete and written in an area between the cities Passau and Vienna" (Collitz, 1910, p. 147). The version used here is the manuscript C, which is the most known one. The second work included here is *The sorrow of young Werther*. This novel was published for the first time in 1774 and represents one of the most famous works of Johann Wolfgang von Goethe. It is an epistolary narration of the young Werther and his unfortunate and unrequited love for the beautiful Lotte, which will end with the tragic suicide of the protagonist. The sorrow of young Werther is the expression of Goethe's participation in the Storm and Stress literary movement, which dominates the panorama of the German literature from 1770 to the end of 1780 and anticipate the advent of Romanticisms.

The software used for the texts analyses is a free web-based tool which allows users to carry on lexical analyses on written texts and to display different data related to key words, word frequency and, most important of all, co-occurrence of words. Voyant has a user-friendly interface (Sinclair & Rockwell, 2015, Privacy v. 1.0 beta, 4692).

#### 4.2 The data

#### 4.2.1 The Lay of the Nibelungs

The analysis made with the software, *Voyant*, displays the following preliminary data from the whole poem, which has 81,191 total words with 8,989 unique words. The search toolbar was used to find all the tokens of the verb *haben* (to have) conjugated in present tense. Using the co-occurrence visualization tool, it was possible to discriminate the forms that were combined with a participle, which are the forms analyzed here, from the tokens of the verb that were used as a full-verb and not as auxiliary.

The examples below from the Lay of the Nibelungs are intended to clarify the difference between the two usages of the verb *haben*:

(1) Die drîe künege wâren, ich als gesaget hân kings The three Were. Ι said have as "The three kings were, as I have said" (Verse 29)

(2) Div frowe die helden was ir sister hetens in ir plegen their sister the heroes had in their the woman care was "The women was their sister and the heroes took care of her" (Verse 12)

In (1) the verb *haben* is used as an auxiliary verb in combination with a past participle, while in (2) is used as a verb with the meaning of possession. This work focuses on the analysis of the first type of use in both texts, as shown in (1). The chart below shows the amount of these forms found.

Forms	
	Amount
habe (1 <sup>st</sup> person singular)	13
han (1 <sup>st</sup> person singular)	109
hast (2 <sup>nd</sup> person singular)	8
hat (3 <sup>rd</sup> person singular)	124
haben $(1^{st}/3^{rd} \text{ person plural})$	21
Habt (2 <sup>nd</sup> person plural)	74
habst (2 <sup>nd</sup> person singular)	2
habn (1 <sup>st</sup> person plural)	12
habest (2 <sup>nd</sup> person singular)	2
habet (2 <sup>nd</sup> person plural)	1

Table 1: The forms of present perfect in the Lay of The Nibelungs

All of the forms seem to be well established in the text. The third person singular form of the verb has the highest number of forms, reflecting the third person perspective narration. The token *habe* is always combined with the pronoun *ich* (I) while the token *han* is combined largely with but sometimes without the plural form *wir* (we). The forms of *habet*, *habest*, and *habst* seem to be written with a different spelling. In the text, they are combined with participles and, for this reason, were included here.

## 4.2.2 The sorrow of Young Werther

In this section, I will focus on the *haben* present perfect in Goethe's novel which has 39,173 total words and a number of 6,861 unique words. As done for the first text, I will run frequency and co-occurrence analyses, in order to separate the tokens of the verb *haben* used as an auxiliary from the ones when it has been used as a full verb.

Form		Amount
habe	(1 <sup>st</sup> person singular)	100
hab'	(1 <sup>st</sup> person singular)	13
hast	(2 <sup>nd</sup> person singular)	8
hat	(3 <sup>rd</sup> person singular)	70
haben	$(1^{\text{st}}/3^{\text{rd}}\text{person singular})$	14
habt	(2 <sup>nd</sup> person plural)	3

Table 2. The forms of present perfect in The Sorrow of Young Werther

## 4.2.3 Discussion

The forms found in *The Lay of The Nibelungs* show a modest usage of the *haben* present perfect, which appears in both dialogic and narrative parts. The most common verbs used in past participle are *getan*, *genomen*, *verloren* and *gesehen*. An analysis of frequency and co-occurrence of these forms displays the level of evolution of the present perfect in this particular period of the history of the German language. The token *getan*, for example, is used in the text 301 times, but is used just 68 times in combination with the auxiliary *haben*. In Old High German, different scholars like Zieglschmitd (1929), Leiss (1992), Kotin (1999), Zeman (2010) have shown that the first combinations of *eigan/habên* are full verbs with no auxiliary function. The Old High German speakers started drawing an inference from possessive constructions like the one shown below:

(3) phigboum habeta sum giflanzotan in sinemo uuingarte a fig tree winegarden has someone planted in his "Someone has a fig tree planted in his wine garden" Tatian (ca. 830, 102,2))

In (3) both the verb *haben* and the past participle are used as normal verbs and not as a unique construction.

Bybee (2006) argues, "as a particular string grows more frequent, it comes to be processed as a unit rather than through its individual parts. As it is accessed more and more as a unit, it grows autonomous from the construction that originally gave rise to it" (Bybee, 2006, p.720). The combination of these two verbs also started to be seen as a unit in Old High German. Bybee, Pekins and Pagliuca (1994) claim that "the modern perfect develops out of early resultatives as the participle loses its adjectival nature and becomes part of the verb rather than an adjective modifying a noun" (Bybee, Perkins, Pagliuca, 1994, p. 68) and that "a resultative expresses the rather complex meaning that a present state exists as the result of a prevision action" (Bybee, Perkins, Pagliuca, 1994, p. 69). The cognitive association and generalization between resultative and past, should represent the first step of the development process of the German present perfect. Dan Slobin in his article (1994) analyzed the present perfect in Old English (*Ic haebbe gibunden pone feond pe hi drehte*). It had two different readings, an adjectival and a perfect one. The first was similar to a report (*I inform you that the enemy is bound and in my possession*), while the second was more like a claim and a negotiation (*It is I who captured the enemy, so give me my reward*). The have + past participle constructions contrasted with the preterite, which emphasized only the subject's past actions, and not the current state of the enemy. The Old English hearer, in drawing an inference from the possessive construction, must also have had a background knowledge of the contrasting option of the preterite and this option must have played a role as soon as the ancestor of the perfect contrasted with the preterite in given speech context (Slobin, 1994).

Also in German this contraction started to be uses in given speech context to express claim and to contrast to the preterite, as shown in the example below:

fúntan mir fand ih (4) Ih haben iz in ni líbes uu iht Ι have it found in me never found I good in you I have found it in myself, I never found something good in you. Evangelienbuch (ca.890, I-18-28)

In (4) a present perfect is used in a sentence that also contains a preterite. The claim is made here in the first part of the statement, which is highlighted by the writer through the usage of the present perfect. At the same time, when the present perfect was starting to emerge, the past participle alone started to lose its autonomy. This process began in Old High German and continued through the history of German. This explains the presence of a high number of past participles used without the auxiliary *haben* in the Lay of The Nibelungs. The Middle High German age can be seen as an intermediate stage in the evolutionary scale of the present perfect when it started to show preferential attachment tendency.

The forms found in Goethe's novel show a large use of the present perfect. The presence of such high use of the *haben-Perfekt* is the reflection of the type of narration. Klaus Welke from the Humboldt University in Berlin claims that "das Perfekt ist auf Grund seiner spezifischen semantischen Eigenschaften das Tempus des konstatierenden Berichten [vom Vergangenen] und das Präteritum auf Grund seiner spezifischen semantischen Eigenschaften das Tempus des fortlaufenden Erzählen [vom Vergangenen]" [The present perfect is the past tense of the comment because of its semantic features, while the Preterite is the past tense of the narration because of its semantic features] (Welke, 2010, p. 22). In the same way, Nicole Schumacher from the Free University of Berlin asserts that "die Differenz [zwichen Perfekt und Präteritum] liegt in der subjektiven, sprecherbezogenen Dimension der Distanz begründet, die sich durch Weinrichs (1993) Konzepte des Erzählens und Besprechens erfassen last" [The difference between Present Perfect and Preterite lies in the subjective dimension of "DISTANCE", which refers to Weinrich's categories of comment and narration] (Schumacher, 2005, p. 191) and "um die Gebrauchspräferenzen von Perfekt und Präteritum in Vergangenheitskontexten zu veranschaulichen, sind nicht mehr

temporale und aspektuale Phänomene, sondern die Subjektive Ausprägung von Distanz herauszuziehen" [In order to highlight the usage differences between preterite and present perfect, the temporal and aspectual phenomena do not have to be considered, but the subjective category of the "DISTANCE"] (Schumacher, 2011, p. 22). The present perfect is therefore used in the so-called commentary parts of every kind of narration (Concu 2015), which is why in Werther, Goethe made a large use of this construction.

The chart below shows a comparison between the forms found in the two texts.

Forms	The Lay of The Nibelungs	Forms	The Sorrow of Young Werther
habe	13	habe	100
han	109	hab'	13
hast	8	hast	8
hat	124	hat	70
haben	21	haben	14
habt	74	habt	3
habst	2		
habn	12		
habest	2		
habet	1		

#### Total 366

208

*Table 3: The amounts of forms in the Lay of The Nibelungs and in The Sorrow of Young Werther.* 

The data in both tables show a very similar percentage of usage of present perfect (around the 1% of all the words used). The differences between both texts lie in the participle combined with auxiliary verbs. While in *The Lay of The Nibelungs* the majority of combinations are with the verbs like *getan*, *genomen*, *verloren* and *gesehen*, the variety in Goethe's novel is greater than the one in the Middle High German poem. The next charts show the most frequent past participles in the *Lay of The Nibelungs* and the comparison with the same forms in *The Sorrow of Young Werther*:

The Lay of the Nibelungs	The sorrow of young Werther	Translation
getan: 77	getan: 4	done
gesehn/gesehen: 15/5	gesehen: 11	seen
genomen/genommen: 12/1	genommen: 4	taken
verlorn: 10	verloren: 1	lost
geseget: 11	gesagt: 3	said

*Table 4: The most frequent participle in the Lay of the Nibelungs and in the Sorrow of Young Werther* 

#### 5 Conclusion

The analysis in this works shows evidence for the preferential attachment tendency in the evolution of the present perfect. The Rich-get-Richer model can, therefore, be seen a common pattern in the dynamics involved in the development of complex systems like languages. One of the particular features found through the comparison between *The Lay of the Nibelungs* and *The Sorrow of Young Werther* is that the growth in connectivity of a specific hub negatively affects the connectivity of another one. In the specific case of the German present perfect, the larger number of links of *haben* pushed back the amount of links of the past participle that, especially in the Old High German period and still at the beginning of the Middle High German era, had a greater autonomy. The usage in Modern German of the participle in attributive position is a relict of this lost autonomy.

#### References

- Bearabási, A. L. & Réka, A. (1999). Emergence of scaling in random networks. *Science*, 286, 509-512.
- Burton, R. (2006). *Das nibelungenlied song of the nibelungs*. New Haven: Yale University Press.
- Bybee, J., Perkins, R. & Pagliuca, W. (1994). *The evolution of grammar: Tense, aspect, and modality in the languages of the world.* Chicago-London: The University Chicago Press.
- Bybee, J. (2003). Mechanisms of change in grammaticization: The role of frequency. Retrieved from:

http://www.colorado.edu/ling/courses/LAM7420/FrequencyGn.pdf.

- Bybee, J. (2006). From usage to grammar: The mind's response to repetition. Project Muse. *Language*, 82(4), 711–733.
- Bybee, J. (2007). *Frequency of use and the organization of language*. New York: Oxford University Press.
- Bybee, J. (2010). *Language, usage and cognition*. Leiden: Cambridge University Press.
- Concu, V. (forthcoming 2015). The German present perfect as an emergent structure. *Interdisciplinary Journal for Germanic Linguistics and Semiotic Analysis*, 20(2).
- Choudhury, M. & Mukherjee, A. (2009). The structure and dynamics of linguistic networks. In N. Ganguly, A. Deutsch, & A. Mukherjee (Eds.), *Dynamics* on and of complex networks: Applications to biology, computer science and the social sciences (145–166), Boston: Birkhäuser.
- Collitz, K. H. (1910). *Selections from early German literature*. New York: American Book Company.
- Cong, J. & Liu, H. (2014). Approaching human language with complex networks. *Physics of Life*, 11(4), 598–618.

- Ellis, N., Blythe, R., Holland, J., Bybee, J., Ke, J., Christiansen, M., Larsen-Freeman, D., Croft & Schoenemann, W. T. (2009). Language is a complex adaptive system: Position Paper. *Language Learning*, 59(Suppl. 1), 1–26.
- Hopper, P. J. (1998). Emergent grammar. In T. Michael (Ed.), *The new psycology* of language: Cognitive and functional approach to language structure (155). Mahwah: Lawrence Erlbaum Associates.
- Ke, J., Gong, T. & Wang, W. S.-Y. (2008), Language change and social networks. Communications in Computational Physics, 3(4), 935–949.
- Ke, Y. (2007). Complex networks and human language. arXiv:cs/0701135.
- Larsen-Freeman, D. (2012). Chaos/Complexity Theory for second language acquisition. The Encyclopedia of Applied Linguistics. Retrieved from: DOI:10.1002/9781405198431.wbeal0125.
- Larsen-Freeman, D., & Ellis, N. (2009). Constructing a second language: Analyses and computational simulations of the emergence of linguistic constructions from usage. *Language Learning*, 59(Suppl. 1), 90–125.
- Larsen-Freeman, D., & Cameron, L. (2009). Complex system and applied linguistics. New York: Oxford University Press.
- Hasty, W. & Hardin, J. (1995). German writers and works of the early middle ages. Farmington Hills: Gale.
- Perc, M. (2012). Evolution of the most common English words and phrases over the centuries. *Journal of the Royal Society, Interface*, 9(77), 3323–3328. Retrieved from: doi:10.1098/rsif.2012.0491
- Schumacher, N. (2005). Tempus als Lerngegenstand. Ein Modell für Deutsch als Fremdsprache und seine Anwendung für italienische Lernende. Tübingen: Gunter Narr.
- Schumacher, N. (2011). Nachzustand, Distanz und Aspektualität als Komponenten einer formfokussierten Steuerung von Perfekt und Präteritum. *Linguistik Online*, 49, 61–74.
- Tomasello, M. (Ed.) (1998). *The new psychology of language*. Mahwah: Lawrence Erlbaum Associates.