A computational model of power in collaborative negotiation dialogues

Abstract. This paper presents a conversational agent that can deploy different strategies of negotiation based on its social power. The underlying computational model is based on three principles of collaborative negotiation from the literature in social psychology. The social behavior of the agent is made visible through its dialogue strategy. We evaluated our model by showing that these principles are correctly perceived by a human observer in a synthetic dialogue.

1 Introduction

With the rise in popularity of artificial conversational agents, they have become capable of holding a conversation with a human user and potentially collaborate with the user in order to achieve a common objective. Such example of collaboration can be found in artificial tutors which discuss with the student so as to define a relevant set of exercices for pedagogical goals [15]. Another example is the companion agent by [17] which help elderly to follow a specific diet. They collaborate through.... In many situations, the user and the agent typically negotiate in a collaborative manner about the way to achieve the shared task. For instance.... [donner un exemple de negotiation compatible avec l'un des deux exemples precedents]. This specific type of discussion is called *collaborative negotiation*. Unlike adversarial negotiation [24], collaborative negotiation assumes that each participant is motivated by the goal of finding a trade-off that best satisfies the interests of both the participants, instead of one that maximizes his own interest[23, 6].

In order to build Intelligent Virtual Agents capable of credible collaborative negotiation, we need to understand how human beings behave in such situation. Indeed, previous research has shown that people tend to respond to computers as social actors [2]. This is the reason why a growing body of research in the community investigated the psychosocial relationship between the user and the agent during an interaction. In the context of human-human negotiation, social psychology and communication [10, 8] investigated the impact of social relations and emotion on the negotiation. They showed that *social power* directly affects the strategies of negotiators. Therefore, in order to build intelligent conversational agents that conduct good collaborative negotiations, O.L: je trouve que cette phrase n'apporte rien it is very important to allow them to adapt their negotiation strategies to different levels of interpersonal power.

In this paper, we present a conversational agent that deploys different strategies of negotiation based on the social power it wants to express. In the next

section, we discuss existing works on interpersonal power in the domain of social psychology and affective computing. Section 3 presents the computational model of negotiation, based on a set of utterance types and a model of preferences. It implements general model of negotiation based on three principles of collaborative negotiation from the literature in social psychology. In section 4, we present an experiment conducted with two virtual agents on a negotiation about restaurants showing that the principles are correctly perceived by human observers.

2 Related work

The notion of social power has been widely studied in the fields of interpersonal communication and psychology [16]. It can be defined as the capacity to produce intended effects and to influence the behavior of the other person in the conversation [10]. In the context of communication, power is a dyadic variable that takes place during the dialogue. Behaviors related to power can contribute either positively or negatively to the dialogue. Positive contributions include keeping the conversation going and making quick decisions. Negative contributions include not considering the partner (*e.g.* not giving the occasion to express his opinion) and appearing offensive. In our work, we focus on negotiation dialogues, in which several researchers already shown the impact of social power[7, 4].

2.1 Behaviors of power in dialogue

During a dialogue, power can manifest through verbal and nonverbal behaviors. At the nonverbal level, a wide range of behaviors have been associated with the relation of power in kinestesic behaviors (facial expression, body movements and gestures) and voice (speaking duration, speaking intensity, voice control and pitch) [4]. Based on this work, several conversational agents have been developed with the ability to exhibit social power through nonverbal behavior, such as gaze [19], body movements [21] or head tilt [13, 5] in relation to high-power and low-power perception.

However, power is also expressed through verbal behaviors. A considerable body of research in social science and communication has documented the effects of power on negotiation behaviors and outcomes. De Dreu [8] demonstrated that high-power negotiators have higher aspirations, demand more and concede less. Galinsky [12] affirms that power increases the action orientation: high-power negotiators control the flow of the negotiation. In addition, high power increase task orientation and goal-directed behavior. Giebels [14] shows that this leads powerful negotiators to end up with the larger share of the pie.

Furthermore, power affects the way that negotiators gather information about their partners [7]. Low-power negotiators have a stronger desire to develop an accurate understanding of their negotiation partner, which leads them to ask more *diagnostic* rather than *leading* questions.

It was also shown that high-power negotiators are self-centered and tend not to pay attention to the preferences of the less powerful negotiators [11, 8].

Our goal is develop a model of dialogue for Virtual Agents which considers these properties related to social power. We want to make visible *the strategies* deployed during the negotiation depending on the power. In order to implement these different behaviors, we identified three principle related to the relation of power and their impact on the strategy of negotiation:

1. **level of demand and concession:** High-power negotiators show a higher level of demand than the low-power ones. In addition, low-power negotiator's demand decrease over time, and he tends to make larger concessions than high-power negotiators. [8]
2. **Self vs other:** Low-power negotiators consider the preferences of other in the negotiation, whereas high-power negotiators are self-centered and only interested by satisfying their own preferences. [11, 8]
3. **Controlling the flow of the negotiation:** High-power negotiators tend to make the first move [20] and take the lead in the negotiation. Low-power negotiators aim to construct an accurate model of other preferences, which leads them to ask more questions about other preferences rather than keeping the negotiation going (*e.g* by making proposals)[7].

2.2 Similar work in the literature

Only few researchers have considered the expression of power in the verbal behavior of a conversational agent. [1] developed an agent that expresses social power through gaze and linguistic features. They demonstrated that linguistic personality traits influence the perception of power. However, this work does not consider how power affects the strategies of negotiation in dialogue. More recently, [24, 9] consider trust, expression of emotions as anger and happiness as dimensions of the negotiation strategy of a virtual agents. However, this research focus more on the negotiation aspect than on the expression of social power. In our work, we want to investigate the expression of power through the dialogue strategy, which has not been considered by previous work.

3 Model of negotiation based on the relation of power

In this section, we present our model of dialogue for a Virtual Agent in the context of collaborative negotiation based on power. First, we present the data structure for the agent's preferences and the topics of the negotiation. Second, we present the implementation of the principles of behaviors of power in negotiation discussed in section 2.1.

3.1 Domain model

The overall goal of a negotiation is to choose an **option** in a set of possible options $\mathcal{O}$. The evaluation of each option by participants is based on a set of **criteria** that reflect the option's characteristics. Let us consider a set $\mathcal{C}$ of $\mathfrak{n}$ criteria and let $C_1, \ldots, C_\mathfrak{n}$ be their respective domains of values. $\mathcal{O}$ can be simply

defined as the cross-product $C_1 \times \ldots \times C_n$ and each option $o \in \mathcal{O}$ is a tuple $(v_1, \ldots, v_n)$, making the simplifying assumption that all options are available. For instance, in a dialogue about restaurants, the criteria might be the type of cuisine and the price, we could have the option: $(\mathtt{French}, \mathtt{expensive})$.

3.2 Preference model

The conversational agent is defined with a set of preferences, formalized as a set $\prec$ of partial orders $\prec_i$ on each C_i. For instance, if the agent prefers French food to Italian, $\mathtt{Italian} \prec_{\mathtt{cuisine}} \mathtt{French}$.

For a given criterion $i \in \mathcal{C}$, for a given value $v \in C_i$, the agent computes its *satisfaction* $\mathtt{sat}_{\mathtt{self}}(v \prec_i)$ for this value as the number of values it prefers less in the partial order $\prec_i$, normalized in [0,1]:

$$\mathtt{sat}_{\mathtt{self}}(v, \prec_i) = 1 - \left(\frac{|\{d : d \neq c \ \wedge \ (v \prec_i d)\}|}{(|C_i| - 1)} \right) \tag{1}$$

This notion of satisfaction is generalized to any option $o = (v_1, \ldots, v_n) \in \mathcal{O}$ as a simple average[1]:

$$\mathtt{sat}_{\mathtt{self}}(o, \prec) = \frac{\sum_{i=1}^{n} \mathtt{sat}_{\mathtt{self}}(v_i, \prec_i)}{} \tag{2}$$

NS: I would remove $\prec$ from the left part here. I would replace $\prec_i$ by i above... Lydia disagrees :)

3.3 Dialogue model

Negotiators communicate during the negotiation via utterances. Each utterance type has a specific set of arguments and is associated with a specific expression in natural language (NL). We use five utterance types, based on the work of Sidner [23] and two additional utterances to close the negotiation. Table1 summarizes these utterances types.

Each utterance takes as parameter either a criterion value $v \in C_i$, an option $o \in \mathcal{O}$ or a criterion type $i \in \mathcal{C}$. These utterances allow the agent to ask information about the preferences of its partner (AskValue/AskCriterion) or give information about its own preferences (StateValue). The agent expresses its preferences by naming what it does or not like (*i.e I like Chinese restaurants* or *I don't like French restaurants*), based from the format observed in real dialogues of negotiation about preferences. In addition, it can propose, accept and reject both values of criteria ("Let's go to a Chinese restaurant") or options ("Let's go to *Chez Francis*"). The value /v/ in table1 refers to the natural language format to express a value. Examples of dialogues for restaurants are given in section 4.

The rules of utterance selection are described in section 3.4. For utterance selection, the agent keeps track of statements and proposals in the dialogue. For

[1] There exists a great amount of literature in theoretic decision making on how to combine multiple criteria using Order Weight Averages or Choquet's integrals, for instance. We are not concerned by this question of criteria aggregation in this paper.

Utterance type	**NL generation**	**Postcondition**
StateValue(v)	I (don't) like /v/.	Speaker : $v \in S_i$ Hearer: $v \in A_i$ is likable, $v \in U_i$ otherwise
AskValue(v) AskCriterion(i)	Do you like /v/ ? What kind of /i/ do you like ?	None
ProposeOption(o) ProposeValue(v)	Let's go to /o/. Let's go to a /v/.	$o \in P$ $v \in P_i$
AcceptOption(o) AcceptValue(v)	Okay, let's go to /o/. Okay, let's go to a /v/.	$o \in T$ $v \in T_i$
RejectOption(o) RejectValue(v)	I'd rather choose something else. I'd rather choose something else.	$o \in R$ $v \in R_i$
NegotiationSuccess	We reached an agreement.	None
NegotiationFalure	Sorry, but I no longer want to discuss this.	

Table 1: The list of utterance types in the model of dialogue

each criterion $i \in \mathcal{C}$, we build the set $S_i \subseteq C_i$ of statements that the agent has made about this criterion. This avoids re-statements of previous information. We also have the sets $A_i \subseteq C_i$ and $U_i \subseteq C_i$ of values which have been stated by the partner as liked or not (using a *StateValue* utterance type). We assume that $A_i \cap U_i = \emptyset$.

We also maintain the sets $P_i \subseteq C_i$, $T_i \subseteq C_i$ and $R_i \subseteq C_i$ of all proposed, accepted and rejected values for each criteria. These will be used to make relevant proposals. Similarly, we consider $P \subseteq \mathcal{O}$, $T \subseteq \mathcal{O}$ and $R \subseteq \mathcal{O}$ the sets of all proposed, accepted and rejected options in the dialogue. These sets A_i, U_iserve as a model of partner's likes that evolves during the negotiation.

Satisfiability From these, we can compute the satisfiability of a value $v \in C_i$ for the other (partner) as:

$$sat_{other}(v, A_i, U_i) = \begin{cases} 1 & \text{if } c \in A_i \\ 0 & \text{if } c \in U_i \\ 0.5 & \text{otherwise} \end{cases} \tag{3}$$

Some values might remain unknown that we define as being potentially satisfiable. Therefore we attribute them an arbitrary value fixed to 0.5. This function is generalized to any option $o = (v_1, \ldots, v_n) \in O$ as a simple mean:

$$sat_{other}(o, A, U) = \frac{\sum_i^n sat_{other}(v_i, A_i, U_i)}{n} \tag{4}$$

3.4 Decision based on power in negotiation

In section 2.1, we identified three main principles related to the relation of power which affects negotiators strategies and behaviors. In this section, we present the computational theory implementing each principle.

We denote the agent's belief of its power $pow \in [0, 1]$. It is a constant for a given agent in a given relationship.

Level of demand and concession In collaborative negotiation, both participants reduce their level of demand in time because they want to reach an agreement. According to our first principle, concessions should be greater for low-power agents. To model this behavior, we use a *concession curve*, as illustrated on Figure 1. Let $\mathtt{self}(\mathtt{pow}, t)$ be a time varying value, following the concession curve:

$$\mathtt{self}(\mathtt{pow}, t) = \begin{cases} \mathtt{pow} & \text{if } (t \leqslant \tau) \\ \mathtt{max}(0, \mathtt{pow} - (\frac{\delta}{\mathtt{pow}} \cdot (t - \tau))) & \text{otherwise} \end{cases} \tag{5}$$

where is $t \geqslant 0$ is the number of open or rejected proposals, $\tau > 0$ is the minimum number of proposals before concession begins and $\delta > 0$ is a computational parameter of the concession slope. This value of $\mathtt{self}$ represents the weight an agent gives to its self satisfaction relative to the other.

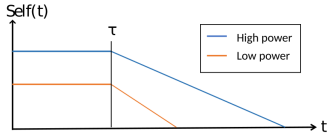

Fig. 1: Concession curve

The acceptability of a proposal of the dialogue $\nu \in C_i$ is defined as a boolean function:

$$\mathtt{acc}(\mathtt{pow}, \nu, t) = \mathtt{sat}_{\mathtt{self}}(\nu, \prec_i) \geqslant \beta \cdot \mathtt{self}(\mathtt{pow}, t). \tag{6}$$

with $\beta > 0$ a parameter of the theory that defines the level of demand in function of the relation of power.

This function is generalized to any option $o \in O$:

$$\mathtt{acc}(\mathtt{pow}, o, t) = \mathtt{sat}_{\mathtt{self}}(o, \prec) \geqslant \beta \cdot \mathtt{self}(t) \tag{7}$$

Self vs other According to our second principle, high-power negotiators give more weight to the satisfaction of their own preferences. To implement this principle in the context of collaborative negotiation, we compute how much a given proposal is *tolerable* considering the satisfiability for both the agent and its interlocutor. The value returned by $\mathtt{tol}$ is used to build proposals during the negotiation.

For a given criteria $i \in \mathcal{C}$, let $V_i \subseteq C_i$ be the subset of values that are acceptable for the agent:

$$V_i(t) = \{\nu \in C_i : \mathtt{acc}(\nu, t)\} \tag{8}$$

We compute the tolerability of a given value $\nu \in V_i$ at a time t knowing the preference order $\prec_i$ and the preference of the interlocutor:

$$\begin{aligned} \mathtt{tol}(\nu, t, \prec_i, A_i, U_i, \mathtt{pow}) = \mathtt{self}(\mathtt{pow}, t).\mathtt{sat}_{\mathtt{self}}(\nu, \prec_i) \\ + (1 - \mathtt{self}(\mathtt{pow}, t)).\mathtt{sat}_{\mathtt{other}}(\nu, A_i, U_i) \end{aligned} \tag{9}$$

And we generalize this function to any option $o = (\nu_1, \ldots, \nu_n) \in O$:

$$\mathtt{tol}(o, t, \prec, A, U, \mathtt{pow}) = \frac{\sum_i^n \mathtt{tol}(\nu_i, t, \prec_i, A_i, U_i, \mathtt{pow})}{n} \tag{10}$$

	Line nb	**Utterance type**	**Condition**
$\mathbf{pow} > \pi$	1	NegotiationSuccess	$\exists o \in T \cup P,\ acc(pow, o, t)$
	2	NegotiationFailure	$\forall o \in \mathcal{O}, \neg acc(pow, o, t)$
	3	StateValue(v)	$type(u^{-1}) = AskPreference \wedge n < \alpha$ where n is the number of successive statement moves
	4	AcceptValue(v)+ ProposeValue(c)	$\exists v \in P_i \ / \ acc(pow, v, t) \wedge \exists i \in \mathcal{C}, acc(pow, c, t)$
	5	AcceptValue(v)+ ProposeOption(o)	$\exists v \in P_i \ / \ acc(pow, v, t) \wedge \exists o \in \mathcal{O} / \ v \in o \wedge acc(pow, o, t)$
	6	RejectValue(v)+ ProposeValue(c)	$\exists v \in P_i \ / \ \neg acc(pow, v, t) \wedge \exists i \in \mathcal{C}, acc(pow, c, t)$
	7	RejectValue(v)+ ProposeOption(o)	$\exists v \in P_i \ / \ \neg acc(pow, v, t) \wedge \exists o \in \mathcal{O} / \ acc(pow, o, t)$
	8	RejectOption(o_1)+ ProposeOption(o_2)	$\exists o_1 \in P \ / \ \neg acc(pow, o_1, t) \wedge \exists o_2 \in \mathcal{O}, acc(pow, o_2, t)$
	9	ProposeValue(v)	$\exists v \in C_i \ / \ tol(v, t, \prec_i, A_i, U_i, pow)$
	10	ProposeOption(o)	$\exists o \in \mathcal{O} \ / \ tol(o, t, \prec_i, A_i, U_i, pow)$
$\mathbf{pow} \leqslant \pi$	11	Negotiation success	$\exists o \in T$
	12	AcceptValue(v)	$\exists i \in \mathcal{C}, \exists v \in P_i, acc(pow, v, t)$
	13	AcceptOption(o)	$\exists o \in P, acc(pow, o, t)$
	14	RejectValue(v)+ StateValue(v)	$t < \tau \wedge (\exists i \in \mathcal{C}, \exists v \in P_i, \neg acc(pow, v, t))$.
	15	RejectOption(o)+ StateValue(v)	$t < \tau \wedge (\exists o \in P, \neg acc(pow, o, t) \wedge \exists v \in o, \neg acc(pow, v, t))$.
	16	ProposeValue(v)	$\exists i \in \mathcal{C}, \exists v \in C_i, v \in A_i \wedge acc(pow, v, t)$
	17	ProposeOption(o)	$\forall i \in \mathcal{C}, \exists v \in C_i, v \in T_i \wedge v \in o$
	18	AskValue(v)	$t > \tau \wedge \exists i \in \mathcal{C}, \exists c \in P_i, \neg acc(c, t)$
	19	AskCriterion(i)	$\exists i \in \mathcal{C}, A_i \cup U_i = \emptyset$
	20	StateValue(v)	$\exists i \in \mathcal{C}, C_i \cap S_i \neq \emptyset$
	21	ProposeValue(v)	$\exists v \in C_i \ / \ tol(v, t, \prec_i, A_i, U_i, pow)$
	22	ProposeOption(o)	$\exists o \in \mathcal{O} \ / \ tol(o, t, \prec_i, A_i, U_i, pow)$

Table 2: Selection of utterance types

Lead of the negotiation According to our third principle, high-power negotiators tend to lead the negotiation. We implemented this principle through the choice of utterance types described on table 2. An agent can express more than one utterance in a single turn. A high-power agent will focus on keeping the negotiation going by choosing *negotiation moves* (ProposeValue /ProposeOption, RejectValue /RejectOption, AcceptValue/ AcceptOption). On the contrary, a lower power negotiator will focus on building an accurate model of other preferences in order to take the fairest decision. It will focus more on *statement moves* (StateValue or AskValue/ AskCriterion).

We define a threshold π to split the spectrum of power in two. We describe on table 2 the rules for utterance selection. Depending on the power, the previous utterance u^{-1} type and the current dialogue state, the agent will select the first utterance type for which the condition is satisfied. For instance, a high-power agent will stop the negotiation as soon as all the remaining options are unacceptable (line 2). A low-power agent will reject and state a preference, so as to explain why the proposal is not acceptable (line 14). If there is no open proposal, the low-power agent will ask for new information (line 18 -19).

4 Evaluation

In order to validate our model, we conducted a perceptual study in which participants have to determine the behaviors of two agents generated using our model. We have implemented the model in Java with the DISCO platform [22] and we generated synthetic dialogues between two artificial agents with different values of power and preferences.

4.1 Study design

We simulate a collaborative negotiation for choosing a restaurant. We built a set of four criteria (cuisine, ambiance, price and location) for a total of 420 options. An example of dialogue is given in figure 2. The following parameter values were used in our simulation: $\tau = 2$, $\pi = 0.5$, $\alpha = 2$, $\beta = 1$ and $\delta = 0.1$. We generated three preferences sets and we measured the difference between the preference sets using Kendall's distance [3]. We manipulated two simulation parameters: the power of both agents (named *pow-a* and *pow-b*) and the preference sets. This later affects the generation of dialogues in term of values and lengtht. Table 3 summarizes the 4 experimental conditions that results from this combination. Note that we only consider one configuration of social power for the similar preference sets condition, because the resulting dialogues are very similar. The first speaker (Speaker A) is always the high-power agent, as stated by our principle 3 on leading the dialogue.

Our goal is to show these dialogues to human observers so as to evaluate how the relation pf power is perceived in the different dialogues.

Preferences	**pow-a**	**pow-b**	**Label**
Different preferences (Kendall's tau = 0.96)	0.9	0.4	Dialogue 1
	0.7	0.4	Dialogue 2
	0.7	0.2	Dialogue 3
Similar preferences (Kendall's tau = 0.46)	0.7	0.4	Dialogue 4

Table 3: Initial condition's setting for generating dialogues

4.2 Hypotheses

Based on our three principles and the literature in on the perception of social power in negotiation, we investigated four hypotheses:

- **H1:** The high-power speaker will more strongly be perceived as self-centered than the lower power speaker.
- **H2:** The low-power speaker will be more strongly perceived as making larger concessions than the higher-power speaker.
- **H3:** The high-power speaker will more strongly be perceived as having a higher level of demand than to the low-power speaker.
- **H4:** The high-power speaker will more strongly be perceived as taking the lead in the negotiation than the low-power speaker.

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A: "Let's go to a Chinese restaurant."
  B: "I don't like Chinese restaurants, let's choose something else."
A: "Let's go to a cheap restaurant."
  B: "Do you like expensive restaurants?"
A: "I don't like expensive restaurants."
(...)
  B: "What kind of atmosphere do you like?"
A: "Let's go to a cheap restaurant."
  B: "Okay, let's go to a cheap restaurant."
A: "Let's go to Sap. It's a quiet, cheap Japanese restaurant on the south side."
  B: "Okay, let's go to Sap.
```

Fig. 2: Excerpt of Dialogue 2.

4.3 Experimental Procedure

We conducted a between-subject study using the online crowdsoursing website *CrowdFlower*[2]. Each participant was shown only one dialogue. Agents were described as two friends trying to find a restaurant where to have dinner. Participants were invited to read the assigned dialogue and answer a questionnaire.

We defined two questions for each hypothesis. Two sanity-check questions were added. Each one of these questions was to be answered on a 5 points Likert scale ranging from "I totally disagree" to "I totally agree".

Hypothesis	question 1	question 2
H1	Speaker (A/B) is self-centered.	Speaker (A/B) takes his friend's preferences into account in the choice of the restaurant.
H2	Speaker (A/B) makes concessions in the negotiation.	Speaker (A/B) gives up his position in the negotiation
H3	Speaker (A/B) is demanding	Speaker (A/B) presses his position in the negotiation.
H4	Speaker (A/B) takes the lead in the negotiation.	Speaker (A/B) takes the initiative in the negotiation

Table 4: List of questions asked for the questionnaire

A total of 120 native English subjects participated to the experiment (30 for each condition). Each subject received *25 cents* and we excluded 15 participants after sanity check.

4.4 Results and discussion

Table 5 summarizes the results of our study, which strongly support all of our four hypotheses: in each dialogue, the high-power agent and the low-power agent were clearly distinguished on all aspects. We first computed the correlation for each pair of questions (the average correlation is at .5 for all pairs of questions in all dialogues). This permits us to use the data to compare the speakers behavior on each dialogue. Since our data are not normally distributed, we used a non parametric Wilcoxon signed-rank test for paired data. The high-power

[2] https://www.crowdflower.com/

		Dialogue1		Dialogue2		Dialogue3		Dialogue4	
		SpeakerA	SpeakerB	SpeakerA	SpeakerB	SpeakerA	SpeakerB	SpeakerA	SpeakerB
H1	*Mean* ± *SD*	3.9 ± 1.1	2.2± 0.9	3.6 ±0.9	2.2 ±0.8	2.8 ±1.1	2.13± 0.7	3.4 ± 1	2 ±0.9
	p-value	<< 0.01		<< 0.01		< 0.01		<< 0.01	
H2	*Mean* ± *SD*	2.2 ± 1.1	4.3± 0.8	2.5 ±1.2	3.8 ±1.04	2.7 ±1.2	3.6± 0.8	2.3 ± 1	3.2 ±1.2
	p-value	<< 0.01		<< 0.01		= 0.01		<< 0.01	
H3	*Mean* ± *SD*	4.1 ± 0.8	2.6± 1.1	4.03 ± 0.8	2.7 ±0.9	3.5 ±1.1	2.3± 1	3.8 ± 1.8	1.8 ±0.8
	p-value	<< 0.01		<< 0.01		< 0.01		<< 0.01	
H4	*Mean* ± *SD*	4.2 ± 0.9	2.3± 1.1	3.8 ±0.9	2.6 ±1.07	3.8 ±0.9	2.8± 1.1	4.5 ±0.5	1.9 ± 0.9
	p-value	<< 0.01		<< 0.01		< 0.05		<< 0.01	

Table 5: Summary of the obtained results for each hypothesis

speaker was correctly perceived as more self-centered (**H1**), making less concessions (**H2**), having a higher level of demand (**H3**) and leading the negotiation (**H4**).

Interpersonal nature of power Finally, we made a post-study analysis by comparing the participant's judgments on the behaviors of Speaker A across different dialogues. Our hypothesis was that a greater difference in power would lead to a better perception of behaviors related to power. We computed the differences between the evaluations of Speakers A and B in Dialogue 1 and Dialogue 2 (pow-b remains unchanged at 0.4 whereas pow-a changes from 0.7 to 0.9). We did not obtain significant results, however, a tendency was observed ($p \simeq 0.1$) for self-centeredness, concessions and the lead of dialogue was clearly better perceived ($p = 0.043$). This lack of result might be explained by the interpersonal nature of power, which means that participants rate the power of Speaker A as opposed to the behavior of Speaker B, which makes the comparison of agents behaviors from different dialogues partly irrelevant.

Limitations In this present experiment, we studied the perception of all the principles related to power simultaneously. One of the limits of this study concerns the fact that we did not investigate the perception of each principle individually. However, due to the fact that the principles are interdependent, an independent evaluation would be difficult. (MAL DIT)

4.5 Conclusion

Our research aims to model a conversational agent which is able to deploy different strategies of negotiation depending on its representation of social power. Based on research in social psychology, we defined three principles of behaviors related to power in collaborative negotiation. We proposed a model of utterance selection based on modeling of preferences and the implementation of these principles. We showed that the behaviors related to social power are correctly perceived in the resulting dialogues. Our findings validate our model of dialogue in general and specifically confirmed the coherence of the generated behaviors of power.

Our next study will focus on using this model in a human-agent interaction. It was proven by [18] that having a model of the other impacts the negotiation strategy and improves the outcomes. Therefore, we aim to use our dialogue model to build a representation of the interlocutor's social power, following a theory of mind approach. We would like to show that an agent that adapts its own strategy to the perceived power of its interlocutor makes a better collaborative negotiator.

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