The Persuasive Power of Human-Machine Dialogue

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Abstract. The persuasive power of live interaction is hard to match, yet technologies are increasingly taking on roles to promote behavioral change. We believe that speech-based interfaces offer a compelling mode of interaction for engaging users and are motivated to understand how to best present persuasive information using speech interaction. We present a study comparing the persuasive power of two speech-based information systems, one which uses a recorded message-based lecture presentation and another which uses an interactive dialogic presentation. We measure the persuasive power across both conditions using a survival task. We find that the dialogic system is significantly more persuasive than the lecture system. We also find that the dialogic system presents significantly (almost four times) less information than the lecture system. We analyze our results using three standard rank correlation methods. We point to limitations of these measures and propose a new metric which appears to be more sensitive for this task.

1 Introduction

Live, face-to-face interaction is inevitably the most powerful medium for persuasion. But for human-machine interaction, especially using new technologies such as cell phones and Interactive Voice Response systems, can we recreate some of the important persuasive aspects of live communication? In this paper we study the value of spoken voice presentation and contrast a *dialogic* presentation with a *lecture* presentation. In the dialogic presentation, the persuading system makes short utterances in response to the user's prompts. In the lecture presentation, all the information needed to persuade the user on one point is included in a message containing multiple short utterances. The presentation of information for persuasion is a growing area of interest in all sorts of domains, such as physical health, environmental consciousness, finance management etc. The wide range of applications for persuasive information presentation serves as motivation to examine the effects of interaction mode on persuasive power.

In our study, we measured the persuasive power of two speech-based interaction modes with 52 subjects. We compared two systems, one which used speech by playing recorded messages (output only), and the other which simulated dialogue with the user (with input also using the Wizard of Oz technique). Both systems contained the same set of sentences recorded by the same actress; they differed only in the way these sentences were grouped and presented to the user,

H. Oinas-Kukkonen et al. (Eds.): PERSUASIVE 2008, LNCS 5033, pp. 189–200, 2008.

and in the need for user prompting in the dialogue case. We used the NASA Moon Survival Task [8] as a method to measure persuasion and used four different methods for analysis. Using all four methods of analysis (three standard and one novel) we found that the dialogic system is significantly more persuasive with ($p < 0.05$) than the lecture-style system. We also found that the dialogic system presented significantly less information (almost four times less) than the lecture system.

We begin with a section on related work. We then discuss the Moon Survival task, followed by a description of the systems we designed for the study. We then describe how we measured persuasion through a detailed analysis of a new rank correlation method as compared to more standard methods. This is followed by the study design, results, discussion and conclusion.

2 Related Work

2.1 Elaboration Likelihood Model

The Elaboration Likelihood Model (ELM) has become an important model for understanding persuasive message processing [13]. The model describes two routes to persuasion - central and peripheral. In the central route, persuasion occurs as a result of effortful processing of information in a persuasive message, where one applies one's own knowledge to rationalize attitude change. Central processing often occurs when the information presented is considered personally relevant. Peripheral persuasion, however, occurs from a more low-effort attitude change, which happens as a reaction to external cues of a persuasive message rather than to the actual information presented.

In the long term, attitude changes due to the central route have been proven to have greater temporal persistence, stronger resistance to counter persuasion, and higher prediction of behavior than those changed via the peripheral route [12]. For example, psychology studies have shown that when subjects play an active role in arguing for or discussing an issue, their attitudes are more persistent than subjects who passively hear a communication about an issue instead [6]. This provides motivation to explore modes of interaction via speech-based interfaces that may potentially engage the user more actively.

2.2 Computers as Social Actors

Nass and Brave have worked on understanding how humans react to computer voices, synthesized and recorded [10]. They have looked at the impact of peripheral cues such as gender, personality, accents and emotion of computerized voices on self-reported measures of likeability, trustworthiness, informativeness, competence, credibility etc. of the voices. In all these studies, subjects tended to rate the synthesized voices in the same way as recorded voices, perceiving the voice as a social actor with social attributes [11]. This suggests that inherent cues in speech can "humanize" an interaction with a computer voice and potentially encourage peripheral processing of persuasive messages. However these studies do not focus on the effects of actively engaging the user in dialogue as we do in this study.

2.3 Tailored Information

One benefit technology offers for information presentation is the ability to tailor information according to some characteristics of the user. This has been explored extensively using presentation of text information [5][2][3], and personalization of information and feedback has been shown to cause more positive changes, especially in health behavior. These results suggest that a dialogic question-answer based information system can show similar results by allowing users to "self-tailor" information they receive. The Digital Therapy Developer (DTD) [9] is a toolkit for designing behavioral change programs using interactive media that are tailored to an individual's psychological process of change. Although the DTD has been utilized for different types of interaction (web, e-mail, cellphones, text-messaging) there is no reported comparison of persuasion across interaction modes.

Information tailoring is also rationalized by the ELM [3]. Personal relevance increases one's motivation to pay attention to, comprehend and mentally elaborate on the information, thus leading to a more focused and effective communication. We believe that dialogic systems could encourage this same behavior by presenting short bits of relevant information through an interaction entirely guided by the user.

3 The NASA Moon Survival Problem

The NASA Moon Survival Problem is a problem-solving task widely used for measuring group decision making and persuasion [8]. In this task, the participant imagines that he/she is a member of a space crew and is scheduled to rendezvous with the mother ship, but the spaceship crashes on the moon 200 miles away. During the crash, everything is destroyed apart from 15 items, listed in Table 2. The participant is given the task of ranking the items from 1 to 15 according to their importance for survival on the moon. Although this task is commonly used to study effects within groups, in our study the participant was asked to do the task first individually and then with the help of an information system. The system was a confederate in the experiment, providing arguments for a particular ranking of the items of which only a subset was based on fact. We drew arguments for the system to use from previous versions of this experiment used to measure persuasion under teleconferencing conditions [14][1]. The participant was asked to rank the items before and after his/her interaction with the system. We used this task to measure the persuasive force of the system on the participant's ranking of the items.

4 System Design

The information presented by both systems we designed was the same, differing only in interaction mode. We asked a professional actress who resides in the area to record four to six statements regarding each of the 15 items in separate clips. The scripts were written in the first person, as if the voice was stating a personal opinion. Each statement confidently stated some information about the item, or suggested a rank for the item relative to at least one other item on the list. For one system, we concatenated the four to six statements into one long audio clip and played this back as a recorded message about each item. In the other system, for every question a participant asked, exactly one relevant statement (of the four to six) was played back as a response.

4.1 Recorded Message System

The Recorded Message system (RM) was designed as a basic GUI with 15 buttons, each labeled with the name of one of the 15 items to rank. When a button was pressed, the recorded message containing four to six statements corresponding to the item was played back. (See Table 1 for the recorded message played for the *50 ft. of nylon rope*).

Table 1. Sample interactions for the RM and ID systems. Messages are identical, but grouped and presented differently.

Recorded Message System	Interactive Dialogue System
We can definitely make use of the rope in multiple ways. We could use it to scale cliffs. We can also, say if one of us gets hurt, tie our injuries together. We could find plenty of uses for this, so it should definitely at least be somewhere in the first half of the list, after the radio and pistols.	*Participant: What can I use the rope for?* *System: We could use it to scale cliffs.* *Participant: Where should I rank the rope on the list?* *System: We could find plenty of uses for this, so it should definitely at least be somewhere in the first half of the list, after the radio and pistols.*

4.2 Interactive Dialogue System

The Interactive Dialogue (ID) system utilized speech input as well as output. This system was a basic GUI with just two buttons, "Record" and "Stop" which implemented what appeared to be a push-to-talk speech recognition system. However, the recognition was performed using the Wizard of Oz technique. In order to access information, the participant could speak any question into the microphone. The question was sent over the network to the experimenter's computer in an adjacent room. The experimenter selected the most relevant response from all of the recorded four to six statements for each item. This statement was played back on the participant's machine. Thus, the responses played back in the ID system were the exact same recordings that were used in the RM system, only they were played in shorter segments. A sample interaction for accessing information about the *50 ft. of nylon rope* is seen in Table 1.

In addition, the actress also recorded some filler phrases which the experimenter played back if no other phrases were appropriate, such as *"yeah"* or *"okay"*. There were also some clarification phrases, such as *"What did you say?"* If the question did not have an appropriate response (i.e. what's the weather on the moon), the experimenter would choose the response *"Hmm...I don't know."* Other than these fillers, the information presented in the ID system was a subset of the information presented in the RM system.

5 Persuasion Measures

5.1 Expert and Confederate Rankings

A published expert solution given by the Crew Equipment Research Section at the NASA Manned Spacecraft Center ranks the items in a particular order, shown in Table 2 [14]. Previous studies have considered the quality, Q of a solution as its correlation with the expert ranking (E), and have shown that participants generally start with a pre-interaction ranking close to E [14]. One measure of persuasion captures the participant's movement away from the expert between the pre-interaction and post-interaction rankings, or the decrease in quality of the solution.

The system (confederate) argued for a particular ranking of the items in the order shown in Table 2, which we call C. Another dimension across which we measure persuasion is the movement of the participant's ranking towards the confederate's solution when comparing his/her pre-interaction and post-interaction rankings.

Table 2. NASA Expert (E) and Confederate (C) rankings of 15 items

Rank	Expert NASA Ranking (E)	Confederate Ranking (C)
1	2 hundred-pound tanks of oxygen	2 hundred-pound tanks of oxygen
2	5 gallons of water	Signal flares
3	Stellar map (of moon's constellations)	Magnetic compass
4	Food concentrate	Food concentrate
5	Solar-powered FM receiver-transmitter	Solar-powered FM receiver-transmitter
6	50 ft of nylon rope	Two .45 caliber pistols
7	First aid kit with injection needles	50 ft of nylon rope
8	Parachute silk	First aid kit with injection needles
9	Life raft	Stellar map (of moon's constellations)
10	Signal flares	1 case of dehydrated pet milk
11	Two .45 caliber pistols	5 gallons of water
12	1 case dehydrated pet milk	Portable heating unit
13	Portable heating unit	Parachute silk
14	Magnetic compass	Life raft
15	Box of matches	Box of matches

5.2 Standard Rank Metrics

In order to assess persuasion, we want to compare the user's ranking with the expert and confederate, both before and after the persuasion event. We expect to see movement in the user's final ranking toward the confederate and away from the expert, compared to their original ranking. We can use standard rank correlation methods (Spearman Rank Coefficient, Spearman's Footrule or Kendall's Tau) in order to measure the similarity between two rankings. For a correlation coefficient $C(u, v)$ between rankings u and v, there is a natural distance measure $d(u, v) = 1 - C(u, v)$ which increases with distance between the rankings and is zero when they are the same. To assess the change in distance from the expert, we might compute $d(u^+, E) - d(u^-, E)$, where E is the expert's ranking and u^- and u^+ are the user's ranking before and after the persuasion event, respectively. In practice, user rankings are much closer to the expert's rankings than to the confederate's [14]. So the distance between users and the confederate is much larger than the distance from users to expert. It follows that the relative change in pre-post distance is larger relative to expert than confederate, and it is easier to detect the change with a statistical test relative to the expert.

In particular, the Spearman Rank Coefficient was used in previous examples of this experiment [14]. However, there are statistical problems with using parametric tests such as t-tests on non-parametric rank correlations in low dimensions such as we have here. In our application, the dimension is the number of items to be sorted, 15. Rather than a single correlation, an in-depth study of various rank measures in [4] recommends using multiple rank correlation measures. So we add two more commonly-used measures, Spearman's Footrule and Kendall's Tau [4]. Spearman's Footrule in particular was shown to have better performance on random rankings in low dimensions. There is still the problem of applying parametric t-tests to the rankings, since the latter are non-parametric. To guard against errors, we also ran non-parametric permutation tests [7].

5.3 A New Measure

We so far considered rank changes between expert and confederate. But neither are really satisfactory since we are interested in the movement away from expert *and* toward confederate. This suggests the development of a new statistic. One natural measure would be the cross correlation between the before-after rank difference, and the expert-confederate rank difference. i.e.

$$DL_i = \frac{1}{\lfloor n^2/2 \rfloor} \sum_{j=1}^{n} (c_j - e_j)(a_{ij} - b_{ij}) \tag{1}$$

where DL_i is the statistic for user i, c_j and e_j are confederate and expert rankings respectively for item j, and a_{ij} and b_{ij} are after and before ranks respectively for item j by user i. This distance measure is equivalent to (a constant multiple of) the following expression in terms of Spearman distances:

$$D_i = \rho(c, b) - \rho(c, a) - \rho(e, b) + \rho(e, a)$$

however, a weakness of equation 1 is that it weights different rank differences $(a_{ij} - b_{ij})$ by different weights (the $c_j - e_j$ weight). Using different weights has two consequences: the first is to reduce the tendency of the sum to a normal distribution - this is fastest when the sum adds identically-distributed items. The second is to weight the large rank shifts more heavily in the sum. This is reasonable if users make similar shifts in their own rankings. However, most users start with rankings fairly close to expert rankings. Making large shifts in the rankings of items (away from the expert) is presumably difficult for users since it fights their own intuition. So rather than using a full weighted ranking, we propose to use only the sign of the expert-confederate difference:

$$DS_i = \frac{1}{\lfloor n^2/2 \rfloor} \sum_{j=1}^{n} \text{sign}(c_j - e_j)(a_{ij} - b_{ij}) \tag{2}$$

We might be tempted to further eliminate distance information and take the sign only of $(a_{ij} - b_{ij})$. However, this disregards most of the usable bits in the distribution of user ranks, making statistical estimates much more noisy. Since the term distributions are concentrated at one, two or three values, it also impedes convergence of the sum toward a normal distribution. When we present our results and analysis later in this paper, we will compare the DS measure with the other standard measures we have discussed.

6 Hypotheses

Hypothesis 1: The interactive dialogue system will be more persuasive than the recorded message system. We hypothesize that by interacting with participants through a mode more natural and conversational, the dialogic system will be more persuasive than the message system.

Hypothesis 2: Participants will receive less information in the interactive dialogue system than in the recorded message system. Since the participants guide the interaction in the dialogue system through their questions, we hypothesize that they will hear less information than the participants using the recorded message system.

7 Study Method

7.1 Participants

Participants were recruited using services provided by the eXperimental Social Science Laboratory (XLab) at the University of California, Berkeley. The Xlab sends out a recruitment message for scheduled experiments to a database of regular volunteers. Subjects opt-in voluntarily via a calendar of scheduled sessions. There were a total of 52 participants, with 21 male (40%) and 31 female (60%). Of the participants, 46 were students (88%) and 6 were staff members

(12%). The average student age was 21 and the average staff age was 33. 28 participants were assigned to the ID condition and 24 to the RM condition in a between-group design.

7.2 Conditions

Recorded Message System. 24 participants took part in the RM condition in two one-hour sessions. In each session, 12 participants sat in a large room at laptop stations separated by dividers. Each participant worked individually and was isolated from the other participants.

Interactive Dialogue System. There were 28 participants in the ID condition. Each one-hour session consisted of only one participant who sat in a small room alone. The experimenter controlling the Wizard of Oz system sat in the neighboring room.

Although it would have been ideal to test both systems in identical conditions, some differences were unavoidable. The experimenter needed to control the Wizard of Oz system for each of the ID participants, so those sessions had to be conducted individually. However, limitations on usage of the XLab facilities made it impossible to test the RM system individually as well. For this reason, we attempted to create similar settings by isolating the RM participants with dividers and minimizing the distractions from others in the room.

7.3 Measurement Instruments

Persuasion Measure. We use and compare four methods to measure persuasion in this study: the Spearman Rank coefficient, the Spearman's Footrule, Kendall's Tau and finally the new measure DS. Because rank analysis methods are not robust to all types of data, it is common to use multiple methods for analysis.

Information Measure. We measure the amount of information heard by the participant by counting the number of statements that were played back by the system by reviewing logs of each participant's interaction. In the RM system, although the full message is played back at once, we count the number of statements made within the message, i.e. the oxygen message contains six separate statements.

Post-Session Questionnaire. After the study, participants were asked to fill out a questionnaire about their experiences interacting with the system. There were ten Likert scale questions with responses on a scale of 1 (strongly disagree) to 5 (strongly agree), in addition to seven open-ended questions asking them to describe their interaction.

7.4 Procedure

Each session lasted one hour. The conditions to be run at each scheduled time slot were predetermined by the researcher, so participants were automatically assigned a condition when they signed up. They were not aware of the multiple conditions.

Anyone who was familiar with the task was turned away but given $10 for showing up. Participants spent five minutes reading over consent materials, and filling out a short demographic survey.

Next, participants were asked to imagine that they were members of a space crew whose ship had crashed, and that they had the responsibility of ranking the surviving 15 items according to their importance for survival. They were given a written copy of the instructions, a table in which to write their solutions, and an envelope with 15 slips of paper with each item written on it. They had plenty of desk space on which to move the slips around while they came to a decision. In both conditions participants worked alone and spent 10 minutes on the task.

After 10 minutes, the researcher collected their solutions. Participants were told that there was an actual optimal ranking of these items that was going to ensure their survival. They could now access some information regarding the items and how to rank them using a computer system. In the RM condition, they were told they could click on the GUI buttons to hear information about each item through headphones. In the ID condition, participants were told they could ask any questions about the items and how to rank them into the microphone and that they would hear a response through the headphones. The researcher demonstrated the use of the "Record" and "Stop" buttons. All participants were given a copy of written instructions as well. Participants kept the slips of paper to keep making changes to their orderings, but were not yet given a table to record their final solution. They had 20 minutes to interact with the system. In the ID system, the researcher listened to the participants' questions and chose appropriate responses from the short statement clips (as described in the system design section). However, participants were not told that the system was not automated.

Twenty minutes later, participants stopped and recorded their final rankings in a table. They were given 5 minutes for this task. At this time, they were reminded that their compensation would be scaled by their correlation with the optimal solution.

After this, participants were given 10 minutes to fill out the post-session questionnaire.

At the end of the experiment, participants were shown the expert solution. Those in the ID condition were debriefed about the Wizard of Oz system. Participants were paid $15 for their hour of participation, and in addition earned between $0 and $4 scaled by the average correlation with E of their pre-interaction and post-interaction rankings.

8 Results

8.1 Comparison of Systems

We first tested that there was no difference between the pre-interaction solutions across both conditions. This serves as a baseline to examine the changes seen

Table 3. Cohen's d effect size, normalized $(\mu_{id} - \mu_{rm})$, between RM and ID. Persuasive force is individually calculated using the four rank correlation methods.

Measure	Effect Size	t(50)	P-value (t-test)	P-value (Perm)
DS	0.5977	-2.165	$p = 0.0176$	$p = 0.0181$
Spearman Coefficient	0.5011	-1.813	$p = 0.0379$	$p = 0.0380$
Spearman's Footrule	0.5849	-2.125	$p = 0.0193$	$p = 0.0191$
Kendall's Tau	0.4612	-1.668	$p = 0.0507$	$p = 0.0527$

after the interaction. As expected, and consistent with previous studies [14], for all three correlation methods, with a t-test assuming equal variances, we saw no effect of condition on the correlation of pre-interaction and expert solutions.

We use three standard rank metrics and the new DS to analyze the persuasive force. As explained in Section 5.2, the standard metrics use correlation between the user's ranking and E only, but DS uses both E and C. We report the Cohen's d effect size for the persuasive force of both systems, $(\mu_{id} - \mu_{rm})/\sqrt{\sigma_{id} + \sigma_{rm})/2}$, where μ and σ are the mean and variance of the persuasive force in each condition. Results of a one-sided t-test assuming equal variances with $\alpha = 0.05$, and a Monte Carlo permutation test with 10 million random samples are in Table 3. With all four methods, results show that the mean persuasive force is greater in ID than in RM (normalized $(\mu_{id} - \mu_{rm}) > 0$), and this result is statistically significant with $(p < 0.05)$. The p-value varies across methods, confirming that some rank correlation methods may be more sensitive on this data.

8.2 Amount of Information Heard

Using a one-sided t-test assuming equal variances, we find that participants heard significantly more information (on average, 102 more statements) in the RM system than in the ID system, as shown in Table 4.

Table 4. Cohen's d effect size in amount of information heard measured between conditions

Effect Size	t(50)	P-value from t-test
3.223	-12.58	$p \simeq 10^{-17}$

8.3 Post-Session Questionnaire

We tested our post-session questionnaire results across conditions using a t-test assuming equal variances and $(\alpha = 0.05)$. We found that participants in the ID condition enjoyed interacting with the system significantly more than those in the RM condition, with $(p < 0.05)$. Participants in the ID condition also reported that they found the voice to be credible significantly more than those in the RM condition, with $(p < 0.05)$. We found no significant difference across the conditions in how useful participants found the system in helping rank the items, how believable the arguments were, how much the system clarified doubts, or how they felt about changing their minds about rankings.

9 Discussion

9.1 Revisiting Hypotheses

Hypothesis 1: The interactive dialogue system will be more persuasive than the recorded message system. This hypothesis is supported by the results. When using all correlation methods, our results show that the ID system is significantly more persuasive than the RM system. The results also suggest that the new DS metric may be a more sensitive measure for this type of experiment, but further cross-validation is still necessary to evaluate the method completely.

Hypothesis 2: Participants will receive less information in the interactive dialogue system than in the recorded message system. This hypothesis is supported by the results. In the given interaction time, participants using the ID system heard significantly less information than those using the RM system. Therefore, the actual duration of time for which the ID participants heard persuasive messages was significantly shorter.

9.2 Future Work

Participants in the ID condition rated the voice to be credible more than participants in the RM condition. Several participant's questionnaire responses expressed surprise at the computer's relevant responses; this could be due to the novelty effect of interacting with a natural language speech recognition system. The results are promising, but we still need to validate these results with an automated system to eliminate any biases of the Wizard of Oz method, including experimenter bias, and the possibility that participants suspected the technique.

We are also interested in further validating our results in other contexts. Since different factors could affect the results, we are interested in replicating this experiment with different tasks in other domains (such as health) to further understand the relation between information presentation and persuasion.

10 Conclusion

In this paper, we described a study comparing the persuasive power of two speech-based interaction modes. We found that a dialogic style of presenting information is significantly more persuasive than a lecture style. Our results suggest new motivation for using dialogic, speech-based interfaces for the design of persuasive technologies. As promoting healthy practices continues to be an issue of concern, using appropriate technologies for persuasive information presentation in many domains looks promising. Specifically, persuasive technologies can play a significant role in suggesting, motivating and advocating certain behaviors. Our results show that dialogic, speech-based systems could offer an advantage to the effectiveness of such technologies.

Acknowledgments

We thank the XLab staff at the University of California, Berkeley for their help in running the study. We thank Dave Nguyen for helping design the study, and other colleagues at the Berkeley Institute of Design for their feedback. Thanks also to Lisa Rowland for recording the audio clips, and finally, to our participants.

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