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. We evaluated our model by showing that these principles are correctly perceived by human observers; the social behavior of the agent is made visible through its dialogue strategy.

1 Introduction

With the rise in popularity of artificial conversational agents, they became capable to hold a conversation with a human user and potentially collaborate with the user in order to achieve a common objective. For example, artificial tutors collaborate with students [16], or companion agents can help elderly to follow a specific diet [18]. In this context, the user(s) and the agent have to negotiate in collaborative manner about the way to achieve the common task. This is called *collaborative negotiation*. Unlike adversarial negotiation [26], collaborative negotiation assumes that each participant is driven by the goal of finding a trade-off that best satisfies the interests of all the participants as a group, instead of one that maximizes his own interest[24, 7].

Moreover, previous research has shown that people tend to respond to computers as social actors [3]. This led the IVA community to study the psychosocial relationship between the user and the agent during their interaction: a growing

body of research is investigating the use of appropriate social behavior for virtual agents in different roles and types of user-computer relationship [2, 3, 18]. In the context of human-human communication involving negotiation, social psychology and communication [11, 9] investigated the impact of social relations and emotion on the negotiation. They ~~proved~~ showed that *interpersonal power* directly affects the strategies of negotiators. Therefore, in order to build intelligent conversational agents that conduct good collaborative negotiations, it is very important to allow them to adapt their negotiation strategies to different levels of interpersonal power. Existing works on IVA [26, 10] investigated the impact of social affects in the context of adversarial negotiation. We consider the case of collaborative one-to-one dialogue.

In this paper, we present a ~~model of~~ conversational agent that ~~can~~ deploys different strategies of negotiation based on the social power it wants to express ~~for the user~~. In the next section, we discuss existing works on interpersonal power in the domain of social psychology and affective computing. Section 3 presents the negotiation ~~model~~, based on a set of utterance types and a model of preferences. It implements three principles of collaborative negotiation from the literature in social psychology. In section 4, we present an experiment conducted with two virtual agents ~~and we~~ show that these principles are correctly perceived by ~~a~~ human observers.

2 Related works

The notion of social power has been widely studied in the fields of interpersonal communication and psychology [17]. It can be defined as the capacity to produce intended effects and ability to influence the behavior of other person in the conversation [11]. 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, making quick decisions, ~~etc.~~ Negative contributions include not considering the partner (*e.g.* not giving the occasion to express his opinion), appearing offensive, ~~etc.~~ In our work, we focus on negotiation dialogues, ~~for~~ which several researchers already ~~proved~~ the impact of power[8, 5].

2.1 Behaviors of power in dialogue

During a conversation, 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) [5]. Based on this work, several IVA have been developed with the ability to exhibit social power through nonverbal behavior, such as gaze [20], body movements [22] or head tilt [14, 6] in relation to high-power and low-power perception. Similarly, [25] investigated the perception of nonverbal behaviors of virtual agents with a focus on power and cooperation.

Verbal behaviors of power in the dialogue are related to the type of *strategies* that individuals choose in order to take control ~~of the other~~ especially during a negotiation. A considerable body of research has documented the effects of power on negotiation behaviors and outcomes. De Dreu demonstrated that [9] high-power negotiators have higher aspirations, demands more and concede less. Galinsky [13] affirms that power increases the action orientation: high-power negotiators control the flow of the negotiation. In addition, high power increases task orientation and goal-directed behavior. [15] 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 [8]. Less-power negotiators have a stronger desire to develop an

accurate understanding of their negotiation partner, which would lead them to ask more *diagnostic* rather than *leading* questions.

It was also shown that high-power negotiators are self-centered and tend to not pay attention to the preferences of the less powerful negotiators [12, 9].

In our work, we use a text-oriented dialogue system and we therefore focus on the verbal behaviors. Our goal is to make visible *the strategies* deployed during the negotiation depending on the power. In order to implement these different behaviors, we extracted three principle related to the relation of power that impact strategies of negotiation:

1. **Representation of demands:** High-power negotiators show a higher level of demand than the low-powerful ones. In addition, low-power negotiator's demand decrease over time, and tends to make larger concessions than high-power negotiators. [9]
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. [12, 9]
3. **Control the flow of the negotiation:** High-power negotiators tend to make the first move [21]. In addition, they take the lead of the negotiation. Otherwise, low-power negotiators aim to construct an accurate model of other preferences, which lead them to ask more questions about other preferences rather than keeping the negotiation going (makes proposals)[8].

Only few models consider the expression of power in the verbal behavior of an IVA. [1] developed an agent that expresses social power through gaze and linguistic features. They demonstrated that the linguistic personality traits influence the perception of power. However, this work does not consider the how power affects the strategies of negotiation in dialogue. More recently, [26, 10] 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. Moreover, it considers only adversarial negotiation.

3 Model of negotiation based on ~~the relation of~~ power

In this section, we present our model of dialogue of negotiation of preferences. 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 ~~(see 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 n criteria and let $C_1, \ldots, C_n$ 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 $(v_1, \ldots, v_n) \in \mathcal{O}$. For instance, in a dialogue about restaurants, ~~for which~~ the criteria ~~would~~ be the type of cuisine and the price, ~~we could have the~~ option ~~"Chez Francis" that is an expensive French restaurant.~~ (French, expensive).

3.2 Preference model

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

For a given value $v \in C_i$, the agent computes ~~the~~ *satisfaction* sat_{self} ~~it has~~ for this value as the number of ~~ancestors~~ in the ~~preference~~ order $\prec_i$, normalized in [0,1]:

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

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

$$sat_{self}(v, \prec_i) = 1 - \left(\frac{|\{d : d \neq c \ \wedge \ (v \prec_i d)\}|}{(|C_i| - 1)} \right) \quad (1)$$

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

$$sat_{self}(o, \prec) = \frac{\sum_i^n sat_{self}(v_i, \prec_i)}{n} \quad (2)$$

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 ~~format~~. We ~~defined~~ five utterance types, based on the work of Sidner [?]. The utterances take as parameter either a value of criterion $v \in C_i$, 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 ~~interlocutor~~ (AskValue/AskCriterion) or give information about its own preferences (StateValue). The agent expresses its preferences by naming what it does or not like, based from the format observed in real dialogues

[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.

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/ refers to the natural language format to express a value. For example, in dialogue about restaurants, /Chinese/ means *Chinese restaurants*. Examples of dialogues are given in section 4.

The rules of utterance selection are described in section 3.4. For the utterance selection, the agent keeps track of statements and proposals all along the dialogue. For 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 and U_i of values which have been stated by the interlocutor as satisfiable or not (using a *State Value* utterance type). We assume that $A_i \cap U_i = \emptyset$ and $A_i \cup U_i \subseteq C_i$. Some values can still be unknown that we define as being potentially satisfiable for other. These sets serve as a model of the interlocutor's preferences that evolves during the negotiation. From these, we can compute the satisfiability of a value $v \in C_i$ for the other as:

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

We choose 0.5 as an arbitrary value to define the unknown values. This function is generalized to any option $o = (v_1, \ldots, v_n) \in O$ as an average:

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

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 $\mathsf{P} \subseteq \mathcal{O}$, $\mathsf{T} \subseteq \mathcal{O}$ and $\mathsf{R} \subseteq \mathcal{O}$ the sets of all proposed, accepted and rejected options in the dialogue.

3.4 Decision based on power in negotiation

Based from research from social psychology, we defined three mains principles related to the relation of power which affects negotiators strategies and behaviors (see section 2.1). We present in this section, the computational theory implementing each principle.

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

Level of demand and concessions 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 higher for low-power agents. To implement this mechanism, we use a *concession curve*, as illustrated on figure 1.

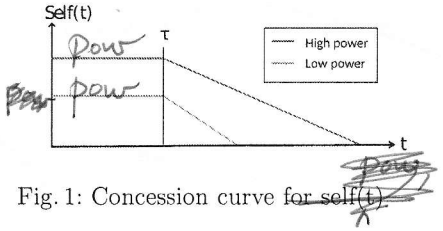

Fig. 1: Concession curve for self(t)

This mechanism is defined as follows. Let $\mathtt{self}(\mathtt{pow}, \mathrm{t})$ be a time varying value, following the concession curve:

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

where is $\mathrm{t} \geqslant 0$ 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. are parameters of the theory. This value of

self represents the weight an agent gives to its self satisfaction relative to the ~~other.~~

The acceptability of a value $v \in C_i$ is defined as a boolean function:

$$acc(pow, v, t) = sat_{self}(v, \prec_i) \geqslant \left(\beta \cdot self(pow, t)\right) \tag{6}$$

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 $o \in O$:

$$acc(pow, o, t) = sat_{self}(o, \prec) \geqslant \left(\beta \cdot self(t)\right) \tag{7}$$

Self vs other According to our second principle, high-power negotiators give more weight to their 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.~~

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:

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

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

$$\begin{aligned} tol(v, t, \prec_i, A_i, U_i, pow) = {} & self(pow, t).sat_{self}(v, \prec_i) \\ & + (1 - self(pow, t)).sat_{other}(v, A_i, U_i) \end{aligned} \tag{9}$$

And we generalize this function to any option $o = (v_1, \ldots, v_n) \in O$:

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

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. 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 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). In addition, we allow the agent to express to two utterance in one turn in order to explicit the desired behaviors.

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 [23] and we generated synthetic dialogues between two artificial agents with different values of power and preferences.

	Type	Utterance type	Condition
pow > π	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)	$\exists o \in \mathcal{O}\ /\ tol(o, t, \prec_i, A_i, U_i, pow)$
pow ≤ π	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

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. 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 [4]. 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. An example dialogue is given on figure 2. 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

```
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.

4.2 Hypotheses

Based on our three principles and the literature 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.

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. Each subject received *25 cents* and we excluded 15 participants after sanity check.

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

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 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**).

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.

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.

		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

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 [19] 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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