A Study on Preference Impartation and Decision Support in E-negotiation ♦

Gregory E. Kersten[1], Eva Chen[1], Jesus Rios[2], Stefan Strecker[3]

[1] InterNeg Research Centre, Concordia University, Montreal, Canada, {gregory; chen}@jmsb.concordia.ca

[2] Manchester Business School, The University of Manchester, Manchester, U.K., jesus.rios@mbs.ac.uk

[3] Institute for Computer Science and Bus. Inf. Systems (ICB), Duisburg-Essen University, Duisburg, Germany, stefan.strecker@uni-duisburg-essen.de

Abstract

Decision support and the impartation of the principal's preferences to the agent may influence the negotiation outcome. A multi-attribute two-party contract e-negotiation was conducted in a controlled laboratory environment. The results indicate that the effectiveness of analytical support depends on the elicitation of the numerical preference values. When preference information is transmitted in qualitative terms to the negotiation agents, analytical support may be counterproductive.

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1. Introduction

Experimental studies indicate that electronic negotiation systems (ENS) contribute to reduction of impasse rates and increase in agreement quality [1]. However, related studies on electronic meeting systems report mixed [2]. One reason may be that some systems focus on process support [3], while others provide analytical support with tools coming from decision support systems (DSS) [4]. The focus on process implies the use of tools to enhance communication and structure the process, whereas decision support focuses on problem representation, preference elicitation and utility construction, and the analysis of offers and counteroffers.

This work addresses the conditions, in which analytically supported negotiations lead to better outcomes. It reports the results of a laboratory experiment with DSS tools embedded in e-negotiation systems and their impact on the substantive outcome in bilateral, multi-issue e-negotiations.

Many negotiations are conducted by agents who act on behalf of principals, e.g., organizations and individuals [5]. The agent-principal relationship is of concern to agency theory [6, 7], which focuses on the degree of information given to the agent, incentive structure, and monitoring [8]. An important but not well studied issue is the principal's willingness and ability to formulate and present detailed information, e.g., about her preferences. Lax and Sebenius [9, p. 475] describe negotiation exercises in which "subjects were given crisp, multi-attribute utility functions and reservation prices and others, playing the same roles, received similar information in precise, but verbal form." They focus on the uncertainty in the agent's knowledge of the principal's reservation prices and formulate prescriptive models. . In contrast to Lax and Sebenius, we study e-negotiations under controlled laboratory conditions in which some participants receive imprecise and others precise information on the principal's preferences—a unique experimental design to our knowledge.

Section 2 discusses analytical support and preference representation and impartation. Section 3 presents the model and the hypotheses. Section 4 describes the experimental design and defines performance measurement variables. Experiment results are given in Section 5, followed by the conclusions given in Section 6.

2. Background

In the case of multi-attribute decision making the consistent specification of preferences is a difficult task for which specialized methods have been used. This task becomes more complicated when one person's preferences need to be communicated to another person who often has her own preferences. Decision analysis provides a framework for dealing with difficult decisions in a rational way. However, application of decision analysis requires that the users have the knowledge of normative theories, the skills to apply them and the time and inclination to do so.

2.1 Analytical support for negotiations

The validity of analytical support depends on the consistency of users' input with their interests and values. Support effectiveness also depends on the users' perceptions which often depends more on the user understanding and trust than on logical coherence. In effect some support tools may be weak in terms of their logical soundness, yet be successfully adopted.

Effortless but theoretical imperfect elicitation procedures for additive multi-attribute value function are implemented and used successfully in many decision and negotiation support systems.

In addition to studying the losses during a normatively imperfect analysis, one may study its usefulness in empirical settings. This is a behavioural perspective on the analytical support affecting the negotiation outcomes.

2.2 Communication of preferences

Many contract negotiations are undertaken on behalf of an organization which requires that the negotiators represent interests of the organization they represent. These problems have been studied in agency theory, which focuses on incentive and compensation, information revelation, organization and control [6, 7, 10]. This paper discusses situations in which the principal informs the agent-negotiator about the firm's interests and preferences and assumes that the agent does not willingly distort this information. This information may be conveyed in different ways which may affect the process and its outcomes [11]. There are many ways of preference impartation, including verbal, graphical and numerical.

Communication of preferences differs in terms of their expressiveness, precision and expression effort. The choice of a particular communication mode affects communication effort and the required accuracy. Although ordinal preference information can be transmitted using any of these means (verbal, graphical and/or numerical), cardinal preferences cannot be transmitted unequivocally using verbal methods. Graphical means increase accuracy but only the numerical ones convey precise information. Each method requires more effort than verbal communication. Thus, the first question is if it is worth for the organizations to make this extra effort; will numerical information help the negotiators to perform better for the firm?

2.3 True and used preference discrepancy

The relationship between the principal's true preferences and the preferences used by the agent negotiating on behalf of the principals is important but analytically not well examined [9]. The differences between the preferences may be due to both objective and subjective reasons.

Principals may not have well elaborated preferences or be purposefully be vague and not reveal their preferences to the agent. The latter may be due to their expectation that the agents' would be tougher negotiators and bargain harder [12]. It is also possible that the principals do not have precise preference information and can only convey it in vague terms. In both situations, we may expect a difference between the true preferences (of the principal) and the preferences used by the agent.

From the agent's perspective the discrepancy is caused by:

1. Multiple interpretations of information that is conveyed in imprecise and qualitative terms, and
2. Errors caused by the elicitation procedure which requires translating preferential judgments into the numerical representation [13].

Many ENSs use quantitative models to elicit and represent preferences. When this kind of analytical support is provided, preference information, which requires numerical judgmental inputs from the user, is needed.

Provided analytical support requires that preferences be represented as numbers. When the preferences are transmitted to the negotiator numerically, the process is straightforward.

When the agent's knowledge about the principal's interests and preferences is inaccurate but she is requested to use a preference elicitation tool, the resulting utility function does not represent the function she should maximize. In such a case, the analytical support would not provide useful insight and it may even be counterproductive.

3. Research model and hypothesis

Different aspects of decision making and negotiation may be supported with analytical and communication tools. In this study the analytical support is limited to preference elicitation, utility construction, and calculation of the utility value for every offer exchanged. The communication support is limited to the exchange of structured offers, free-text messages, and maintenance of the negotiation transcript and graph showing the offer exchange process [14].

The research model (Fig. 1) has two independent variables:

(1) analytical support for the negotiation dyad, and

(2) the preference information mode.

The qualitative mode of preference transmission is verbal and graphical, while the quantitative mode includes both qualitative and numerical representations.

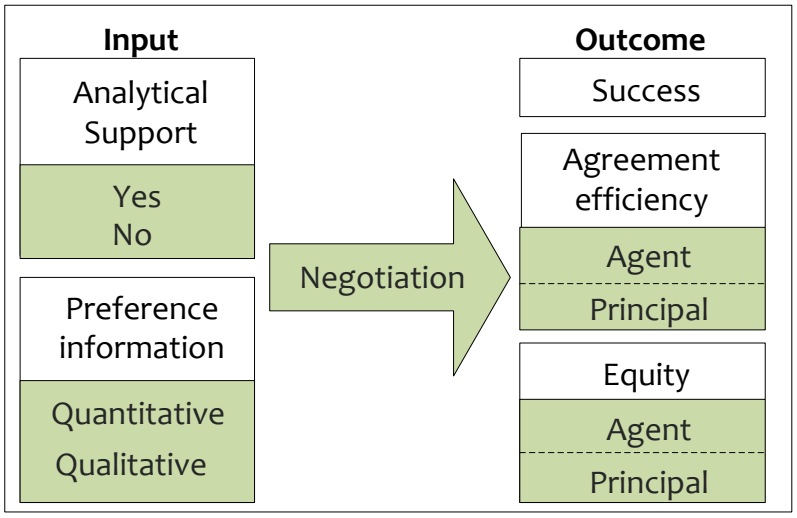

Figure 1. Research model

Negotiators, who want to take advantage of the additional numerical information about their principals' preferences, need to analyze the information exchanged during the negotiation so that they can evaluate tradeoffs and compare offers quantitatively. This requires high cognitive effort and an analytically oriented inclination. This may slow the negotiation and—in negotiations with a deadline—decrease the agreement rate. It is also possible that negotiators provided with extra numerical information do not use it.

To evaluate how the independent variables impact the negotiation outcome, we use negotiation success, which is the achievement of an agreement, the quality of the reached agreement in terms of its efficiency, and equity regarding both the values negotiators try to maximize (agent's perspective) and those values they should maximize (principals' perspective).

Hypothesis H1: If analytical support is not provided, there is no difference, in terms of substantive outcome, between receiving or *not* receiving additional numerical values describing the principals' preferences to the negotiating agents.

Negotiators often fail to reach efficient agreements. Rangaswamy and Shell [15] have empirically shown that analytical support increases the agreement rate. This and other studies assumed that the participants use either their own or imposed preferences.

Hypothesis H2: When preferences transmitted to the agents include numerical information, then analytically supported dyads have better outcomes than non analytically supported ones.

The previous hypothesis is based on the assumption that the supported negotiators have access to their principals' preferences in a quantitative way. Thus, the aid provided is based on an error free representation of these preferences. It implies that the previous hypothesis is not considering the elicitation of these preferences. However, when the preferences of the negotiators' principals are given only in qualitative terms, negotiators have to translate these preferences in numerical terms in order to be analytically supported. It raises the question of how preference information has to be given to human agents and which appropriate elicitation methods are valid in translation of these preferences into the system.

When preference information is given only qualitatively, the values that agents are actually trying to maximize may differ from those they should maximize (from the perspective of the principal). This is due to the lack of an unambiguous interpretation of such information. Such discrepancy can be aggravated with the use of analytical support with an improperly elicited input of the values they want or should maximize.

Thus, a possible discrepancy between the elicited values used by the analytical support and the values negotiators should or want to maximize, may render analytical support counterproductive. Indeed, although analytical support may lead to better outcomes from the viewpoint of the values entered into the system by the negotiators, it may not be the case from the viewpoint of the values negotiators should or want to maximize. Thus, we hypothesize that analytical support will not be necessarily useful if agents receive only qualitative information on the values they should maximize.

Hypothesis H3.1: When the agents receive only qualitative information (verbal and graphical) about their principals' interests, analytically supported dyads do not reach better outcomes than non-analytically supported ones.

Therefore, when the information about the interests of the principals is qualitatively given to their agents, usefulness of analytical support based on numerical preference representation depends on the accuracy of the elicitation procedure. The user's judgmental inputs depend on how agents understand and process the qualitative information representing the interests of their principals as well as understanding of the elicitation procedure and its theoretical soundness. As analytical support uses numerical judgmental inputs, only when elicited preference values correspond to the values which they should or want to maximize, the analytical support will generate a consistent and valuable aid. Therefore, we hypothesizes that

analytical support leads to better outcomes when the numerical preferences used by the system represent accurately those that the user should or wants to maximize, which is the case when the principals' preferences are transmitted in a quantitative mode and the elicitation procedure is free of error.

Hypothesis H3.2: Analytically supported dyads reach better outcomes when the information about their principals' preference includes numerical values.

We expect analytically supported dyads performing better than non-supported ones only when numerical information about their principals' preferences is provided.

4. Experimental design

The experiment involved a contract negotiation between an artist and an entertainment company. One negotiator was the artist's agent and the second negotiator represented the company. The case was formulated in such a way that ambiguous formulation of preferences was natural. At the same time, because the parties had to negotiate four issues and the existence of the trade-offs between the issues, having an understanding of the principal's preference structure was important to achieve a satisfactory outcome.

The simulated negotiation task was limited to a contract template comprised of 4 fixed issues to negotiate: (1) number of promotional concerts, (2) number of new songs, (3) royalties for CDs and (4) contract signing bonus. Each issue had a fixed number of options to choose from. Negotiators were not allowed to propose new issues or resolution options. In total, there were 240 possible contracts. Offers were restricted to complete contracts proposed for acceptance consisting of selecting one option per issue. The negotiation protocol allowed the exchange of free-text messages as well as structured offers. Negotiators had one hour to agree on a contract.

We used a 2x2 factorial experimental design. One factor represented the availability of analytical support and the other the availability of numerical information about the represented preferences. Please note that we did not consider negotiations in which one of the sides received analytical support and the other was not supported. . Thus, when analytical support was available or preference information was quantitatively given, it was available to both parties in the negotiation dyad. Subjects were matched randomly into pairs and assigned to one of the four treatments (see Table 1).

The experiment was conducted in a laboratory setting supervised by a facilitator in order to ensure compliance with the experimental design. Each participant was paid CAD24 cash for their participation in the experiment. The interaction between the negotiation parties was computer-mediated via a web browser. In total, 200 undergraduate and graduate students from the two "English-speaking" universities in Montréal participated in the experiment.

Subjects played a role in the simulated negotiation case. They were provided with general public information about the case, including the contract template listing the issues to be negotiated and their possible resolution options. Each subject acted as an agent in the bilateral negotiation exercise. Thus, each side of the table was given according confidential information about the preferences of the principal they represented.

Confidential instructions also provide each side with general indicative information about the other side's interests. The subjects had to correctly answer a quiz before starting the actual

negotiation in order to ensure their understanding of the case.

There were four treatments, shown in Table 1.

Treatments T1 and T4 subjects received only qualitative (verbal & graphical) information about their principal's interests. T2 and T3 included extra numerical information given through a numerically scored template representing the interests of their principals.

A scoring system was used to help participants numerically represent their principals' preferences in order to clarify tradeoffs among the issues to negotiate. The scoring system assumed an additive value function method [16, Stewart, 1996 #16], allowing not only for the ordinal contracts ranking but also for clarification of the cardinal value tradeoffs.

Table 1. Experimental treatments

Analytical support	Preferences	Treatment
No	Verbal + graphical	T1
	Verbal + graphical + numerical	T2
Yes	Verbal + graphical + numerical	T3
	Verbal + graphical	T4

A specific numerical value was assigned to each option of each issue. These values were given directly in the case instructions (T2 and T3) or were elicited (T1 and T4). Complete contract offers, constructed by selecting one option per issue, were scored by adding their options' scores to obtain an overall numerical value. The analytical support provided to each party in T4 and T3 consisted of: (a) displaying offers' rating when making or receiving them, (b) a graph with the negotiation history of scored offers and counteroffers, and (c) a post-settlement mechanism to potentially improve an inefficient contract agreement.

When principals' preference information was given quantitatively (T2 and T3), analytical support is directly based on the principals' ratings. When principals' preference information was given qualitatively (T1 and T4), analytical support was based on the ratings elicited by the subjects.

All subjects received verbal and graphical information on the importance of issues and options from the viewpoint of their principals (Fig. 2). In our experimental design, additional numerical preference information was also given in treatment T2 and T3.

Preferences were numerically represented with an additive rating system quantifying the relative importance of issues and options. Therefore, the dyads in the treatments in which preferences were quantitatively transmitted received the principals' scores evaluating the template (issues and options) within the set of instructions.

The qualitative preference transmission mode did not include the principals' numerical rating values. Instead, the qualitative (verbal and graphical) information was prepared by omitting the numbers used in the quantitative version, yet keeping the indicative sizes of the circles.

For each treatment, subjects who reached the highest negotiation score had the opportunity to earn another CAD40 extra. This reward mechanism was made clear to the subjects before the experiment in order to induce a "value maximizing" behaviour. Thus, contracts with higher

scores were preferred.

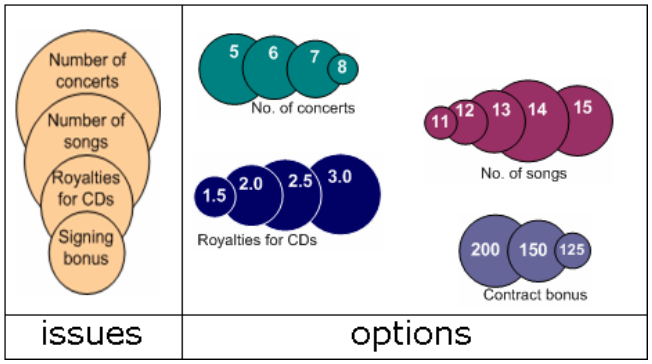

Figure 2. Graphical preference representation

Subjects in T2 and T3 received confidential instructions including a numerically scored template representing their principals' preferences. These scores were common to both treatments.

In treatments T1 and T4 the numerical scores were not given and were instead elicited from the subjects. To do so, they needed to evaluate the negotiation template (issues and their options) according to their numerical understanding of the qualitative (verbal and graphical) information describing their principals' interests. We note that the analytical support provided in T4 used each concrete subject's values elicited prior to the negotiation task in order to evaluate every contract during the negotiation.

The Inspire system, which was used in the experiments, implements a hybrid-conjoint elicitation procedure [16]. This procedure has two phases. In the analytical phase, each subject privately evaluated the negotiation template, rating directly the relative importance of the issues and their corresponding options by: (1) distributing 100 points among the issues based on their relative importance; and (2) assigning within each issue, the issue's score to its most preferred option(s): 0 to less preferred one(s), and an intermediate score to the rest of options based on their relative importance within this issue. In the holistic phase, the subjects assessed the resulting scores of the selected alternatives (contracts) and adjusted their ratings.

A quasi-linear regression model was used to determine option scores based on the adjusted ratings of the selected alternatives. During the negotiation, the total score of a contract was calculated by adding up the scores of the options selected for each issue of this contract.

The measures of the three negotiation outcomes (see Figure 1) are presented in Table 2.

Table 2. Outcome measures

Outcome	Measurement
Success	Agreement rate
Agreement efficiency	Agreement distance to the Pareto Frontier: Dist(PF) Agreement joint value (sum, prod, min)
Agreement equity	Contract balance Agreement distance to U, N, K: Dist(U), Dist(N), Dist(K)

5. Experimental results

Observations from 100 negotiation dyads were obtained, whose distribution and agreement rates per treatment are shown in Table 3.

Table 3. Four experiments

	Treatment				Total
	T1	T2	T4	T3	
No. of dyads	21	24	26	29	100
No. of agreements	18	16	19	25	78
Agreement rate	86%	67%	73%	86%	78%

Statistical analysis of the experimental data was performed using the R statistical software (http://www.r-project.org). Besides descriptive statistics, we have used the Pearson's chi-squared test for proportion comparison and we have performed the non-parametric Mann-Whitney *U*-test to compare the median of two independent samples due to the non-normality of the empirical distribution and the relatively small sample sizes. For the Mann-Whitney *U*-test, exact p-values are calculated.

5.1 Non-supported dyads (T2 vs. T1)

T1 and T2 participants were not given analytical support. In T2, they were given extra numerical preference information whereas in T1 they only received verbal and graphical information trying to convey the removed numerical scores from the quantitative version.

We test here hypothesis *H1* comparing the negotiation outcomes obtained in T1 and T2 and answer the question: Is there any statistically significant difference between the outcomes of non analytically supported dyads that received quantitative information on their principal's interests (T2) and those that received only qualitative information (T1)?

The negotiation success measured with the percentage of agreements in the two treatments is shown in the Table 4.

Table 4. Agreement rates comparison

Treatment	Sample	Success	p-value (2-sided)
T2	24	67 %	0.256
T1	21	86 %	

The lower proportion of agreement observed in T2 may be a consequence of the fact that subjects in T2 required more time in order to process the extra numerical information than subjects in T1 and it made the search for an agreement slower. However, there is no sufficient statistical evidence in the observed data to conclude that the agreement rates in T1 and T2 are significantly different.

Next, we compare the agreements' joint scores with respect to the principals' values. Figure 3 depicts all possible contracts in the principals' utility space, i.e., from the principals' viewpoint.

The agreements obtained in T2 are indicated with blue crosses (+) and those in T1—with red crosses (x).

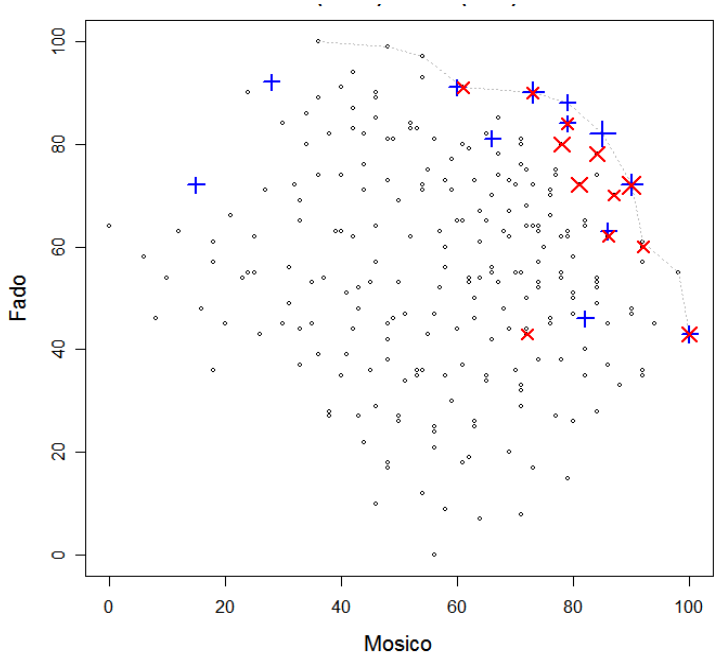

Figure 3. Agreement ratings in T1 (red x) and T2 (blue +)

Table 4 shows that there is no statistically significant difference between the contract agreements reached in T1 and T2, in terms of efficiency, joint value and equity with respect to the principals' viewpoint.

Table 4. Agreement utility for the organization

Measure		Mean	S.D.	p-value (2-sided)
Dist PF (efficiency)	T2	2.24	5.94	0.62
	T1	1.60	5.035	
Joint value (sum)	T2	150.37	22.15	0.47
	T1	153.78	11.71	
Joint value (prod)	T2	5534.37	1762.90	0.53
	T1	5782.39	983.65	
Joint value (min)	T2	63.43	20.31	0.76
	T1	67.00	12.45	
Contract balance	T2	23.50	20.21	0.75
	T1	19.78	16.48	
Dist(U)	T2	17.94	20.27	0.70
	T1	15.91	12.93	
Dist(N)=Dist(K)	T2	21.07	20.82	0.72
	T1	16.90	12.77	

The same analysis as above can be done using the scores elicited by the subjects in T1 instead of the principal's ones. The agreement quality variables measured using the subjects' elicited values for treatment T1 is given in Table 5. Notice that joint elicited agreement values in T1 are not considered as they are not comparable among negotiations when subjects' elicited scores are used.

From these results, we can conclude, considering both the elicited values of the subjects in T1 and also the values of their principals, that when analytical support is not provided, there are no statistically significant differences between negotiation outcomes if extra numerical preference information is used to describe their principals' preferences. Thus, this conclusion is valid from both the agents' and the principals' perspective.

Table 5. Agreement quality using elicited scores (T1)

Measure		Mean	S.D.	p-value (2-sided)
Dist PF (efficiency)	T2	2.24	5.94	0.77
	T1	1.25	3.59	
Contract balance	T2	23.50	20.21	0.72
	T1	23.78	24.86	
Dist(U)	T2	17.94	20.27	0.48
	T1	24.98	27.13	
Dist(N)	T2	21.07	20.82	0.64
	T1	26.02	26.61	
Dist(K)	T2	21.07	20.82	0.88
	T1	21.78	19.85	

An interesting issue here is whether the elicited values for subjects in T1 are close to those of their principals on whose behalf the negotiated. The difference between the elicited values and their principal values measures the error in the translation into numbers of the qualitative information describing their principal's interest. We tested that the observed differences between the elicited values and the principals' values of agreements reached by subjects in T1 were normally distributed with mean 0 and an estimated standard deviation of 15.45 score points.

5.2 Analytical support (T3 vs. T2)

We consider now the treatments T2 and T3 in which quantitative preference information is provided, and test hypothesis H-2 to see whether analytically supported dyads (T3) performed better than non-analytically supported ones (T2) by means of the comparison of their negotiation outcomes.

Table 6 shows the proportion of agreements in each treatment and provides sufficient statistically significant evidence to conclude that the agreement rate in T3 is higher than in T2 with a p-value of 0.045.

The quality of the agreements obtained in T2 and T3 is given in Table 6. In these treatments, the subjects received the principals' numerical preferences in a tabulated form.

Table 6. Agreements rates for T2 and T3

Treatment	Sample	Proportion of agreements	p-value (1sided)
T3	29	86 %	0.045
T2	24	67%	

Figure 4 shows the agreements' joint scores for treatments T2 and T3. We note that for treatment T3, in which the post-settlement mechanism is available, we have plotted the final scores if parties used it.

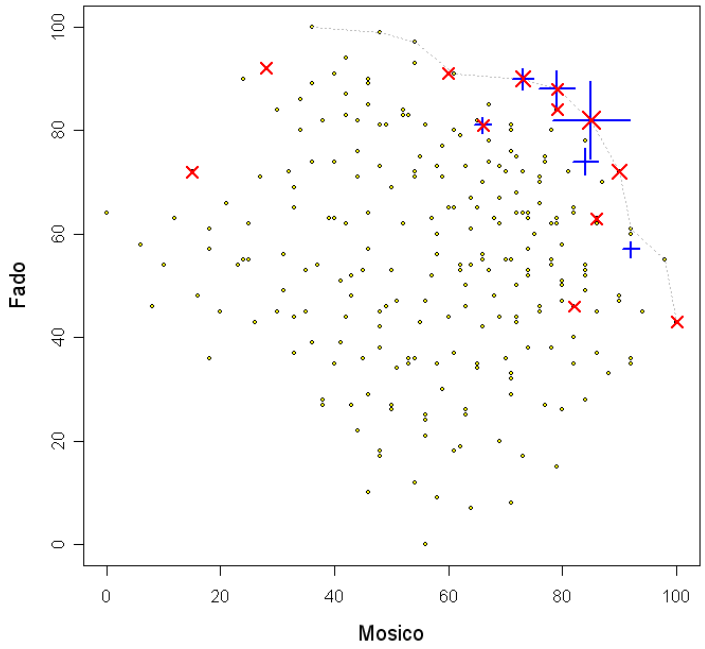

Figure 4. Joint agreement scores in T2 (red x) and T3 (blue +)

The T3 agreements are closer to the Pareto frontier (Fig. 4). Indeed, 84% of the final T3 agreements are on the Pareto frontier, whereas only 68.75% of T2 agreements are efficient. T3 agreements are also closer and more concentrated around balanced values on the Pareto frontier than T2 agreements. Measures of the agreements reached in T3 and T2 are given in Table 7.

This experimental data provides enough statistically significant evidence (p=0.068) to conclude that the distance of the agreements to the Pareto frontier in T3 is lower than in T2. Therefore, there are more efficient agreements in T3 than in T2. There is also statistical evidence to conclude that agreements in T3 have statistically significant higher joint value than in T2, in terms of their score sum (p=0.001), product (p=0.003) and minimum (p=0.001). The experimental data also supports the claim that agreements in T3 are statistically significantly more balanced than in T2, as their absolute differences of scores are lower.

Table 7. Comparison of agreement quality measures

Measure		Mean	S.D.	p-value (1-sided)
Dist PF (efficiency)	T2	2.24	5.94	0.068
	T3	0.13	0.43	
Joint value (sum)	T2	150.37	22.15	0.001
	T3	164.08	5.72	
Joint value (prod)	T2	5534.37	1762.90	0.003
	T3	6709.92	498.02	
Joint value (min)	T2	63.43	20.31	0.001
	T3	78.08	6.11	
Contract balance	T2	23.50	20.21	0.001
	T3	7.92	7.31	
Dist(U)	T2	17.94	20.27	0.001
	T3	3.10	6.21	
Dist(N)=Dist(K)	T2	21.07	20.82	0.001
	T3	5.62	7.12	

From the data shown in Tables 7 and 8, we conclude that agreements in T3 are closer to the utilitarian, Nash and maximin contracts, as their Euclidian distance to them is lower.

In treatment T3, 72% of the final agreements coincide with one of the two utilitarian contracts, versus the 25% in T2 (Table 8). The 52% of T3 agreements coincide with the maximin and the Nash solution, as both solutions lie in the same point, versus the 18.75 % for the agreements in T2.

Table 8. Agreements coinciding with U, N and K

	T3	T2
U	72%	25%
N=K	52%	18%

Not only is the agreement rate higher in T3 than in T2, but also the agreement quality is better in T3, as T3 agreements are more efficient, have higher joint value, are more balanced, and concentrate more around those contracts representing some principle of equity. Thus, hypothesis *H-2* is supported and we conclude that analytically supported negotiations result in more efficient and equitable outcomes when numerical information about the principals' preferences is given.

5.3 Non-numerical preference information

T4 vs. T1. Analytical support leads to better outcomes when subjects receive exact numerical information concerning the values they should maximize. Under this treatment condition, in which the preferences are numerically given to the agents, the analytical support is straightforward and consistent with the preferences that agents should maximize. However, when the preferences which agents should maximize are not numerically specified the usefulness of the analytical support depends on the elicitation method to translate into numerical values these preferences (described only verbally and graphically) as well as on how

well subjects understand both the elicitation method and the qualitative preference information.

We compare T1 and T4 to study the impact of analytical support when only qualitative (verbal and graphical) information about the principals' preferences is provided. This is used to test hypothesis *H3.1* which posits that analytically supported dyads (T4) reach better negotiation outcomes than non-analytically supported ones (T1) when they do not receive numerical information concerning their principals' interests.

Based on data given in Table 9, we conclude that there is no statistical evidence to conclude that the proportion of agreements in T4 is greater than in T1.

Table 9. T1 and T4 agreement rate comparison

Treatment	Sample	Prop. of agreements	p-value (1-sided)
T4	26	73 %	0.854
T1	21	86%	

We compare the quality of the agreements in T4 and T1 from the point of view of: (1) the principals' and (2) the subjects' who gave the values. The agreement is measured by the comparison of the principals' and actual (elicited) scores.

Figure 8 shows the joint scores of the agreements obtained in T1 and T4 from the principals' viewpoint.

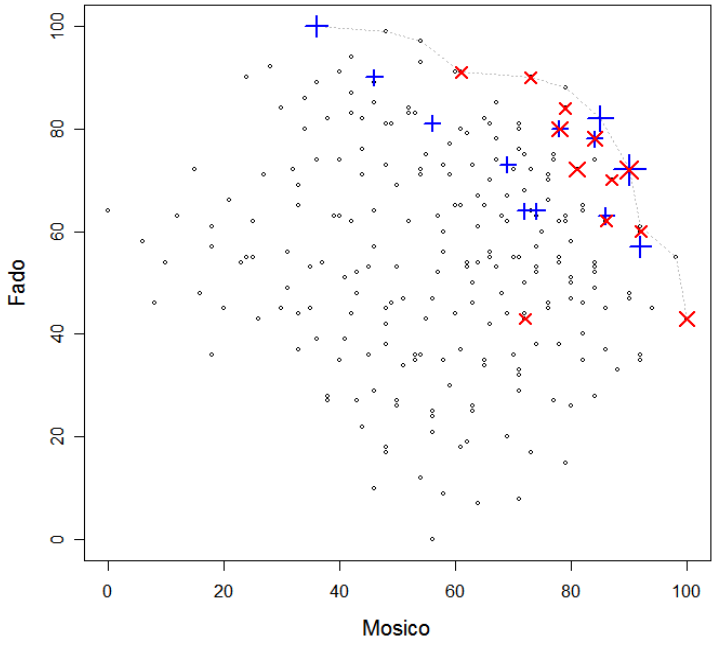

Figure 5. Joint agreement scores in T1 (red x) and T4 (blue +)

The agreements achieved in T4 and T1 treatments are compared in Table 10, based on the principals' preferences. The data indicates that we have no statistical evidence to conclude that

there is any difference among the agreements when the principals' viewpoint is used.

The agreements may also be compared using the viewpoint of the subjects' elicited values. The question is if analytically supported agents reach better agreements from their own viewpoint helping them to maximize the values which should be maximized. If we compare the results with the results from the principals' perspective, we can assess the impact of the preference presentation on agreements from both viewpoints.

Table 10. Comparison of agreements in principals' utility space

Measure		Mean	S.D.	p-value (1-sided)
Dist PF (efficiency)	T4	1.40	2.35	0.523
	T1	1.60	5.04	
Joint value (sum)	T4	151.42	12.42	0.736
	T1	153.78	11.71	
Joint value (prod)	T4	5568	1146	0.699
	T1	5782	984	
Joint value (min)	T4	65.16	14.29	0.656
	T1	67.00	12.45	
Contract balance	T4	21.11	19.45	0.563
	T1	19.78	16.48	
Dist(U)	T4	17.62	13.54	0.759
	T1	15.91	12.93	
Dist(N)=Dist(K)	T4	19.05	15.88	0.666
	T1	16.90	12.77	

The values elicited from the agents may differ from actual principals' values. If the values agents try or want to maximize are different from those they should maximize, dyads may perform well with respect to their perceived or elicited values but not with respect to their principals' values.

The statistical comparison of the agreement quality from the subjects' viewpoint is displayed in Table 11, in which the agreements' joint elicited values are not considered as they are not comparable.

Table 11. Agreements evaluated with their subjects' elicited scores

Measure		Mean	S.D.	p-value (2-sided)
Dist PF (efficiency)	T4	0.22	0.60	0.044
	T1	1.25	3.59	
Contract balance	T4	22.72	23.91	0.427
	T1	23.78	24.86	
Dist(U)	T4	24.93	24.41	0.572
	T1	24.98	27.13	
Dist(N)	T4	24.50	23.76	0.509
	T1	26.02	26.61	
Dist(K)	T4	16.48	21.74	0.077
	T1	21.78	19.85	

There is sufficient statistical evidence (p-vale = 0.044) to conclude that agreements in T4 are more efficient than in T1 when we measure it with respect to the subjects' elicited values. Moreover, 84% of the agreements in T4 result to be Pareto optimal versus the 55% in T1. However, although agreements in T4 are closer to the PF than those in T1 from the perceived subjects' values, T4 agreements are not more efficient from the viewpoint of the actual principals' values.

The experimental observations support hypothesis *H3.1* when agents receive only verbal and graphical but not numerical information about their principals' preferences. Specifically, although there is statistical evidence that analytically supported dyads (T4) reach more efficient agreements than non-supported ones (T1) from the viewpoint of the subject's elicited values, there is no statistical evidence to support it from the viewpoint of the principal's values.

We can conclude here that analytically supported negotiations will lead to more efficient agreements only if there are no discrepancies between the elicited preference values used by the analytical support and the actual values which the agents should try to maximize.

T3 vs T4. We test now hypothesis H-3.2 comparing T4 and T3 negotiation outcomes to see whether analytically supported dyads with numerical information about their principals' preference reach better outcomes than when this preference information is only given in qualitative terms (verbally and graphically).

Table 12 shows that there is no statistical evidence supporting the claim that T3 has a higher agreement rate than T4.

Table 12. Agreements rate comparison test

Treatment	Sample	Proportion of agreements	p-value (one-sided)
T4	26	73%	0.112
T3	29	86%	

Table 13. Agreement quality for principals

Measure		Mean	S.D.	p-value (1-sided)
Dist PF (efficiency)	T4	1.40	2.35	0.013
	T3	0.13	0.43	
Joint value (sum)	T4	151.42	12.42	0.000
	T3	164.08	5.72	
Joint value (prod)	T4	5568	1146	0.000
	T3	6709.92	498.02	
Joint value (min)	T4	65.16	14.29	0.000
	T3	78.08	6.11	
Contract balance	T4	21.11	19.45	0.004
	T3	7.92	7.31	
Dist(U)	T4	17.62	13.54	0.000
	T3	3.10	6.21	
Dist(N)=Dist(K)	T4	19.05	15.88	0.001
	T3	5.62	7.12	

When comparing the quality of these agreements from the principals' viewpoint (see Fig. 6), we find statistical evidence supporting the claim that T3 agreements are better that T4 agreements in terms of efficiency and equity, as shown in Table 13.

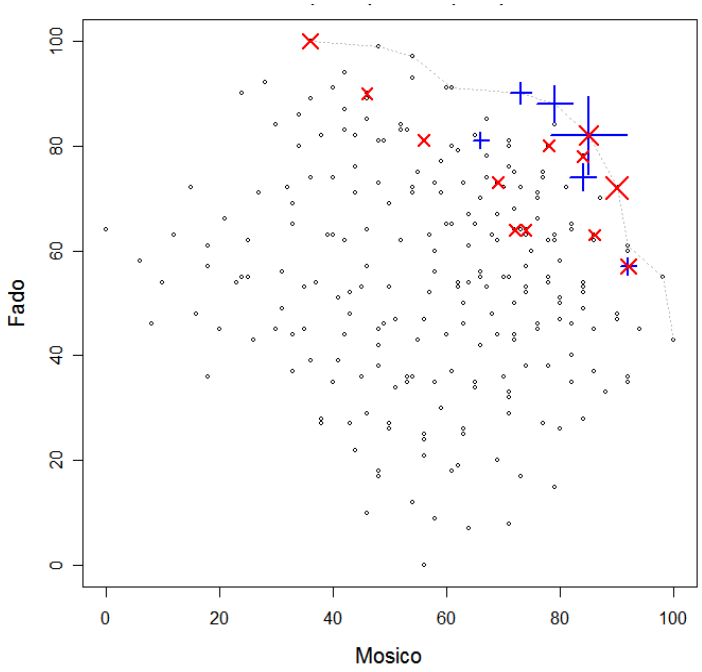

Figure 6. Agreements in principals' utility space in T4 (red x) and T3 (blue +)

6. Conclusion and discussion

When analytical support was not provided, there were no significant differences in the dyads' performance between preferences described quantitatively and only qualitatively. Thus, the inclusion of numerical information to explain the principals' interests for non-analytically supported dyads seems to have no impact on the negotiation outcome.

On the other hand, our experiments showed conclusively that analytical support leads to more efficient and equitable agreements when the principal preference information included numerical scores.

The agreements reached by non-analytically supported dyads presented more variability and were more inefficient, falling farther from the efficient frontier, than those agreements reached by supported dyads. However, when preference information was given using only verbal and graphical representations (qualitatively) and the agents needed to translate their principal's interest into numbers, analytical supported dyads did not perform better from the perspective of the principals. Indeed, they performed slightly worse.

The results indicate that analytical support provides better quality agreements only when agents are able to correctly translate into numbers their principals' interests. Otherwise, incorrect numerical representation of preferences may render the analytical support counterproductive.

The reliability and usefulness of analytical support based on the numerical representation of preferences, is essentially dependent on the accuracy of the elicitation procedure. In particular, if a negotiator's preferences are not clearly and explicitly established in numerical terms, analytical support might be useless. Thus, if analytical support is available and the user wants to use it, then she should make an effort to formulate preferences in crisp numerical terms. If an agent conducts the negotiation, then the principal needs to make sure that the preferences are formulated in a way that the agent can effectively use the ENS's analytical support tools.

Table 14. Summary of main results

Hypothesis	Treatments	Analytical support	Num. prefs.	Different outcomes
H-1	T2 vs. T1	No		No
H-2	T3 vs. T2		Yes	T3 better than T2
H-3.1	T4 vs. T1		No	Not for the principals
H-3.2	T3 vs. T4	Yes		T3 better than T4

The current findings are limited to our lab setting. A moderately complex computer-mediated negotiation task was conduct in a controlled environment. The experiments indicate that gender, negotiation style and other background variables do not have significant effect on agreements.

This study used a non-guided direct method to input the preferences into the system. Therefore, the results cannot be generalized to preference elicitation procedures other than hybrid conjoint analysis used in these e-negotiations. Further research is necessary to determine valid preference elicitation procedures appropriate for web implementation, with special care given to error models when assessment is unassisted and done on internet.

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