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Complexity in Electronic Negotiation Support Systems

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Abstract: *It is generally acknowledged that the medium influences the way we communicate and negotiation research directs considerable attention to the impact of different electronic communication modes on the negotiation process and outcomes. Complexity theories offer models and methods that allow the investigation of how pattern and temporal sequences unfold over time in negotiation interactions. By focusing on the dynamic and interactive quality of negotiations as well as the information, choice, and uncertainty contained in the negotiation process, the complexity perspective addresses several issues of central interest in classical negotiation research. In the present study we compare the complexity of the negotiation communication process among synchronous and asynchronous negotiations (IM vs. e-mail) as well as an electronic negotiation support system including a decision support system (DSS). For this purpose, transcripts of 145 negotiations have been coded and analyzed with the Shannon entropy and the grammar complexity. Our results show that negotiating asynchronically via e-mail as well as including a DSS significantly reduces the complexity of the negotiation process. Furthermore, a reduction of the complexity increases the probability of reaching an agreement.*

Key Words: electronic negotiations, decision support systems, Shannon entropy, grammar complexity, symbolic dynamics

INTRODUCTION

Nonlinear dynamical systems (NDS) and complexity theories have been employed in various fields of research including medicine (Burton, Heath, Weller & Sharpe, 2010; Cecen & Erkal, 2009; Kenton, Diamond, Helfant, Khan & Karagueuzian, 1990; Mackey & Milton, 1987; Sara & Pistoia, 2010), economics (Baumol & Benhabib, 1989; Dore & Singh, 2009; Keen, 1997; Rosser, 1999;), or psychotherapy (Badalamenti & Langs, 1992; Lichtenberg & Heck, 1986; Tschacher, Scheier & Grawe, 1998; Tschacher, Schiepek &

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Brunner, 1992; Walter et al., 2009). In organizational theory, "complexity has been a central construct in the vocabulary of organization scientists" since the 1960s (Anderson, 1999, p. 216). Scholars successfully applied NDS, for instance, to organizational change (Dooley, 1997; Van de Ven & Poole, 1995) and dynamics (Cheng & Van de Ven, 1996; Dooley & Van de Ven, 1999; Strunk, Schiffinger & Mayrhofer, 2004), strategy (Levy, 1994; Peirce, 2000), supply networks (Choi, Dooley & Rungtusanatham, 2001), leadership (Guastello, 1995, 2010), careers (Strunk, 2009), and creativity (Guastello, Hyde & Odak, 1998; McGavin, 1997; Torre, 1995; Zausner, 1996) – "complexity caused self-organizing structures are now seen as ubiquitous natural phenomenon" (McKelvey, 1999, p. 300). Although (electronic) negotiations are an important part of organizational life (Raiffa, 1982; Rangaswamy & Shell, 1997; Shea, 1983), they have not yet been assessed with the complexity lens. However, there are several reasons to view negotiations as complex dynamic systems and to expect the application of complexity theories to (electronic) negotiations to be a fruitful area of research. In the first section we address these linkages between negotiation and complexity research. Furthermore, the role of information, choice, and uncertainty as well as process characteristics in negotiation are discussed in the context of the Shannon entropy (Shannon, 1948) and the grammar complexity (Ebeling & Jiménez-Montaño, 1980; Jiménez-Montaño, 1984) which are also employed in the empirical analysis. Subsequently, we address the impact that different electronic communication channels and the use of a decision support system (DSS) may have on the complexity of a negotiation interaction and develop respective hypotheses. Finally, we present an empirical analysis of electronic negotiation protocols using complexity measures. We show that the complexity of the process has a significant impact on whether negotiators are able to reach an agreement. Furthermore, the level of complexity contained in the negotiation process is influenced by the negotiation system used. Negotiating with e-mail rather than instant messaging (IM) as well as employing a DSS significantly decreases the complexity of the negotiation process.

NEGOTIATIONS AND COMPLEXITY

A comprehensive definition of negotiations is provided by Kersten (2003, p. 27) who characterizes them as "(…) a process of social interaction and communication about distribution and redistribution of power, resources, and commitments. It involves two or more people who make decisions and engage in exchange of information in order to determine a compromise. Each participant is an independent decision-maker but they all are interdependent because none can achieve goals unilaterally." Only a limited number of scholars have assessed negotiation interactions using the complexity lens (Wheeler & Morris, 2002; Zimmerman & Hayday, 1999), yet negotiations and complex dynamic systems share common characteristics that are addressed in Kersten's definition. As a result, the two research streams have also joint perspectives.

Process Perspective: First, negotiations as well as complex systems are not static but dynamic processes that evolve over time. Accordingly, in negotiation research and theory much emphasis is put on the process character of negotiations (Adair & Brett, 2005; Brett, Northcraft & Pinkley, 1999; Olekalns & Smith, 2003; Weingart, Olekalns & Smith, 2004). Zartman (1977, p. 624) even states that "to analyze the agent rather than the process is to focus on the secondary data rather than the primary element of decision-making". In the context of electronic negotiations and decision support systems, DeSanctis and Gallupe (1987, p. 603) postulate that the impact of "technology will be revealed in the pattern of interpersonal communication". Consequently, a deeper understanding of negotiation support systems (NSS) requires "intensive analysis of the actual process of negotiation, using content communication analysis" (Foroughi, 1998, p. 23). Nonlinear dynamic systems theory specifically addresses process features. Among the approaches provided by this framework, symbol dynamics is especially suitable for communication content analysis (Guastello et al., 1998). It provides means to analyze "regularities, sequences, and patterns of messages as essential features of bargaining interaction ... [and the] ... dynamic or evolving nature of negotiation" (Putnam & Roloff, 1992, p. 7f). By focusing on complex patterns that unfold over time (Guastello, 2000, p. 169), nonlinear dynamic systems theory provides novel perspectives and methods complementing existing negotiation process research.

Interdependence and Interaction: A second linkage between negotiations and complex adaptive systems is interaction and interdependence. In both, the elements generating the process are not isolated but influence each other in a mutual interdependent manner. Goals in negotiations cannot be achieved unilaterally and the action of one of the negotiators is a reaction to the behaviour of the counterpart (Adair & Brett, 2005; Olekalns & Smith, 2000; Weingart, Prietula, Hyder & Genovese, 1999). This becomes especially evident in formal game-theoretic approaches of negotiation analysis assessing possible optimal solutions for both actors (Raiffa, 1982). Interacting and interdependent elements are also considered constituent for complex systems by the majority of authors. The core in Kauffman's theory (1993) and its applications to organizational theory (Boisot & Child, 1999; Levinthal & Warglien, 1999; McKelvey, 1999), for instance, is the density of interdependencies among the elements. Likewise, in the conception of organizations as complex adaptive systems the basic building blocks are interacting agents with schemata (Anderson, 1999; Dooley, 1997; Morel & Ramanujam, 1999).

Information Exchange and Communication: In social systems such as negotiations or organizations the interaction process "is primarily informational rather than energetic" and realized by means of communication (Boisot & Child, 1999, p. 238). Many negotiation scholars consider negotiations as being communicative in nature (Chatman, Putnam & Sondak, 1991; Lewicki & Litterer, 1985; Putnam & Roloff, 1992; Shea, 1983; Thompson, 1990). As pointed out by Koehne et al. (2004, p. 421) "(n)egotiation in traditional as well as in electronic commerce is a complex communication process." This view is also shared by scholars applying nonlinear dynamic systems theory to social phenomena. Levinthal and Warglien (1999) consider communication as a primary instrument for supporting coordination in rugged landscapes and Weick (1993) highlights its function for preventing social disintegration. Conceptions based on Luhmann's (1984) social system theory and discourse analysis (Putnam, Phillips & Chapman, 1996; Taylor, Flanagin, Cheney & Seibold, 2001) even see communication as the constituent element of organizations. According to this perspective, communication is both the medium and the outcome of organizing processes (Dooley, Corman, McPhee & Kuhn, 2003, p. 80). Communication is not only "at the heart" of negotiation (Lewicki & Litterer, 1985) and social organization but can itself be considered a complex phenomenon (Dooley et al., 2003; Pincus, 2001; Porter & Hogue, 1998). Guastello and colleagues (Guastello et al., 1998; Guastello & Philippe, 1997) state that formation and evolvement of communication patterns in interactions involves processes of self-organization. Furthermore, communication interaction, face-to-face as well as computer mediated, has already been successfully analyzed with tools stemming from NDS theory finding evidence of complex dynamics (Guastello, 2000; Guastello et al., 1998; Guastello & Philippe, 1997; Pincus, 2001; Pincus, Fox, Perez, Turner & McGeehan, 2008; Pincus & Guastello, 2005; Strunk & Schiepek, 2002; Tschacher et al., 1998; Walter et al., 2009).

Conflict and Compromise: Negotiations are a special form of communication involving the distribution and redistribution of power, resources, and commitments (Kersten 2003). Although intermediate solutions or compromises must be possible, a certain level of conflict, factual or believed, is inherent to negotiations (Thompson 1990). Negotiation literature discusses a multitude of factors affecting the strength of the conflict, why negotiators reach an impasse, and how negotiators can overcome the conflict (e.g., Bazerman et al. 2000). Vallacher Coleman, Nowak, and Bui-Wrzosinska, (2010) recently proposed to employ nonlinear dynamic systems theory as integrating frame-work. The authors argue that underlying the dynamics of conflicts is the general tendency of systems to integrate the basic elements into a global state that provides coherence and stability. Once an attractor is established, the system is resistant to external influences that would otherwise effect change. Concepts common to conflict as well as negotiation research such as schema, goal, attitude, or disposition can be reformulated as attractor. The notion of attractor, however, encompasses idiosyncratic features of such concepts and highlights their dynamic properties. Resolving conflicts within this framework involves destabilizing the conflicting attractor and induce the system to move to a new, favorable attractor. Although Vallacher et al. (2010) focus on intractable conflict, their general framework and many of the issues they address are also crucial in negotiations (e.g., Bazerman et al. 2000; Thompson 1990).

Structure and Flexibility: A final important issue uniting complexity and negotiation research regards the interplay between structure and flexibility. In order to come to a mutually satisfactory conclusion, negotiators require structure such as a shared understanding of the process and roles as well as rules, norms, and expectations (Wheeler, 2004; Wheeler & Morris, 2002). Formal procedures and rigid structures, however, can also impede the adaptability and creativity necessary in successful negotiations (Olekalns, Smith & Walsh, 1996; Pruitt & Rubin, 1986; Wheeler, 2004; Wheeler & Morris, 2002). Consequently, Wheeler and Morris (2002, p.12) conclude that negotiators face the challenge "to find the delicate balance between structure and flexibility" which is also encountered in complex systems. In complex systems, however, order is not predetermined but emergent. This allows the systems to adapt to unpredictable change and innovate while at the same time maintaining required states of stability (Dooley, 1997; Shakun, 1999). From a methodological perspective, complexity measures provide the means to quantify the flexibility-rigidity continuum (Pincus, 2001; Pincus et al., 2008). Generally, more complex systems exhibit a more flexible and a less complex system a more rigid behaviour.

Information, Choice, and Uncertainty in Electronic Negotiation Processes: Shannon Entropy

Based on works of Nyquist (1928) and Hartley (1928), Claude E. Shannon attempted to formalize and conceptualize the process of communication. He developed a measure, H, for the rate "of information, choice, and uncertainty" (1948, p. 9) produced by such a process. The three facets captured by this measure are also core elements in negotiations. Negotiators constantly exchange information during the negotiation process and make communicative and behavioural choices based on the acquired information, often under uncertainty. The main body of negotiation research assesses these three aspects as characteristics of the negotiators (studies employing process analysis will be discussed in subsequent sections). In this perspective, the information processing capabilities of the negotiators (Bazerman, 1983), the heuristics they employ for making decisions (De Dreu & Carnevale, 2003; Northcraft & Neale, 1987) and evaluating the counterpart and its interest (De Dreu, Yzerbyt & Leyens, 1995; Thompson & Hastie, 1990; Trope, 1986) as well as judgmental and cognitive biases (Bazerman & Carroll, 1987) are the focus of the investigation. Similarly, a vast amount of literature assesses decision making under uncertainty (Bottom, 1998; Zeleznikow, 2002) and the "psychology of choices" (Tversky & Kahneman, 1981) negotiators make under certain contingencies (Payne, 1982). However, as pointed out by Foroughi (1998, p. 23), "(m)ost important, NSS need to be studied (…) with intensive analysis of the actual process of negotiation, using content communication analysis." The Shannon entropy addresses this claim by considering the amount of information, choice, and uncertainty contained in the very process itself (Guastello et al., 1998). Furthermore, in its original formulation, Shannon (1948) was concerned with the transmission of messages via a medium such as negotiating via e-mail or IM.

In Shannon's conception, a negotiation interaction would be characterized as a string of symbols i taken from a given alphabet A with each of the symbols i occurring with a certain probability p_i. The negotiation interaction can then be described by a discrete and finite probability distribution $p_1,\ldots,p_i$. Appearing rather abstract at first sight, it resembles communication content analysis commonly used in negotiation research (Adair & Brett, 2005; Olekalns, Brett & Weingart, 2003; Weingart, Brett & Olekalns, 2002; Weingart et al., 2004). The alphabet A is constituted by the coding scheme (e.g., Bargaining Process Analysis II by Walcott & Hopmann 1978). The symbols i are given by the different types of possible negotiation communication included in the coding scheme. The substantial interpretation of the Shannon entropy depends on content and type of the coding scheme (e.g., different offers with respective attributes, the bargaining steps proposed by Filzmoser and Vetschera (2008) used in the examples, or general negotiation communication as used in the empirical analysis). A coded negotiation interaction results in a string of symbols as exemplarily shown in Table 1.

Table 1. Example of Coded Negotiation Interaction Resulting in String of Symbols.

Negotiation 1:	D	I	T	C	D	I	T	C	D	I	T	C
Negotiation 2:	D	D	D	I	D	D	C	D	D	T	D	D

Time

Note: D demand; I insistence; T trade-off; C concession

The probability distribution $p_1,\ldots,p_i$ can be empirically estimated by calculating the relative frequency with which the different types of communication are employed during the negotiation. For instance, negotiation 2 in Table 1 is dominated by demands (D) whereas in negotiation 1 the negotiators use their options evenly distributed. Based on the distribution, the Shannon entropy H is obtained via

$$H = -\sum_i p_i \log_2 p_i \,. \tag{1}$$

If the probabilities of the symbols p_i are equally distributed ($p_1 = p_2 = \ldots = p_i$), such as in negotiation 1, the entropy H takes its maximum. Conversely, it decreases when some symbols have higher probabilities compared to the others (e.g., when negotiators focus on exchanging demands and do not employ the other options at their disposal). A higher H is indicative for a higher complexity of the process. The Shannon entropy has been successfully employed to analyse various phenomena such as creativity (McGavin, 1997), the temporal dynamics of brain activity in human memory

processes (Guastello, Nielson & Ross, 2002), order creation in agent based simulations of ant colony food foraging (Guerin & Kunkle, 2004), problem solving (Guastello, 2000; Guastello et al., 1998), conflict dynamics (Pincus et al., 2008), or therapy processes (Badalamenti & Langs, 1992; Pincus, 2001; Pincus & Guastello, 2005; Tschacher et al., 1998). Its meaning and interpretation, however, is subject to discussion and contradictory at first sight (Brissaud, 2005; McGavin, 1997).

(Freedom of) Choice: The degree of (freedom of) choice expressed by the Shannon entropy refers to "the behavioural choices that negotiators make during negotiation" (Olekalns & Smith, 2003, p. 233). The negotiating parties have a certain set of options at their disposal from which they select a subset that is employed in the actual negotiation. The entropy of a negotiation process now reflects the diversity of the options the negotiators have used during the interaction (e.g., the diversity of offers or the variety in communicative behaviour, depending on the coding scheme). In negotiation 2 (Table 1), for instance, the negotiators have limited themselves primarily to exchanging demands (D) resulting in a rather low entropy. Negotiation 1, on the other hand, exhibits high entropy as the negotiators have explored a variety of their possible choices. The number of options negotiators explore during an interaction is also associated with the degree of flexibility, adaptability, and creativity (Pincus, 2001; Pincus et al., 2008). These are central aspects in negotiations (Olekalns & Smith, 1999; Olekalns et al., 1996; Pruitt & Rubin, 1986; Wheeler, 2004; Wheeler & Morris, 2002).

Exchanged Information: The degree of freedom of choice exercised in a negotiation directly determines the amount of information exchanged in a negotiation interaction. In Shannon's conception, information is represented by the degree of novelty present in the symbol sequence (Pincus & Guastello, 2005). It is defined by the so called self-information or surprisal (Tribus, 1961) expressed by the logarithm in Eq. 1. The surprisal indicates the rate of additional information that the knowledge about (the occurrence of) an event adds to the overall knowledge. An absolutely certain event ($p_i = 1$) would add no additional information to our knowledge ($\log_2 1 = 0$) whereas an uncertain event increases our knowledge after its occurrence. In a negotiation interaction consisting for instance mainly of demands, such as negotiation 2 in the example above, only a limited amount of novel information is exchanged. When most of the offers are countered with demands, it is not very 'surprising' to encounter another demand. The rate of additional knowledge is consequently rather low as we already knew with a high probability that it would happen. Conversely, the negotiation process 1, in which the negotiators explore a higher variety of options, contains also more novel information.

Uncertainty: A higher amount of freedom of choice and information, however, also implies more uncertainty for the involved parties. Processes exhibiting high entropy are less predictable (Pincus, 2001). Luhmann's (1984) social system theory points out that successful interaction requires connectivity, i.e. "communication emerges only to the extent that the sender's utterance is picked up and processed by a receiver" (Vanderstraeten, 2000, p. 9). The more 'surprising' information contained in a negotiation process, the less the chance that the counterpart can connect. For effective information exchange, thus, not only novelty but also a certain level of confirmation and redundancy is required (von Weizsäcker & von Weizsäcker, 1972). In the context of negotiations, Wheeler points out that (2004, p. 4) "(w)e don't do any favours for our negotiation counterparts when we offer them too many alternatives. Information overload can block their ability to say yes to any of them." Although exploring options and exchanging information is generally considered beneficial in negotiations, the Shannon entropy points to their relation to uncertainty and the resulting potential drawbacks. This measure, however, only considers the frequency with which the symbols occur during the negotiation interaction and not patterns and dynamics they form. A complexity measure that does not suffer such limitations is the grammar complexity (Ebeling & Jiménez-Montaño, 1980; Jiménez-Montaño, 1984).

Patterns and Dynamics in Negotiation Processes: Grammar Complexity

In negotiation research, classical approaches to understanding the process of negotiation can be classified as the frequency, the interaction, and the phase model approach (Weingart et al., 2004). Within the frequency approach it is implicitly assumed that a negotiation process is an expression of the (relative) amount of communicative and behavioural enactments. For instance, research has consistently shown that the more negotiators employ integrative strategies compared to distributive strategies, the higher the chance for reaching an agreement (Olekalns et al., 1996; Weingart et al., 2002). In the primer strategy the negotiators focus on the communication of priorities, needs and interests. The latter strategy is characterized by the communication of positions, substantiation and threats. With regard to electronic negotiations, the use of a negotiation support system leads to less tactical and more socio-emotional communication during the negotiation process (Koeszegi, Srnka & Pesendorfer, 2006; Poole, Shannon & DeSanctis, 1992). The frequency approach, however, does not consider the timing with which a certain behaviour or communication is used and the specific patterns and interplay they form. These two aspects are covered in the phase model approach and the interaction approach, respectively.

The phase model approach has long tradition in negotiation research (Douglas, 1962; Gulliver, 1979; Walton, 1969). Although the models vary substantially in terms of number and content of the phases (Holmes, 1992), research has established strong empirical evidence that negotiations evolve over time and exhibit distinct phases (Adair & Brett, 2005; Holmes, 1992; Olekalns et al., 2003; Putnam, Wilson & Turner, 1990). Furthermore, the timing of strategies and specific process developments impact the outcome (Holmes, 1992; Putnam, 1990; Simons, 1993). For instance, negotiation processes resulting in optimum integrative outcomes are characterized by a rapid decrease in positional arguing and a slight increase in restructuring. Greater creativity and flexibility in the final stages of the negotiation often result in integrative outcomes (Olekalns et al., 1996).

In the interaction approach, rather than considering the timing, action-reaction sequences and sequential combinations are at the centre of the analysis. Interactions are considered more appropriate than frequencies as a negotiation is "a highly interdependent process in which each party continuously incorporates information from the other party to develop responses that might lead to resolution of the conflict at hand" (Weingart et al., 1999, p. 367). Furthermore, "each negotiator constrains and is constrained by the other party's strategy choices" (Olekalns & Smith, 2003, p. 235). A theoretical foundation of this view is given by Gouldner's (1960) reciprocity theory and Weick (1969) who considers interactions as the fundamental unit of social behaviour. The negotiation literature typically distinguishes three types of interaction sequences: reciprocal sequences, complementary sequences, and structural sequences (Adair & Brett, 2005; Donohue, 1981; Olekalns & Smith, 2000; Putnam & Jones, 1982; Weingart, Thompson, Bazerman & Carroll, 1990). The identification of these different interaction sequences provides important information as they indicate the confirmation or disconfirmation of a given strategy. Reciprocal response signals that the negotiators follow the same strategic orientation. Structural action-reaction sequences, i.e. when a specific behaviour is countered by behaviour from a different strategic group, suggest that a negotiator attempts to redirect the counterpart (Adair & Brett, 2005; Olekalns & Smith, 2000). In general, negotiators tend to reciprocate distributive as well as integrative behaviour (Weingart et al., 1999). When confronted with extreme tactics, however, they are more likely to respond with the opposite extreme tactic (Donohue, 1981). Reciprocating integrative behaviour is considered central to move from distributive to integrative bargaining (Putnam & Jones, 1982; Weingart et al., 1999; Weingart et al., 1990). Olekalns and Smith (2003) showed that whereas low joint gain was associated with reciprocal contention sequences and contentions that elicited proposals, high joint gain was primarily characterized by reciprocation of information about underlying needs and interests.

Patterns and regularities as well as dynamic features captured by the interaction and phase model approach are central to the understanding of negotiation processes (Chatman et al., 1991; Putnam & Roloff, 1992). The Shannon entropy, however, follows the logic of the frequency approach by considering only the distribution of the elements constituting the negotiation process. By averaging the results over the entire chain or proportions of the chain important structural information as well as the temporal sequence of the material is lost (Rapp, Jiménez-Montaño, Langs, Thomson & Mees, 1991; Zimmerman, Eliezer & Simha, 1968). Not considering the order of a negotiation process in terms of its dynamic structure and patterns emerging during the interaction is the main drawback for the sole use of the Shannon entropy (Lambert, 1999; Pincus, 2001; Pincus & Guastello, 2005). Table 2 shows the negotiation interaction from Table 1 and its randomized pendant. Both negotiation interactions exhibit high Shannon entropy; however, in the first one a clear pattern not accounted for by the Shannon entropy that was destroyed by the randomization is visible.

Table 2. Example of Coded Negotiation Interaction and Randomized Pendant.

Negotiation 1:	D	I	T	C	D	I	T	C	D	I	T	C
Negotiation 1_r:	D	T	I	C	I	D	C	C	T	I	T	D

Time

Note: D demand; I insistence; T trade-off; C concession

Grammar complexity (Ebeling & Jiménez-Montaño, 1980; Jiménez-Montaño, 1984), on the other hand, is sensitive to such dynamical and structural features. It is based on a context free grammar (Chomsky, 1957) and rooted in the theory of algorithmic complexity (Chaitin, 1974; Kolmogorov, 1965). Accordingly, a sequence exhibits high complexity if a program based on the same alphabet capable of reconstructing the original sequence is not much shorter than the original sequence. A program for a purely random string requires as many bits of information as its original pendant (Guastello et al., 1998). The shorter the program compared to the original sequence the more patterns and dynamical structure is contained in the sequence and the lower its complexity. For instance, negotiation 1 (Table 2) would exhibit a rather low complexity as it shows a distinct dynamic pattern. Each demand (D) is countered by insistence (I) followed by a trade-off (T) leading to a concession (C). This interaction pattern can be replaced by a single symbol which is repeated three times. This leads to a shorter program

$$\sigma^3 \rightarrow \sigma\sigma\sigma$$

$$\sigma \rightarrow \text{D-I-T-C}$$

than the original sequence. Conversely, the randomized pendant of this negotiation exhibits a high complexity as it contains no interaction patterns and dynamic structure for formulating a significantly shorter program (for a comprehensive description and implementation of the grammar complexity see Ebeling & Feistel, 1982; Rapp et al., 1991). It has to be noted, that the grammar complexity does not identify the 'true' algorithmic complexity, which can not be determined for a given sequence (Chaitin, 1974). It provides, however, a systematic and standardized approximation in terms of an upper bound especially suitable for short, nominal sequences as encountered in negotiation research (for an overview of algorithms see, Schürmann & Grassberger, 1996). By comparing the grammar complexity (*GC*) of a negotiation process with the grammar complexity of n randomized surrogates of the original sequence, a z-value (GC_z) indicating the degree of complexity can be calculated (Tschacher &

Scheier, 1995). This measure does not only provide a statistical test for each negotiation interaction but is also more invariant regarding the length of the sequences (Rapp, Cellucci, Korslund, Watanabe & Jiménez-Montaño, 2001).

Following a similar logic to the Shannon entropy, the grammar complexity can also be considered a representation of choice, information and uncertainty of a negotiation interaction. For instance, when a demand from a negotiator is always countered by insistence from the counterpart forming a regular pattern throughout the negotiation process, the negotiators have not exercised much freedom of choice by limiting themselves to this specific temporal pattern. Furthermore, the process contains only a limited amount of information as expressed by the rather short program capable of capturing the information in the negotiation interaction. The low complexity also results in low uncertainty experienced by the actors as the reaction of the counterpart is very predictable for both negotiators. To illustrate the additional properties of the grammar complexity compared to the Shannon entropy, five different negotiation scenarios based on the bargaining steps of Filzmoser and Vetschera (2008) have been constructed. In scenario (a) the negotiators use the four possible bargaining steps uniformly distributed and randomly; in scenario (b) they still use the bargaining steps randomly but they focus on concession and trade-offs which are used twice as often as demands and insistence; in scenario (c) the negotiators combine the bargaining steps into patterns of two (e.g. a concession is always preceded by a trade-off) but use these patterns randomly; in (d) a certain pattern is used only in the first half of the negotiation while another pattern is used only in the second half; finally, in (e) the negotiators combine the strategic groups of behaviour into a coherent and completely ordered strategy (e.g., each demand is countered by insistence followed by a trade-off leading to a concession). Table 3 shows *H* and GC_z for the five scenarios.

Table 3. Comparison of GC_z and *H* for Exemplary Negotiation Interaction Scenarios.

l = 80	Scenario (a)	Scenario (b)	Scenario (c)	Scenario (d)	Scenario (e)
H	2.00	1.81	2.00	2.00	2.00
GC_z	1.35	1.91	16.80	22.71	26.25

Note: l = length of the interaction scenario (time steps); *H* = Shannon entropy (higher values indicate a higher complexity); GC_z z-transformed grammar complexity (higher values indicate a lower complexity).

Each of the process characteristics has proven to have substantial impact on the outcome of negotiations. Although the Shannon entropy reflects only the change in distribution of the bargaining steps in scenario (b), the grammar complexity is sensitive to frequencies, patterns, and temporal structure in measuring information, choice, and uncertainty. The more negotiators focus on certain options and introduce patterns and dynamic structure, the lower the grammar complexity of the process (reflected in higher values of GC_z).

ELECTRONIC NEGOTIATION SUPPORT SYSTEMS: A COMPLEXITY PERSPECTIVE

Computer-mediated communication (CMC) has become a central component of organizational life (Baltes, Dickson, Sherman, Bauer & LaGanke, 2002; Hedlund, Ilgen & Hollenbeck, 1998; Hinds & Kiesler, 2002) and also negotiations are increasingly conducted via CMC (Hobson, 1999; Holtom & Kenworthy-U'Ren, 2006; Larson, 2003; McKersie & Fonstad, 1997; Thompson, 2005). In a recent survey reported by Loewenstein et al. (2005), a majority of the executives considered non-face-to-face negotiations as very or extremely relevant. This trend also gave rise to the development of electronic negotiation support systems (NSS). NSS provide communication and decision tools aiding negotiators in reviewing the negotiation process, evaluating and structuring the offers, identifying and resolving conflicts, searching for consensus, and assessing the stability of the agreements (Kersten & Lai, 2007). Since first proposed in the 1980s (Korhonen, Wallenius & Zionts, 1980; Tanino, Nakayama & Sawaragi, 1981), a considerable number of NSS have been developed (e.g., Chen, Kersten & Vahidov, 2005; Druckman, Ramberg & Harris, 2002; Kersten & Noronha, 1999; Rangaswamy & Shell, 1997; Schoop, Jertila & List, 2003). At a minimum level, however, they all consist of an individual decision support system (DSS) and an electronic communication channel (Lim & Benbasat, 1992-93).

Empirical evidence shows that both, the communication medium as well as whether a DSS is employed, influence a number of crucial issues in negotiations such as collaborative behaviour (Delaney, Foroughi & Perkins, 1997; Foroughi, Perkins & Jelassi, 1995; Hill, Bartol, Tesluk & Langa, 2009), conflict escalation (Friedman & Currall, 2003), trust (Rockmann & Northcraft, 2008; Wilson, Straus & McEvily, 2006), fairness (Tangirala & Alge, 2006), emotional climate (Moore, Kurtzberg, Thompson & Morris, 1999; Walther, Loh & Granka, 2005) as well as decision making accuracy (Hedlund et al., 1998) and negotiation outcomes (Delaney et al., 1997; Lim & Benbasat, 1992-93; Perkins, Hershauer, Foroughi & Delaney, 1996). The complexity theory perspective extends this line of research by addressing process characteristics reflecting the interplay of choice, information, and uncertainty influenced by the NSS and its components. In dynamical systems, the process of self-organization leads to pattern formation increasing the system's order (Haken, 1990; Tschacher et al., 1998). The employed technology, however, plays an immanent role in this process (Guastello, 2000).

The Impact of Medium on Negotiation Process Complexity

Although it is recognized that the choice of the medium can be crucial to the process and outcome of a negotiation (Bazerman, Curhan, Moore & Valley, 2000; Carnevale & Propst, 1997; Sheffield, 1995), "it is generally unknown how that reliance on technology changes the nature of interaction" (Rockmann & Northcraft, 2008, p. 106). This is especially true for synchronous media such as Instant Messaging (IM) (Bell & Kozlowski, 2002). They are investigated only by a limited number of studies (Alge, Wiethoff & Klein, 2003; Galin, Gross & Gosalker, 2007; Loewenstein et al., 2005; Pesendorfer & Koeszegi, 2006) in contrast to the large number of comparisons between face-to-face and asynchronous computer mediated communication (Baltes et al., 2002; Delaney et al., 1997; Hollingshead & McGrath, 1993; Laughlin, Chandler, Shupe, Magley & Hulbert, 1995; Rangaswamy & Shell, 1997; Tangirala & Alge, 2006; Walther, 1995; Wilson et al., 2006). Yet, "face-to-face communications will have to give way to technologically mediated communications" (Moore et al., 1999, p. 40). As reported by Loewenstein et al. (2005), IM is already widely used and is forecasted to surpass e-mail as the primary online communication tool in the United States. Thus, the choice might not be whether to negotiate face-to-face or electronically but which electronic medium should be employed.

E-Mail and IM are very similar on several dimensions commonly employed to evaluate communication (Loewenstein et al., 2005) including the limited possibility of providing multiple information cues simultaneously (Lengel & Daft, 1988), the lack of visibility and audibility as well as their textual nature (Friedman & Currall, 2003; Poole et al., 1992). They differ, however, on the time dimension. E-mail is an asynchronous communication medium comparable to writing a letter. "(T)he two parties are not co-present, but rather each reads the other's e-mail whenever desired and responds whenever desired" (Friedman & Currall, 2003, p. 1327). IM, on the other hand, is a synchronous communication medium in which the communication is in real time allowing for giving and receiving immediate feedback. As the negotiators are "together in time", immediate response is also expected. This results in turn taking norms that are comparable to face-to-face communication (Loewenstein et al., 2005). In a first step, the increased turn-taking tempo results in higher time pressure affecting the behavioural choices of the negotiators during the interaction. For instance, it has been found that under time pressure negotiators make quicker concessions, lower demands, decrease integrative tactics and use different strategies in making offers (Carnevale, O'Connor & McCusker, 1993; Druckman, 1994; Esser, 1989; Lim & Murnighan, 1994; Stuhlmacher, Gillespie & Champagne, 1998).

Furthermore, the different time span required for the reply has also substantial impact on information processing. In Lim and Benbasat's theory (1992-93), the communication component of NSS is postulated to impact mainly the sociological aspects of the negotiators' interaction whereas DSS plays the role of improving information processing. Yet, time is a medium for information (Harrison, Price, Gavin & Florey, 2002). "E-mail allows negotiators as much time between messages as they need to calculate the values of various outcomes and to consider the best counteroffers, and complete transcript of the communication allows for more careful information acquisition" (Moore et al., 1999, p. 39f). One of the few studies specifically addressing the interplay of time and information processing in the context of negotiation was done by De Dreu (2003). Drawing on Lay Epistemic Theory, he showed that negotiators under higher time pressure relied more on stereotypes and were less likely to revise unfounded fixed-pie perceptions. Both are expressions of reduced information processing that result in the use of cognitive heuristics and erroneous reasoning. Similarly, Loewenstein et al. (2005) have found out that simple arguments were ineffective regardless the medium. Intricate arguments, however, were only effective in negotiations via IM and not via e-mail because with the latter the receiver has the possibility to digest and reflect on the arguments. From a sender perspective, Rockman and Northcraft (2008) argue that deception is more difficult when chatting online than using e-mail as the latter allows to carefully plan the deceptive message. Thus, although being very similar regarding many characteristics, e-mail communication results in lower time pressure and allows for better information processing than IM as it provides the time to review and reflect received messages, revise and plan messages to be sent as well as collect and analyse information (Friedman & Currall, 2003).

The Impact of Decision Support on Negotiation Process Complexity

Whereas the communication mode influences information processing via the medium time, NSS additionally include a decision support system. They are specifically designed for enhancing information processing capabilities and directly influence the choices made by negotiators (Chu & Spires, 2001; Foroughi, 1998; Kersten & Lai, 2007; Kersten & Noronha, 1999; Lim & Benbasat, 1992-93; Rangaswamy & Shell, 1997). Based on the premises of bounded rationality (March, 1978; March & Simon, 1958) and cost-benefit theory (Beach & Mitchell, 1978; Payne, 1982), NSS provide negotiators with various tools for supporting their choices and alleviating cognitive limitations. For instance, it has been shown that negotiators inadequately asses their own and the counterpart's position and aspiration (Bazerman, Mannix, Sondak & Thompson, 1989). To avoid this problem, planning and preparation systems in NSS provide means to organize and pre-process information as well as assess utilities and alternatives. Thereby, they help negotiators to better understand their priorities, preferences, and objectives as well as prepare negotiation strategies and tactics (Kersten & Lai, 2007; Rangaswamy & Shell, 1997). As pointed out by White et al. (2004), however, suboptimal outcomes are often a failure of process rather than of rationality. Consequently, NSS also "provide support which specifically deals with the negotiation process, by providing assistance to users in gaining understanding of their counterparts' priorities and constraints, predicting their moves, suggesting possible coalitions, and advising about making and justifying a concession" (Kersten & Lai, 2007, p. 555). Furthermore, in NSS the utility is evaluated in real-time making the subjective value of each offer and counteroffer available for the negotiators (Rangaswamy & Shell, 1997). Thus, they provide structuring mechanisms for avoiding process failures by updating the perception of the self, the counterpart and the negotiation task (Arunachalam & Dilla, 1995). NSS also increase the negotiators ability to assess the problem, alternative options and their implications (Kersten & Lai, 2007).

The beneficial effects of DSS have been confirmed in several empirical studies. For instance, it has been shown that additionally employing a DSS leads to an increased number of proposed contracts as well as more integrative trades, improved problem understanding, reduced negative climate and increased user satisfaction (Balke, Hammond & Meyer, 1973; Delaney et al., 1997; Foroughi et al., 1995; Perkins et al., 1996; Rangaswamy & Shell, 1997). Employing a NSS moreover results in superior solution qualities, higher joint outcomes, and more balanced contracts (Delaney et al., 1997; Foroughi et al., 1995; Perkins et al., 1996; Rangaswamy & Shell, 1997). The positive effects of DSS are also maintained under time pressure helping to mitigate problems resulting from it (Chu & Spires, 2001). A comprehensive NSS including a DSS as well as an electronic communication channel, however, provides a broader range of benefits than a DSS alone (Delaney et al., 1997) as both have a beneficial effect on negotiators' information processing, uncertainty, and choices.

Hypotheses

As complexity measures assess the process itself rather than the actor, we expect an inverted relationship: The more and the better the a priori information processing and decision making due to the higher amount of available time or the usage of a decision support, the less choices, information, and consequently uncertainty are brought into the process itself. For instance, when having more time at their disposition, negotiators evaluate their choices more in depth and a DSS further aids the negotiators to set priorities and narrow the alternatives (Chu & Spires, 2000; De Dreu, 2003; Lim & Benbasat, 1992-93; Moore et al., 1999). This reduces the complexity of the process as only a subset of viable options is presented to the counterpart rather than confronting him/her with a multitude of alternatives. Similarly, the enhanced information processing capabilities resulting from decision support and more time to review and reflect messages helps negotiators to articulate their preferences more clearly (Rangaswamy & Shell, 1997), provide sound argumentations (Kersten & Lai, 2007), and directly address possible settlement-points and integrative solutions (Foroughi, 1998; Perkins et al., 1996; Rangaswamy & Shell, 1997). When faced with lower turn taking tempo, negotiators craft their messages more carefully increasing the communication accuracy and concentrate more on the actual issue at hand (Pesendorfer & Koeszegi, 2006). By focusing on the exchange of problem-oriented and substantive information, the negotiators reduce the information load contained in the process and in consequence also its complexity. Moreover, reduced time pressure and decision support also allow the negotiators to plan their strategies and routes of action more carefully (Kersten & Lai, 2007). This results in more consistent patterns of behaviour, structured negotiation dynamics, and predictable development of the negotiation process. By being confronted only with a subset of alternatives and information as well as more focused and predictable negotiation behaviour, the negotiation interaction also involves less uncertainty for the involved parties. Thus, we hypothesize that both, negotiating asynchronically as well as additionally employing a DSS, will reduce the complexity of the process. The reduced complexity will also have a beneficial impact on whether negotiators reach an agreement or not.

H1a: Negotiating via IM (synchronous) compared to e-mail (asynchronous) will reduce the Shannon entropy H of the negotiation interaction.

H1b: Negotiating via IM (synchronous) compared to e-mail (asynchronous) will reduce the grammar complexity of the negotiation interaction (as indicated by a higher GC_z).

H2a: Employing a DSS additionally to negotiating asynchronically via e-mail will further decrease the Shannon entropy H of the negotiation interaction.

H2b: Employing a DSS additionally to negotiating asynchronically via e-mail will further decrease the Grammar Complexity of the negotiation interaction (as indicated by a higher GC_z).

H3a: A reduction of the Shannon entropy H will increase the probability that negotiators reach an agreement.

H3b: A reduction of the grammar complexity (higher GC_z) will increase the probability that negotiators reach an agreement.

Overall, we expect that the grammar complexity will have a stronger effect as it does not only consider the distribution of the symbols but additionally takes into account pattern formation and the temporal structure of the negotiation process.

METHOD

Design and Participants

For the empirical study, data from previous negotiation experiments have been employed resulting in a total of 290 students (145 dyads). The cases involved buyer-seller negotiations in the business-to-business context including both, integrative and distributive elements. There was no specification as to what constitutes a good deal. Both parties were informed that other buyers were available so that they could terminate the negotiation with the counterpart at any time. The participation was voluntary and no further incentives except credit points were offered (for more details on negotiation case and sampling description, see Koeszegi et al., 2006).

The participants negotiated in three different settings using the negotiation systems SimpleNS and Inspire developed by Kersten and colleagues (Kersten & Lai, 2007; Kersten & Noronha, 1999). In the first two settings, SimpleNS was used in synchronous and asynchronous communication mode, respectively. SimpleNS is a communication platform allowing only for exchanging, storing, and retrieving messages and offers without any decision support. Thus, it resembles an IM or e-mail program. In the synchronous setting with time pressure, 57 dyads used SimpleNS like an IM program and had 45 minutes to complete the negotiation task. In the asynchronous setting, 42 dyads used SimpleNS like an e-mail program and had 3 weeks time for the negotiation task. The third group, consisting of 46 dyads, also negotiated asynchronically with 3 weeks time but used Inspire. Inspire is a NSS that has been employed for training and research since 1996. It provides several support features such as structuring the negotiation process into discrete phases and activities, utility elicitation, and visualization of the negotiation process (Kersten & Lai, 2007; Kersten & Noronha, 1999). In the preparation stage, the negotiator is required to analyze the case. Furthermore, the preferences for the different issues to be negotiated are elicited via hybrid conjoint measurement. During the negotiation process, negotiators can explore the utility of different decision alternatives as well as consult a real-time evaluation of each received offer's utility. Finally, Inspire provides a history and a graphical representation of the negotiation process. Table 4 shows the distribution of agreements reached in the three settings.

Table 4. Distribution of Agreements.

	synchronous IM (45 Minutes)	asynchronous e-mail (3 weeks)	NSS Inspire (3 weeks)
	57 (100.0%)	42 (100.0%)	46 (100.0%)
agreement	23 (40.4%)	29 (69.0%)	44 (95.7%)
no agreement	34 (59.6%)	13 (31.0%)	2 (4.3%)

Coding

The resulting negotiation protocols have been coded as suggested by Weingart et al. (2004) and Srnka and Koeszegi (2007) based on a slightly adapted version of the "Bargaining Process Analysis II"-category scheme (Walcott & Hopmann, 1978). A short description of the categories is provided in Table 5 (for more details on the coding scheme and coding procedure we refer to Koeszegi et al., 2006).

In negotiation research speaking turns are most commonly used as unit of analysis (De Dreu, 2003; Weingart, Hyder & Prietula, 1996). A speaking turn is defined as everything a negotiator says in between two utterances of the opposing negotiator. For the purpose of the present study, however, sense units are more appropriate. A sense unit represents a distinct and self-contained communication content conveyed to the counterpart no matter whether it is expressed in a sentence, a paragraph, or a single word. Speaking turns can vary substantially with regard to the amount and variety of information types they contain, especially when comparing synchronous with asynchronous communication. Treating each speaking turn as equivalent unit of analysis rather than employing the more fine grained sense units could thus be misleading in the context of the present investigation.

Table 5. Means and Standard Deviations for Research Variables.

N = 145		M	SD
(1) GC_z		1.89	2.26
(2) H		2.67	0.28
(3) substantive negotiation communication	Fundamental negotiation behavior	16.58	6.80
(4) task oriented communication	Promoting or facilitating problem solving	20.03	11.09
(5) persuasive argumentation	Supporting claims a negotiator makes	9.12	8.57
(6) tactical communication	Influencing expectations and actions of opponent	8.09	7.99
(7) affective communication	Expressing feelings about content, opponent or negotiation situation	9.48	8.36
(8) private communication	Not directly related to negotiation	4.51	6.84
(9) communication protocol	Addressing the counterpart or business letter phrases	19.48	16.73
(10) text specific communication	Communication linked to electronic communication	8.17	9.03
(11) procedural communication	Facilitating the negotiation process	5.07	4.65

Table 6. Correlations Among Research Variables.

N = 145	Bivariate Pearson Correlations									
	1	2	3	4	5	6	7	8	9	10
(1) GC_z										
(2) H	$-.21^{**}$									
(3) substantive negotiation communication	$.27^{**}$	.15								
(4) task oriented communication	$.31^{**}$	$.17^{*}$	$.45^{**}$							
(5) persuasive argumentation	$.23^{**}$	$.35^{**}$	$.38^{**}$	$.54^{**}$						
(6) tactical communication	-.10	$.55^{**}$	$.44^{**}$	$.43^{**}$	$.53^{**}$					
(7) affective communication	-.02	$.45^{**}$	$.33^{**}$	$.29^{**}$	$.36^{**}$	$.61^{**}$				
(8) private communication	.10	$.35^{**}$	.05	$.22^{**}$	$.16^{*}$	$.21^{*}$	$.35^{**}$			
(9) communication protocol	$.66^{**}$	$-.21^{**}$	$.33^{**}$	$.41^{**}$	$.26^{**}$	.01	$.18^{*}$	-.02		
(10) text specific communication	.038	$.45^{**}$	$.39^{**}$	$.39^{**}$	$.31^{**}$	$.52^{**}$	$.42^{**}$	$.30^{**}$	-.01	
(11) procedural communication	.021	$.52^{**}$	$.26^{**}$	$.40^{**}$	$.30^{**}$	$.42^{**}$	$.38^{**}$	$.22^{**}$	$.20^{*}$	$.38^{**}$

The protocols have been coded by two trained and independent coders. For assessing inter-coder reliability we employed Cohen's kappa (Cohen, 1960). It reflects the agreement between the two independent coders in assigning a category of the coding scheme to the sense units. Cohen's kappa is more conservative than simple percentage agreement as it takes into account agreements that could be expected due to chance alone. An in depth discussion of Cohen's kappa is provided by Brennan and Prediger (1981). The Cohen's kappa for the present study ranges from κ = .84 to κ = .86. These values are considered good in literature (Weingart et al., 1990).

RESULTS

Measures and Descriptives

The coding procedure results in a string of symbols. The category scheme constitutes the alphabet and each coded sense unit represents a symbol in the chain. The so generated nominal time lines have been analyzed with the Shannon entropy and the grammar complexity as described above. Calculations were performed with GChaos (www.complexity-research.com), a nonlinear dynamic systems analysis program (Strunk, 2009; Strunk et al., 2004). Means, standard deviations, and correlations for the variables along with a short description are shown in Tables 5 and 6.

Table 7. ANOVA and Scheffé Procedure.

	Model 1 Communication Content		Model 2 DSS		Model 3 Process Complexity	
	EXP(B)	SE	EXP(B)	SE	EXP(B)	SE
Intercept	2.85	1.35	1.15	1.46	-0.86	1.68
substantive	4.92	3.36	4.73	3.34	7.00 **	3.53
task	-5.79	2.82	-2.63	2.98	-1.04	3.21
persuasive	-4.77	4.09	-4.95	4.32	-4.74	4.51
tactical	-8.37	3.83	-2.15	4.75	-2.16	4.80
affective	-3.76	4.06	-1.09	4.18	2.64	4.59
IM			-0.11	0.52	0.62	0.61
DSS			2.17 ***	0.82	1.89 **	0.84
GC_z					0.44 **	0.17
-2LL	150.26		139.27		131.59	
Nagelkerkes R^2	0.16		0.25		0.32	
-2LL Dif.			10.99 ***		7.68***	

Effect of Communication Mode and Decision Support on Negotiation Process Complexity

In order to test whether negotiating via IM or e-mail as well as additionally employing a DSS leads to a reduction of the negotiation interaction's complexity, we applied ANOVA with post-hoc tests (Scheffé procedure). In a first step, it has to be noted that the difference in the length of the chains in terms of number of exchanged sense units is only weakly significant ($p < 0.1$). Thus, approximately the same amount of communication content is exchanged by the negotiators during the negotiation process

regardless of whether they us IM, e-mail, or a NSS with decision support. However, significant differences can be found with regard to the complexity of the negotiation interactions (Table 7).

Negotiating via e-mail rather than IM leads to a significant reduction of procedural ($p < 0.01$), text-specific ($p < 0.01$), and private communication ($p < 0.01$). Furthermore, fewer attempts to influence the expectations and actions of the opponent as expressed by tactical behaviour are made ($p < 0.01$). Thus, when negotiating asynchronically via e-mail, less communication not related to the actual negotiation content is exchanged. This is also reflected in the significant complexity decrease (H $p < 0.01$; GC_z $p < 0.01$). Negotiators focus on specific communicative choices and the exchange of more negotiation related information.

When comparing e-mail with the NSS, adding a decision support system results in an increase of substantive negotiation communication such as the exchange of offers and counteroffers ($p < 0.01$). This replicates the results of previous studies (Foroughi et al., 1995; Perkins et al., 1996). Otherwise, however, only limited change in the distribution of communication content is observable resulting in no significant complexity difference as measured by the Shannon entropy. When additionally considering the dynamic structure as done by the grammar complexity, however, the negotiations performed with the NSS exhibit a significantly lower complexity than the negotiations conducted via e-mail without decision support. Thus, whereas the hypotheses H1a-b are supported for both measures, H2a-b hold only for the grammar complexity.

Impact of Process Complexity on Negotiation Outcome

After determining the impact of the communication mode and the employment of a DSS on the complexity of the negotiation process, in a second step we assessed whether a decreasing Shannon entropy and grammar complexity will improve the probability for reaching an agreement. The main aim of this study is not to find the best prediction of whether negotiators reached an agreement or not, but to learn about the prognostic value of specific variables. Thus, we employed a best predictor procedure (c.f., Harrell, Lee & Mark, 1996; Steyerberg, Eijkemans, Harrell & Habbema, 2000). Accordingly, after testing the complexity measures' explanatory power by *-2LL* comparisons, we additionally perform stepwise logistic regressions with a bootstrap procedure (Efron, 1983; Efron & Gong, 1983; Efron & Tibshirani, 1993) and calculate the regression factor structure coefficient (*RFSC*) (Cooley & Lohnes, 1971).

Following Steyerberg et al. (2000) and Harrell et al. (1996), in a first step we conducted an a priori selection of independent variables in order to improve the relationship between lower frequency of the dichotomous outcome variable and possible degrees of freedom. Thus, "text specific communication" (e.g., redundancies, text structuring, and fillers), "communication protocol" (e.g., addresses and closures, business letter phrases), and "procedural communication" (e.g., technical and time coordination) have been eliminated a priori from the further analyses as there is no theoretical rationale or empirical evidence that these variables have an impact on whether an agreement is reached or not. Furthermore, we excluded the Shannon entropy from the analyses as it exhibits high correlations with the other variables in the model and proved to have no predictive value ($p > 0.1$) as individual variable or when included in the models.

For the *-2LL* comparison we estimated three models with agreement vs. no agreement as the dependent variable (Table 8). The first two represent baseline models with variables previously assessed in negotiation research. Model 1 includes only communication content items; the second model also contains two dummies representing the negotiation systems. In the final model 3, the process complexity has been added as additional predictor. The results are shown in Table 8. Consistent with previous studies (Delaney et al., 1997; Foroughi et al., 1995; Rangaswamy & Shell, 1997), employing a DSS in addition to the asynchronous communication mode (model 2) enhances the likelihood of reaching an agreement ($p < 0.01$) as well as the explanatory value of the model ($p < 0.01$). The third model exhibits a further significant decrease in *-2LL* ($p < 0.01$). Thus, including the grammar complexity to the communication content and negotiation system items significantly improves the explanatory power of the model. A lower process complexity (higher GC_z) increases the probability for reaching an agreement ($p < 0.05$).

Table 8. *-2LL* Comparisons.

	Model 1 Communication Content		Model 2 DSS		Model 3 Process Complexity	
	EXP(B)	SE	EXP(B)	SE	EXP(B)	SE
Intercept	2.85	1.35	1.15	1.46	-0.86	1.68
substantive	4.92	3.36	4.73	3.34	7.00 **	3.53
task	-5.79	2.82	-2.63	2.98	-1.04	3.21
persuasive	-4.77	4.09	-4.95	4.32	-4.74	4.51
tactical	-8.37	3.83	-2.15	4.75	-2.16	4.80
affective	-3.76	4.06	-1.09	4.18	2.64	4.59
IM			-0.11	0.52	0.62	0.61
DSS			2.17 ***	0.82	1.89 **	0.84
GC_z					0.44 **	0.17
-2LL	150.26		139.27		131.59	
Nagelkerkes R^2	0.16		0.25		0.32	
-2LL Dif.			10.99 ***		7.68***	

In order to assess the robustness of the results and further assess the predictive value of the negotiation interaction's complexity, we performed stepwise logistic regressions with bootstrap procedure and calculated the *RFSC* based on model 3. The primer allows to identify the variables that may be considered the best predictors in a prognostic problem (Steyerberg et al., 2000). The latter provides an evaluation of a variable's individual strength within a regression rather than its predictive role in the overall model as reflected by the beta-values (Cooley & Lohnes, 1971). The stepwise logistic regressions have been calculated on 500 bootstrap samples with the p-value for inclusion and exclusion set at 0.05 and 0.10, respectively. The *RFSC* is given by the quotient of the squared predictor-criterion correlation and the variance explanation (squared multiple correlation coefficient) (Cooley & Lohnes, 1971, p. 54f) in Table 9.

Table 9. Percentage of Inclusion during Stepwise Bootstrap Procedure and *RFSC*.

	Inclusion (%)	RSFC
DSS	82.8	0.42
GC_z	60.0	0.34
substantive	53.8	0.16
tactical	41.6	0.17
persuasive	18.4	0.01
affective	7.2	0.02
IM	6.4	0.25
task	6.0	0.00

Both corroborate the results of the model comparisons. The stepwise bootstrap procedure as well as the *RFSC* identify the negotiation process complexity as a valuable predictor for whether negotiators reach an agreement or not only second to the use of a DSS. The hypotheses H3a and H3b are thus supported with regard to the grammar complexity. The Shannon entropy was excluded from the analysis due to high correlations with other variables and low predictive strength, a reduction of the grammar complexity, however, has a significant impact on whether negotiators reach an agreement or not.

DISCUSSION

The complexity lens has been employed to gain a better understanding of various phenomena in the realm of social and life sciences (Dooley & Van de Ven, 1999; Guastello, 2010; Pincus et al., 2008; Strunk, 2009; Tschacher et al., 1998). The present study extends this body of literature by assessing its usefulness for the investigation of electronic negotiation support systems.

Negotiations can be conceived as complex dynamic systems (Wheeler & Morris, 2002; Zimmerman & Hayday, 1999) and the respective research streams share common perspectives. Both, negotiation and complexity research assess interdependent agents (Adair & Brett, 2005; Dooley, 1997; Levinthal & Warglien, 1999; McKelvey, 1999; Olekalns & Smith, 2000) and the process resulting from their interaction (Brett et al., 1999; Guastello, 2000; Olekalns & Smith, 2003; Weingart et al., 2004). The process is thereby realized by means of communication and exchange of information (Dooley et al., 2003; Levinthal & Warglien, 1999; Putnam & Roloff, 1992; Weingart et al., 2004). Negotiation processes are not utterly random nor do they follow a predetermined order. Structure rather emerges during the course of the interaction (Dooley et al., 2003; Guastello, 2000; Wheeler & Morris, 2002). Moreover, the complexity perspective allows addressing the interplay between structure and flexibility in negotiations (Wheeler 2004a; Wheeler & Morris, 2002; Pincus, 2001; Pincus et al., 2008). Finally, complexity measures capture information, choice, and uncertainty (Biggiero, 2001; Guastello et al., 1998; Pincus & Guastello, 2005; Shannon, 1948) which are central aspects in negotiation (Bazerman, 1983; De Dreu & Carnevale, 2003; Payne, 1982; Tversky & Kahneman, 1981).

In the context of electronic negotiation support systems, the latter is of special interest as DSSs are specifically designed to influence these features (Delaney et al., 1997; DeSanctis & Gallupe, 1987; Foroughi, 1998; Lim & Benbasat, 1992-93). Also the communication mode indirectly impacts information, choice, and uncertainty via the medium time (De Dreu, 2003; Harrison et al., 2002; Moore et al., 1999; Rockmann & Northcraft, 2008). Bargaining and decision making is often adversely affected by negotiator's cognitive limitations (Bazerman, 1983; Bazerman & Neale, 1983; Pruitt, 1981), yet, the technology provided by NSS is believed to overcome the resulting deficiencies (Foroughi, 1998; Kersten & Lai, 2007; Lim & Benbasat, 1992-93; Rangaswamy & Shell, 1997). In order to reveal the impact of technology, however, the actual negotiation process and the pattern of interpersonal communication must be investigated (DeSanctis & Gallupe, 1987; Foroughi, 1998).

The present study followed this claim by assessing the impact of the communication mode (asynchronous e-mail and synchronous IM) and decision support on the negotiation process' complexity. In accordance with our hypotheses, both negotiating asynchronically via e-mail as well as additionally employing decision support led to a significant reduction of the negotiation interaction's complexity. Thus, the better the a priori information processing and decision making resulting from more time at one's disposal as well as the usage of a DSS, the less choices, information, and uncertainty as reflected in the complexity are brought into the process itself. Furthermore, reducing the process complexity significantly increases the probability for reaching an agreement. Considering patterns and regularities as well as dynamic properties, however, appears to be crucial (Chatman et al., 1991; Putnam & Roloff, 1992). The Shannon Entropy, considering only frequencies, turned out to have limited prognostic value. The grammar complexity, which also takes into account patterns and temporal sequences, was identified as the most valuable predictor second only to employing an NSS including decision support.

In the present study we only assessed the influence of different communication modes and decision support on the complexity of the negotiation process. Negotiation research has identified numerous variables affecting the interaction and outcome of negotiations such as gender (Kray, Galinsky & Thompson, 2002), culture (Adair & Brett, 2005), strength and kind of relationship (Pfetsch & Landau, 2000), degree of trust (Jeffries & Reed, 2000), or personal characteristics of the negotiators (Bazerman et al., 2000). For instance, it can reasonably be assumed that a lower level of trust, weaker relationships, or cultural differences in negotiating increases the process complexity, which in turn is detrimental for reaching an agreement. Investigating the influence of these factors on the complexity of the negotiation process and, in a second step, on the outcome of the negotiation might be a fruitful area of research.

Furthermore, we argued that reducing the level of information, choice, and uncertainty is beneficial for reaching an agreement. Although supported in the empirical analysis, the results should not be generalized into a simple inverse relationship between complexity and the probability for reaching an agreement. As pointed out by Wheeler and Morris (2002) and shortly discussed in previous paragraphs, a certain level of complexity is required in negotiations to allow for creativity, flexibility, and adaptability. Similarly, von Weizsäcker and von Weizsäcker (1972) argue that effective information exchange among living systems operates between confirmation and newness. The range of optimal complexity and to what extent it is dependent from the context is, however, unclear. For instance, in initial stages of the negotiation in which creativity and exploring a multitude of options is required, a higher level of complexity might be beneficial. The same level of complexity might be detrimental in final stages of the negotiation in which the negotiators should narrow their options and come to a conclusion. The present paper is a first step in empirically showing the usefulness of complexity theories in negotiations. By offering concepts and methods that allow the investigation of complex pattern unfolding over time (Guastello, 2000), complexity theories provide important insights. Developing a contingency model of complexity in negotiations would further enhance our understanding of the negotiation process.

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