Designing Persuasive Robots: How Robots Might Persuade People Using Vocal and Nonverbal Cues

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ABSTRACT

Social robots have to potential to serve as personal, organizational, and public assistants as, for instance, diet coaches, teacher's aides, and emergency respondents. The success of these robots—whether in motivating users to adhere to a diet regimen or in encouraging them to follow evacuation procedures in the case of a fire—will rely largely on their ability to *persuade* people. Research in a range of areas from political communication to education suggest that the nonverbal behaviors of a human speaker play a key role in the persuasiveness of the speaker's message and the listeners' compliance with it. In this paper, we explore how a robot might effectively use these behaviors, particularly vocal and bodily cues, to persuade users. In an experiment with 32 participants, we evaluate how manipulations in a robot's use of nonverbal cues affected participants' perceptions of the robot's persuasiveness and their compliance with the robot's suggestions across four conditions: (1) no vocal or bodily cues, (2) vocal cues only, (3) bodily cues only, and (4) vocal and bodily cues. The results showed that participants complied with the robot's suggestions significantly more when it used nonverbal cues than they did when it did not use these cues and that bodily cues were more effective in persuading participants than vocal cues were. Our model of persuasive nonverbal cues and experimental results have direct implications for the design of persuasive behaviors for humanlike robots.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User/Machine Systems – *human factors, software psychology*; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *evaluation/methodology, user-centered design*

General Terms

Design, Human Factors

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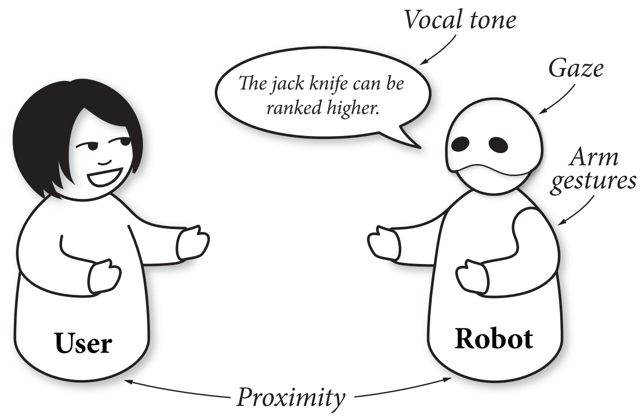

Figure 1: The vocal and bodily cues of persuasion in human-robot interaction.

Keywords

Persuasion, compliance, nonverbal immediacy, nonverbal cues, gaze, gestures, proximity, vocal tone

1. INTRODUCTION

Robots hold great promise as social actors that may positively affect and improve people's motivation and compliance in such areas as education [13], health [31], and well-being [29]. The success of these robots in motivating people will rely largely on their ability to *persuade*. But how could robots persuade people? And how can we design persuasive robots?

Research in human communication has identified a number of behavioral attributes that shape individuals' *nonverbal immediacy*—the degree of perceived bodily and psychological closeness between people—and suggested that individuals' nonverbal immediacy plays a key role in persuading others [35]. These attributes include primarily nonverbal behaviors, particularly *bodily* cues such as proximity, gaze, gestures, posture, facial expressions, touching and *vocal* cues such as vocal tone and expressions [43]. While a considerable amount of research in robotics has explored the role of nonverbal cues in human-robot interaction (e.g., [47, 5, 25]), the way in which these cues might shape the persuasive ability of a robot has not yet been studied.

A few studies in human-robot interaction have explored how robots might be designed as persuasive agents [48, 37]. While existing work highlights the importance of persuasion in human-robot interaction and provides some guidelines for robot design, how behavioral attributes of a robot might improve the robot's persuasiveness and to engender behavior changes in people has not yet ben studied. In this paper, we explore how manipulations in *bodily* cues, particularly proximity, gaze, and gestures, and *vocal* cues, specifically vocal tone and expressions, affect the persuasiveness of a humanlike robot. We designed a set of nonverbal behaviors for a humanlike robot and evaluated the effects of manipulations in these behaviors on people's perceptions of the robot's persuasiveness and their compliance with the robot in a human-robot interaction scenario (Figure 1).

In the next section, we review related work on persuasion and nonverbal behavior in human communication, related research on designing persuasive computer interfaces in human-computer interaction literature, and work to date in human-robot interaction on designing persuasive robots.

2. BACKGROUND

Persuasion, defined as "an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object, or action" [14, 15], is a key social process that enables cooperation, social influence, and attitude changes [42, 53]. An individual's persuasive ability is associated with a number of factors including the verbal and nonverbal behaviors of the individual, the dynamics of social interaction, and psychological and societal factors such as personality and social roles [46, 14, 15, 40].

Research in nonverbal communication has identified a number of nonverbal cues that shape *nonverbal immediacy*—the degree of perceived bodily and psychological closeness between people—and suggests that individuals' nonverbal immediacy is closely associated with their persuasive ability, likability, and attractiveness [35]. These cues include *bodily* behaviors such as proximity, gaze, gestures, posture, facial expressions, and touching as well as *vocal* behaviors such as vocal tone and expressions [43]. Table 1 lists the nonverbal cues that education researchers have identified as key behaviors displayed by teachers with high immediacy in the classroom.

Behavioral cues	Cue affordances
Bodily cues	***Body***
Sits behind desk when teaching. (Reversed)	*Proximity*
Moves around the classroom when teaching.	*Proximity*
Sits on a desk or in a chair when teaching. (Reversed)	*Proximity*
Stands behind podium or desk when talking to the class. (Reversed)	*Proximity*
Gestures when talking to the class.	*Gestures*
Looks at the class when talking.	*Gaze*
Looks at board or notes when talking to the class. (Reversed)	*Gaze*
Has a very tense body position when talking to the class. (Reversed)	*Posture*
Has a very relaxed body position when talking to the class.	*Posture*
Smiles at individual students in the class.	*Facial Expressions*
Smiles at the class as a whole, not just individual students.	*Facial Expressions*
Touches students in the class.	*Touching*
Vocal cues	***Voice***
Uses monotone/dull voice when talking to the class. (Reversed)	*Vocal Tone*
Uses a variety of vocal expressions when talking to the class.	*Vocal Expressions*

Table 1: The bodily and vocal cues identified in educational settings to evaluate the effectiveness of teacher nonverbal behavior (adapted from [43]).

Research results show that nonverbal immediacy and individual nonverbal cues such as gaze and proximity affect persuasion, particularly how much individuals comply with arguments and ideas presented by a speaker [8]. Mehrabian [35] argued that people's perceptions of an individual is shaped 7% by verbal cues (what the individual says), 38% by the tone of their voice, and 55% by their bodily cues, highlighting the role of nonverbal cues in how people evaluate others in social settings. In the context of public presentations, the amount of eye contact that the speaker maintains with the audience affects the persuasiveness of the speaker's message [9] and how much the audience complies with the speaker's message [6]. The proximity of a individual also affects people's compliance with requests made by the individual; closer proximity leads to higher compliance [16]. How much an individual mimics the nonverbal behaviors of others also affects their liking of the individual [10] and their perceptions of the individual's persuasiveness [50].

The persuasive effects of nonverbal immediacy have been studied extensively in research in educational psychology. These studies show that teacher nonverbal immediacy has a positive effect on the teacher's communicative effectiveness [1, 4] and perceived competence, caring, and trustworthiness [52]. Nonverbal immediacy also has positive effects on student motivation [11, 12], participation and attendance [44], and affective and cognitive learning [19]. These positive effects prevail across cultures [41], in large classes [36], and under high workload demands [39].

Research in human-computer interaction (HCI) has explored how principles of persuasion might be used to design computer interfaces that engender constructive changes in domains such as health, safety, education, and public policy [14, 15, 38]. Studies in this area have shown that computer interfaces that draw on the persuasive effects of nonverbal cues improve the likability [3] and persuasiveness of the interface [3, 2, 20, 38]. Users also perceive computer agents that display high behavioral realism to be more influential [20]. In immersive virtual environments (IVEs), avatars that maintain increased eye contact with people are perceived by users to be more persuasive [2].

Robotics researchers have developed a number of applications that draw on social behavior to deliver positive benefits in health management [31], weight loss [29], education [13], and energy conservation [37]. Recent studies have explored how robots might serve as persuasive agents, focusing particularly on the role of perceived robot gender in shaping the persuasiveness of a robot [48]. While this study highlights the importance of persuasion in human-robot interaction and provides some guidelines on how robot design might shape its persuasiveness, how behavioral attributes of the robot might shape the persuasiveness of a robot and affect user compliance are unknown.

In this paper, we explore how manipulations in *bodily* cues, particularly proximity, gaze, and gestures, and *vocal* cues, particularly vocal tone and expressions, affect the persuasiveness of a humanlike robot. The paragraphs below describe the hypotheses we have developed based on findings from research in human communication.

2.1 Hypotheses

Drawing on findings from human communication research, we developed the three hypotheses below on how nonverbal behavior, particularly the *bodily* and *vocal* cues of a robot, might affect the persuasiveness of a robot.

Hypothesis 1: Participants' perceptions of the persuasiveness of the robot and compliance with the robot's suggestions will be higher when the robot displays nonverbal cues (verbal and/or bodily cues) than when it does not display nonverbal cues to communicate with the participant. This hypothesis builds on research that suggests that nonverbal behavior facilitates persuasion in human interaction [40, 46].

Hypothesis 2: Participants' perceptions of the persuasiveness of the robot and compliance with the robot's suggestions will be higher when the robot displays only bodily cues than when it displays only vocal cues. This prediction follows argument that bodily cues might play a stronger role than vocal cues do in people's forming of impressions of others [35].

Hypothesis 3: Women's perceptions of the persuasiveness of the robot and compliance with the robot's suggestions will be higher than those of men in the presence of nonverbal cues. This hypothesis builds on the finding that women are more adept than men at reading nonverbal cues [24, 45].

3. METHOD

To test our hypotheses, we designed and conducted a laboratory experiment in which a humanlike robot sought to persuade participants performing the Desert Survival Task [30]. Below we describe our interaction design of the robot's nonverbal behaviors, the design of our experiment, the manipulations we created in the robot's behaviors, our measurements, and the participants of the experiment.

3.1 Design of the Robot's Behaviors

The design of the robot's nonverbal behaviors were guided by theories of human communication and empirical models derived from data collected from people in communication scenarios. We combined findings from research on nonverbal behavior (e.g., to identify what types of gestures should be designed into the robot) and data collected from a native English speaker performing the robot's utterances (e.g., to further identify the specific gestures that the robot should employ given the context of our experimental task) as bases for our design.

Gaze: [17] suggests that gaze cues communicate the social accessibility of an individual. Looking directly at a person indicates willingness to start a conversation with that person. Accordingly, we designed our robot's gaze behavior to look toward the participant when it spoke and to direct its gaze toward the computer screen when it referred to the Desert Survival items. According to Kendon [26], at the end of an utterance, speakers look toward their addressee, signaling that he/she has finished speaking and that the speaking floor is available for the other person. Accordingly, in our design, the robot looked toward the computer screen while referring to an item and moved its gaze back toward the participant at the end of its utterance.

Proximity: To identify the proximity cue that would contribute to achieving high nonverbal immediacy, we drew on the following classification of interpersonal space developed by Hall [23]:

* Intimate space – within *two* feet of the person.
* Personal space – between *two* and *four* feet of the person.
* Social space – between *four* and *twelve* feet of the person.
* Public space – between *twelve* and *twenty-five* feet of the person.

Research on the persuasive effects of proximity suggests that individuals' persuasive ability increases with closer proximity [16]. On the other hand, entering one's intimate space has the potential to evoke feelings of invasion and discomfort [49]. Therefore, in order to achieve the appropriate balance of increased persuasiveness and low discomfort, we designed our robot's proximity to vary across its partner's personal space boundary. The robot stood within the participant's personal space when it maintained a close proximity, while positioning itself beyond the personal space boundary and within the social space when it maintained a distant proximity.

Gestures: Research in nonverbal behavior suggests that people produce different types of gestures when they speak [34, 27, 28, 18] and that these gestures shape the persuasiveness of their speech [32]. While the literature in this area includes a large number of gesture categorizations and taxonomies, we have identified four types of gestures to be common across most such categorizations, (1) iconic, (2) metaphoric, (3) deictic, and (4) beat gestures, and integrated each type of gesture in the design of the robot's nonverbal behaviors. While the gesture literature helped us determine the types of gestures that the robot should employ, we identified the specific gestures that might accompany the robot's speech from an analysis of the data that we collected from the human performer. Figure 2 shows some of the gestures that the robot produced in alignment with its speech. Below we describe our implementation of each type of gesture into the robot in further detail.

Iconic Gestures: Iconic gestures are closely associated with the semantic content of speech, depicting a concrete event or object by creating a homology to aspects of the event or object. Our design of robot's iconic gestures involved identifying important gestures related to *quantifiers* and *action phrases* from the video data that we collected from the human performer and coding them into the robot. For action phrases, the robot depicted the actions in its speech using gestures. For instance, when the robot said "it would be best to drink the water as you become thirsty," it brought its right hand toward its face, depicting drinking water from a glass at the onset of the segment "drink the water." For quantifiers or comparative phrases, the robot illustrated the relative quantity of the event or object that he verbally described using gestures. For instance, when it said "the trench coat can be ranked higher" in the Desert Survival Task, it vertically raised its arms to above the level of its eyes to depict a "higher" quantity.

Metaphoric Gestures: Unlike iconic gestures, which represent concrete events or objects, metaphoric gestures depict abstract concepts such as knowledge or an idea. In human-to-human conversations, metaphoric gestures usually involve articulate fingers. A common example would be a ring hand, where the thumb and forefinger tips form a circle, to articulate PRECISE. In our design, the robot used one hand or both hands at the same time to form a gesture space containing the abstract ideas it described verbally. For instance, along with the utterance "Do you know that alcohol absorbs water?" the robot forms a gesture space containing the knowledge "alcohol absorbs water" by raising its hands in front of its chest with both hands facing to each other.

Deictic Gestures: Speakers use deictic gestures to direct attention toward concrete entities in the physical environment. These gestures are prototypically performed with

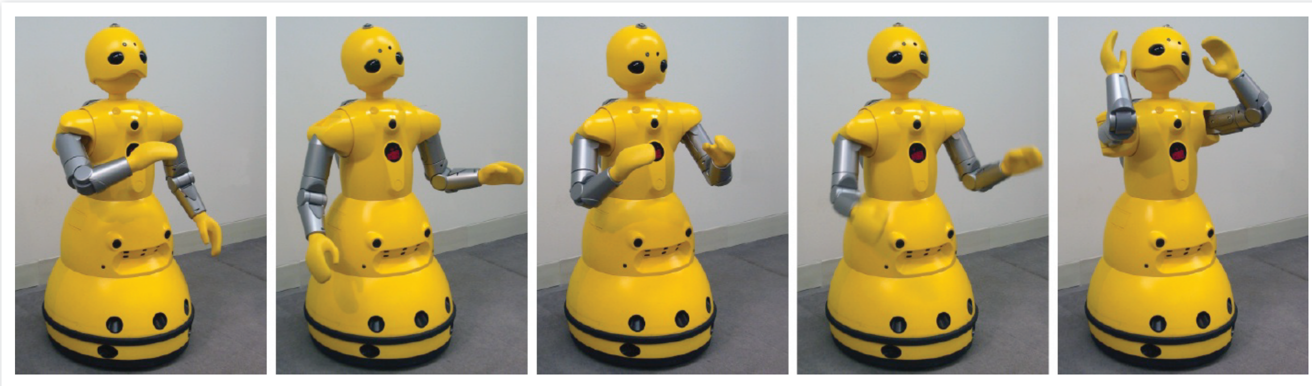

Figure 2: Examples of the gestures that we designed into the robot's nonverbal behavior: (a) *deictic gesture* while referring to itself, (b) *deictic gesture* while referring to the participant, (c) *metaphoric gesture* using both hands to form a gesture space containing an idea, (d) *beat gesture*, moving its arms rhythmically, and (e) *iconic gesture* depicting "higher."

the pointing finger, while pointing can also be involve an open palm or elbow. Our implementation of deictic gestures substituted finger pointing with hand pointing, because the design of our robotic platform does not involve articulate fingers. In our design, the robot used deictic gestures along with personal pronouns, pointing toward itself when it referred to itself, toward the participant when it referred to itself, and toward the environment when it referred to third parties. For example, it placed its right or left hand in front of its torso at the onset of the "I" in "I think the knife should be ranked higher" in the Task.

Beat Gestures: McNeill [34] describes beats as simple up-and-down movements that do not have discernible meanings, but are produced by speakers in conjunction with speech to maintain a rhythm and emphasize certain words or phrases. Our analysis of the video data showed that the speaker performed beat gestures in conjunction with explanations of complex or abstract ideas. In our design, the robot employed rhythmic up-and-down gestures when it explained complex ideas such as uttering "the body loses an enormous amount of water trying to process and remove the alcohol." However, it employed these gestures only it did not produce other forms of gestures.

Vocal Cues: Spoken language involves vocal cues that are used to distinguish lexical or grammatical meaning of words or phrases, add emphasis, and express emotion to verbal content. These cues are shaped by a number of parameters including vocal rate, pitch, and loudness that shape the expressivity of spoken language [7]. In our design, we manipulated vocal tone by varying the pitch of the robot's voice, as studies on the persuasive vocal tone is shown to affect compliance [8].

To implement the robot's speech and manipulate its vocal cues, we used the Festival text-to-speech system [51].

Condition	Vocal cues	Bodily cues	Proximity	Gaze	Gestures
1	No	No	*Outside personal space*	*Static*	*No*
2	No	Yes	*Within personal space*	*Dynamic*	*Yes*
3	Yes	No	*Outside personal space*	*Static*	*No*
4	Yes	Yes	*Within personal space*	*Dynamic*	*Yes*

Table 2: The four conditions of our experiment. We manipulated the robot's use of vocal and bodily cues.

We manipulated the vocal tone parameters of the synthesized speech, creating two versions of each utterance that are identical in verbal content but differ in intonation to be highly monotonic and highly expressive.

3.2 Experimental Design

We designed a two-by-two, between-participants study and created four conditions by manipulating the nonverbal cues that the robot employed: (1) no nonverbal cues, (2) vocal cues only, (3) bodily cues only, and (4) bodily and vocal cues. We measured how these manipulations affected participants' compliance with the robot's suggestions and their perceptions of the robot's persuasiveness.

The *vocal* cue manipulation involved changing the vocal tone and expressiveness that the robot used when it provided verbal suggestions to the participant. In the *no vocal cues* condition, the robot maintained a flat tone of voice for its entire speech, while the the *vocal cues* condition involved the robot varying its vocal tone at different points in its speech. These manipulations are described in more detail in the next subsection.

The second manipulation involved varying the robot's use of *bodily* cues, particularly proximity, gaze, and gestures. The proximity cue captured the bodily distance between the participant and the robot. We manipulated proximity to be either *within* or *outside* the personal space of the participant. We used a distance of two feet and four feet for the within and outside conditions respectively based on the classification developed by [22]. Gaze cues involved the direction in which the robot directed its head during speech and pauses. We manipulated the robot's gaze to be either *static* or *dynamic*. In the static condition, the robot looked straight ahead while talking to the participant, while in the dynamic gaze condition it divided its gaze between the participant and the computer screen, shifting its gaze at key points that were determined by its utterances. *Gestures* captured the robot's arm movements during speech. We manipulated whether gestures, particularly iconic, metaphoric, deictic, and beat gestures, accompanied the robot's speech, creating *gesture* and *no gesture* conditions. Table 2 lists the conditions in our experiment and the manipulation of the cues in each condition.

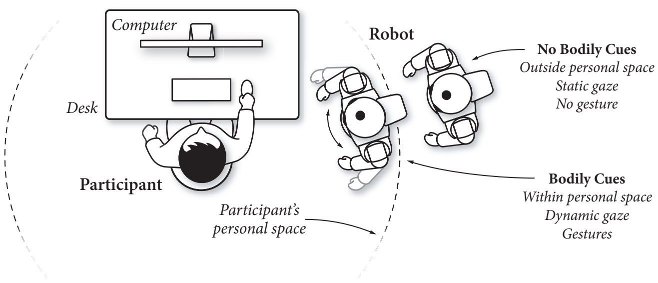

Figure 3: The spatial configuration of the robot and the participant. The robot gave suggestions while the participant was doing the task.

3.3 Experimental Task

We built on the Desert Survival Problem [30] to create a human-robot interaction scenario. In the prototypical task, participants imagine that they have crash-landed in the middle of a desert. They have items such as a torch, a jack knife, a bandage kit, a pair of sunglasses, and so on with them. Their task is to rank these items such that items that might increase their chances of survival receives a higher ranking. In the human-robot interaction scenario, the participants created an initial ranking of the items and the robot sought to persuade them to change their rankings of particular items. In each trial, the robot recommended that the participant rated the fourth-, sixth-, and ninth-ranked items higher, providing the rationale for each change. Participants were able to change their rankings once the robot provided its suggestions.

The robot's suggestions were identical across all conditions and the speaking time for the suggestions was approximately the same across items. The robot used the rankings that the participant provided through the computer interface to determine the appropriate suggestion and confirmations. The robot also followed common social interaction rituals such as greeting the participant at the beginning of the interaction and closing the interaction appropriately at the end of the experimental task. Figure 3 illustrates the spatial setup of the experimental task and the manipulations in the robot's bodily cues.

3.4 Experimental Procedure

Each trial of the experiment involved the following procedure. Participants were first given a brief description of the purpose and the procedure of the experiment. They were asked to review and sign a consent form after the brief introduction. Following their consent, they filled in a pre-experiment questionnaire that measured personality characteristics. The experimenter provided participants with more detail on the experimental task. Participants were brought into the experiment room and seated at a table with a computer. The robot greeted the participant and prompted the participant to start the experimental task. Following the end of the task, the participant left the room and filled in a post-experiment questionnaire on their perceptions of the robot, experience with the experiment, and basic demographic information.

The task and the entire experiment procedure in total took an average of 15 minutes and 25 minutes, respectively. The experiment was run in a dedicated space with controlled lighting and no outside distraction. Only the robot and the participant were present in the room during the experiment. The participants were paid $5 for their participation in the study.

3.5 Measurement

Our independent variables included whether the robot employed bodily cues, whether it employed vocal cues, and participant gender. The main dependent variables involved participants' perceptions of the robot's persuasiveness, their compliance with the robot's suggestions, and their perceptions of the robot's social and intellectual characteristics. We used both objective and subjective measurements to capture the dependent variables. Below we describe each measurement in detail.

Objective Measurements – Our measure of participants' compliance with the robot's suggestions involved the number of changes that the participants made in their rankings. This measure increased with changes in the direction of the robot's suggestions and decreased with changes against the robot's suggestions.

Subjective Measurements – We measured participants' perceptions of the robot and their experience with the task using a post-experiment questionnaire. The questionnaire included several items that measured their perceptions of the robot's persuasiveness, their perceptions of the robot's social and intellectual characteristics, their perceptions of the task, their affective state, and demographic information. Seven-point rating scales were used for all items. We conducted a factor analysis of all items that evaluated the robot to identify reliable scales and developed following three prominent factors that showed high reliability. The *Persuasiveness* scale involved three items: (1) persuasive, (2) helpful, and (3) relevant (Cronbach's $\alpha = 0.78$). *Intelligence* included two items: (1) knowledgable and (2) intelligent (Cronbach's $\alpha = 0.83$). The *Satisfaction* scale contained three items: (1) satisfied, (2) interesting, and (3) happy (Cronbach's $\alpha = 0.79$).

Research in persuasion suggests that personality traits affect persuasion; people with low levels of assertiveness are more easily persuaded [21]. In order to take the personality of the participant into account, we measured participants' assertiveness using a sub-scale of the International Personality Item Pool Interpersonal Circumplex (IPIP-IPC) [33]. The scale included four items: (1) "demand to be the center

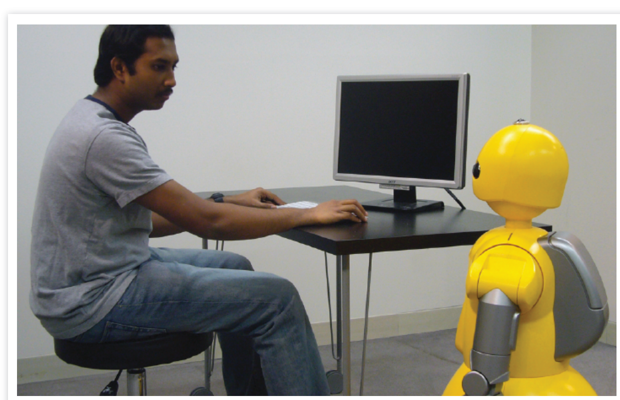

Figure 4: The experimenter demonstrating the experimental setup.

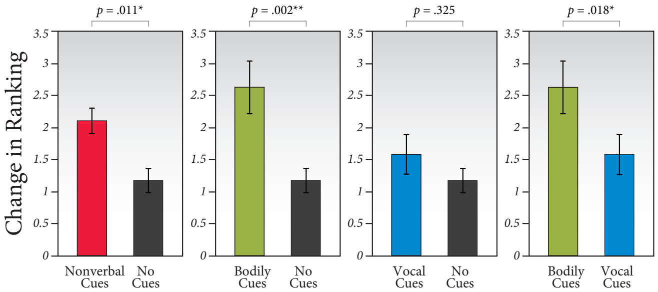

Figure 5: The results from our analysis of the objective data from the experiment.

of interest," (2) "do most of the talking," (3) "speak loudly," and (4) "demand attention" (Cronbach's $\alpha = 0.80$).

Manipulation Checks – The post-experiment questionnaire also included questions to confirm that our manipulations were successful in each condition. We asked participants to rate in a scale of one to seven how much they thought the robot was looking toward them, how much it moved its arms, and the expressiveness of its voice.

3.6 Participation

A total of 32 participants (16 males and 16 females) participated in the experiment. All participants were native-English speakers recruited from the University of Wisconsin–Madison campus. The ages of the participants varied between 19 and 49 with an average of 25.39. Participants represented a variety of university majors and occupations including sociology, biology, genetics, nursing, computer science, computer engineering, mechanical engineering, and finance. Participants were randomly assigned to the experimental conditions. We balanced the conditions for each gender, assigning four males and four females to each unique condition. Our demographic data showed that all participants rated their computer use 7 on a scale of one to seven ($M = 7, SD = 0$), while their familiarity with robots was moderate ($M = 3.67, SD = 1.71$).

4. RESULTS

Our analysis first checked whether the manipulations in the bodily and vocal cues were successful using analysis of variance (ANOVA). Participants rated the robot's use of bodily cues, particularly how much it moved its head and arms, significantly higher in the bodily cues condition than they did in the no bodily cues condition, $F(1, 30) = 47.25$, $p < .001$, $\eta_p^2 = 0.612$ and $F(1, 30) = 142.08$, $p < .001$, $\eta_p^2 = 0.826$ for head and arms, respectively, confirming that our bodily cues manipulation was successful. The results showed that our manipulation of the robot's vocal cues had a marginal effect on how expressive the participants rated the robot's voice, $F(1, 30) = 3.77$, $p = .062$, $\eta_p^2 = 0.112$.

We used analysis of variance also to analyze how our manipulations affected our objective and subjective measures. Our first hypothesis predicted that participants' compliance with the robot's suggestions would be higher when the robot employed *nonverbal cues* (vocal only, bodily only, and vocal and bodily combined) than it would be when the robot did not employ any nonverbal cues. Our analysis confirmed our prediction; participants's compliance with the robot's suggestions were higher when the robot employed nonverbal cues ($M = 2.097$, $SD = 0.971$) than they did when it did not use any nonverbal cues ($M = 1.166$, $SD = 0.535$), $F(1, 30) = 7.53$, $p = .011$, $\eta_p^2 = 0.212$.

Pairwise comparisons also showed that participants changed their ratings in a larger number of items based on the robot's suggestions when the robot employed *bodily cues* alone ($M = 2.626, SD = 1.160$) than when it did not use these cues ($M = 1.166$, $SD = 0.535$), $F(1, 28) = 12.35$, $p = .002$, $\eta_p^2 = 0.306$. *Vocal cues* alone ($M = 1.583$, $SD = 0.868$), on the other hand, did not increase the participants' ratings compared with when the robots did not use these cues ($M = 1.166$, $SD = 0.535$), $F(1, 28) = 1.00$, $p = .325$, $\eta_p^2 = 0.035$.

Our second hypothesis predicted that *bodily cues* alone would have a stronger effect on compliance than *vocal cues* alone would. Our analysis also supported this hypothesis; the change in participants' rankings of the items was higher when the robot used only bodily cues ($M = 2.626$, $SD = 1.160$) than it was when the robot employed only vocal cues ($M = 1.583$, $SD = 0.868$), $F(1, 28) = 6.31$, $p = .018$, $\eta_p^2 = 0.184$. These results are illustrated in Figure 5.

Our last hypothesis predicted that female participants would comply with the robot's suggestions more than male participants would do when the robot employed nonverbal cues. Our analysis did not support this hypothesis; no interaction effect appeared between gender and cue factors, $F(1, 24) = 0.122$, $p = .946$, $\eta_p^2 < 0.001$.

Our analysis showed that the effects of nonverbal cues, bodily cues alone, and vocal cues alone on the participants' compliance with the robot's suggestions did not appear in participants' subjective measures of the persuasiveness of the suggestions, though the participant's compliance with the robot's suggestions and their ratings of its persuasiveness were significantly correlated, $r(32) = .379$, $p = .032$. The analysis of the the intelligence measure showed a main effect of gender, as females rate the robot to be more intelligent, $F(1, 28) = 4.95$, $p = .034$, $\eta_p^2 = 0.150$, and a marginal interaction effect between gender and the bodily cue manipulation, $F(1, 28) = 3.50$, $p = .072$, $\eta_p^2 = 0.111$. Post-hoc tests showed that males evaluated the robot's intelligence significantly higher when it used bodily cues than they did when the robot did not use bodily cues ($p = .024$), while females evaluations of the robot's intelligence were not affected the robot's used of these cues ($p = .803$). The analysis of the satisfaction measure also showed a significant interaction effect between gender and the vocal cue manipulation, $F(1, 28) = 4.41$, $p = .045$, $\eta_p^2 = 0.136$. Post-hoc tests showed that females were significantly more satisfied when the robot used vocal cues than they were when the robot did not use

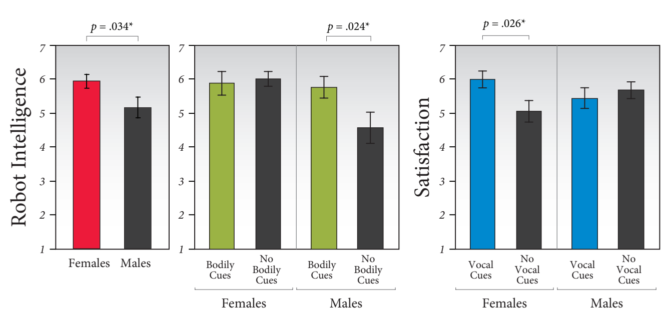

Figure 6: The results from our analysis of the subjective data from the experiment.

vocal cues ($p = .026$), while the robot's use of these cues did not affect males ($p = .537$). These results are illustrated in Figure 6.

Finally, we analyzed data from the personality scale to test whether participants' personality traits, particularly assertiveness, affected their compliance with the robot's suggestions and their ratings of the robot's persuasiveness. An analysis of covariance using assertiveness as a covariate showed that this personality trait was not a significant predictor of participants' compliance with the suggestions of the robot, $F(1, 30) = 0.924$, $p = .344$, $\eta_p^2 = 0.030$, but was a significant predictor of their ratings of the robot's persuasiveness, $F(1, 30) = 4.22$, $p = .089$, $\eta_p^2 = 0.123$, highly assertive participants rating the robot's suggestions low in persuasiveness.

5. DISCUSSION

The results from our experiment provided strong support for our first two hypotheses. We found that people complied with the robot's suggestions more when it employed nonverbal cues than they did when it did not employ nonverbal cues. Detailed analysis showed that the presence of bodily cues alone improved compliance, while the presence of vocal cues alone did not affect participants' compliance. The results also showed that bodily cues alone led to higher compliance in participants than vocal cues alone did. Our third hypothesis was not confirmed by our analysis, as participant gender did not affect participants' perceptions of the robot's persuasiveness and their compliance with the robot.

Limitations – The results presented here have a number of limitations. First, to create experimental conditions, we manipulated the "presence" of high-level categories of cues (e.g., bodily cues vs. no cues), instead of manipulating the presence of individual cues (e.g., gaze only, gestures only, etc.) or presenting these cues at different levels (e.g., more or less frequent). While a more finely granulated set of manipulations would have been more informative, the present study sought to confirm the link between nonverbal cues of a robot and its persuasiveness, only scratching the surface of how robots might persuade people through verbal and nonverbal cues. We plan to conduct follow-up studies to gain a deeper understanding of how individual cues might affect persuasion in human-robot interaction.

Second, our experimental task was based on the Desert Survival Task, which involved participants interacting with the robot in a hypothetical scenario. Whether the persuasive effects of the robot's nonverbal cues will affect decision making in real-world situations such as diet coaching, education, and public safety is unknown. Future work must investigate the generalizability of these results to real-world decision making and across a variety of situations.

Finally, the ethical implications of designing robots to persuade people require further consideration. We argue that persuasion is simply an effective form of communication and that persuasive robots should only be used in such domains as education, health, and wellbeing and only to support goals deemed appropriate by users.

6. CONCLUSION

Robots hold great promise as social actors helping to improve motivation and compliance in such as areas as education, health, and wellbeing. The success of these robots in being effective motivators will rely largely on their ability to *persuade*. In this paper, we explored how the nonverbal behaviors of a humanlike robot, particularly *bodily* cues such as proximity, gaze, and gestures, and *vocal* cues such as vocal tone and expressions, might affect the persuasiveness of a humanlike robot. We designed a set of nonverbal behaviors for a humanlike robot and evaluated, in a human-robot interaction study with 32 participants, the effects of manipulations in these behaviors on people's perceptions of the robot's persuasiveness and their compliance with the robot. Our results showed that the presence of nonverbal cues significantly improved people's compliance with the robot. Bodily cues alone improved compliance, while vocal cues alone did not. Bodily cues alone were also more effective in persuading participants than vocal cues alone were. Our model of persuasive nonverbal cues and experimental results have strong implications for the design of persuasive behaviors for humanlike robots. However, further work is required to understand how individual cues might affect persuasion, to what extent our results generalize to real-world situations, and to consider the ethical implications of designing persuasive technology.

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