Gaze-Speech Coordination Influences the Persuasiveness of Human-Robot Dialog in the Wild

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Abstract. In this study, we argue that the extent to which a robot is persuasive depends on the way a persuasive message is embedded in the robot's other behaviors. In the current study, in which a robot serves water at a large public event, we find that the same robot utterance, namely *skål* (*cheers*) when serving water, is received very differently depending on whether the robot is oriented to the user or not. In particular, if the robot gazes at the user while saying *skål*, almost all users drink immediately, whereas only 44.5% of the people drink if the robot is looking elsewhere. Similarly, the effectiveness of a water-related joke as a persuasive means depends on previously established mutual gaze. Thus, gaze and speech behavior have to be coordinated to improve the robot's persuasiveness in the wild.

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Keywords: Human-robot interaction · Persuasion · Gaze

1 Introduction

One of the many tasks robots may take over in the future is to serve drinks; especially in elderly care, robots can serve water to older people who are not feeling thirsty and who need to be reminded to drink enough. Thus, in addition to serving fluids, robots may also have to be persuasive. Much work on persuasion focuses on identifying the effects of single, specific interventions. Very few studies address the interplay of several factors, and very little of this work has taken place in human-robot interaction research. However, there are good reasons to assume that the persuasiveness of utterances depends crucially on their embedding in other behavior, both in interactions between humans and in human-robot interaction. At the same time, human-robot interaction constitutes an excellent methodological platform to study the interplay between persuasive strategies on the one hand and non-verbal behaviors on the other.

In the current study, we study how effective persuasive messages presented by a robot that serves water at a large public event; in particular, we address to what extent the effectiveness of the robot's verbal utterances depends on the robot's gaze orientation.

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Fig. 1. The robot from the perspective of the wizards

We focus on the effects of the robot utterance *skål* (*cheers*) and of a water-related joke when serving water; in particular, we analyze how these messages are received depending on whether the robot is oriented to the user or not. The human-robot interaction takes place 'in the wild,' i.e. in an uncontrolled scenario, which allows us to investigate the interdependencies between gaze behavior and persuasive dialog in a naturalistic setting.

2 Previous Work

Previous work concerns research a) on the temporal coordination between speech and other robot behaviors, and b) on persuasive robot dialog.

2.1 Speech-Behavior Coordination

Research on interactions between people shows that the timing of their behaviors in modalities, such as speech, silence, gaze and gesture, influences how they make sense of an interaction. For example, concerning the coordination between interaction partners, the length of silence (i.e. the lack of speech and other non-verbal actions) has shown to be a reliable predictor for interactional problems [1]. In human interaction, people generally respond within a timeframe of between 300 ms and about a second [2], with some slight intercultural variation [3]. This means that responses that are delayed by more than one second are considered interactionally problematic.

This observation on data from naturally occurring human interaction also applies to human-robot interactions [4]; for instance, the timing of behaviors between participants influences how polite a robot is perceived to be. For example, Huang et al. [5] find that a robot that responds quickly to the user's need for assistance and then moves quickly to fulfill its task is perceived as more polite than a robot that takes more time to respond.

Concerning the timing between different human communication channels, research has mostly focused on the relationship between speech, gaze and gesture, but has also considered other actions. For instance, Clark and Krych [6] show that individual actions, such as holding or placing an object, are generally very well coordinated with speech in order to allow the partner to infer the other's intentions and to predict the next move (cf. also Clark [7]). Thus, the appropriate timing of multimodal action leads to legibility of the communicative function of this behavior and thus contributes to task success and the predictability of the actor.

Regarding human-robot interaction, a study by Jensen et al. [8], in which the effects of different ways of coordinating speech and robot behaviors were compared, shows that speech is different from other behavioral modalities such that people have much more distinct expectations about the timing of speech than about the timing of other robot behaviors; in particular, if verbal utterances are not tightly coordinated to other robot behaviors, this leads to interaction problems and confusion. Their study concerned the coordination between speech, robot approach and an arm gesture, where simultaneity of these behaviors yielded the best results.

Similarly, concerning the coordination of robot speech and gaze, Yamazaki et al. [9] show that people are more likely to respond to a robotic museum guide with non-verbal behaviors when the robot gazes in their direction at interactionally significant points. The coordination of gaze and other robot behaviors is also relevant during handovers. For example, Zheng et al. and Moon et al. [10] show that people reach for an object sooner when the robot gazes toward the handover position and even sooner if the robot gazes at the person compared to when it gazes away. Admoni et al. [11] show that a slight delay of the handover procedure increases people's attention towards the robot.

People also coordinate their gaze behavior with each other; for instance, Kendon [12] reports that people coordinate their gaze behavior very tightly with their communication partners, where contingent gaze is a direct indicator for joint attention, also in human-robot interaction [13]. Furthermore, mutual gaze is a very important communication cue in human-human interaction [14]; it is established when two people gaze at each other and realize this reciprocity. It is also very effectively used in human-robot interaction to augment communication [15, 16]. Mutual gaze may also be used for addressee selection [17].

2.2 Persuasive Robot Utterances

While persuasion in human interaction has been studied for centuries [18], there is still very little work in human-robot interaction.

Vossen et al. [19] have investigated the influence of robot embodiment on its persuasiveness; in this study, an agent tried to persuade users to choose an ecological program on a washing machine, and the physically embodied robot was more successful than a robot displayed on a screen.

Ham et al. [20] investigate the effects of different types of feedback on the persuasiveness of a robot; they find that feedback that appeals to social norms is more effective than factual feedback. Similarly, Winkle et al. [21] experiment with persuasive robot utterances, focusing on displays of goodwill and similarity to the user. Langedijk et al. [22] investigate effects of the personalization of social proof and reference to research findings and the users' expertise in human-robot interactions.

Very little work has studied the persuasiveness of robot's utterances in relationship to other behaviors; one exception is the study by Ham et al. [23] who had a robot tell a story with moral content and who investigated under which circumstances participants evaluated the story as most persuasive: if the robot looked at them while telling the story, if it used iconic gestures during the story telling, or based on the story content alone. They find that gaze has a significant effect on the persuasiveness of the story. These results suggest that gaze may have a considerable impact on the persuasiveness of robot dialog, but there is as yet no further research on the interplay between gaze and persuasive robot behavior, especially not in the wild, i.e. in uncontrolled environments in which the researcher has no control over who the participants are, whether they are thirsty or not, whether they have their own drinks, whether they want to interact with a robot or not etc. In-the-wild studies on behavior change have been conducted on isolated persuasive strategies in general (e.g. [24]), but not on robots and not in interaction.

In the current paper, we investigate the extent to which conventional communicative practices like jokes and toasting are effective persuasive strategies and the extent to which their persuasiveness depends on the robot's other interactional behaviors, i.e. gaze. In human interaction, according to Black [27], the toasting ritual (at least in one-on-one interactions) consists in participants uttering a fixed phrase, such as "cheers" or "skål", raising their glasses to each other, and engaging in drinking together [cf. also 28]. Thus, one may expect that mutual gaze may play some role in the effectiveness of such a ritual initialized by a robot. In contrast, jokes should be equally funny, and hence effective, independent of the speaker's gaze behavior. The two practices were thus chosen as instances at opposite ends of the spectrum of persuasive strategies in terms of expected relationships with mutual gaze.

3 Method

The current study was carried out in the cafeteria area at the campus of a Danish university that also hosts a major concert hall for the whole region. Thus, in addition to university students and staff during the day, large numbers of members of the general public gather in the building in the evening before the doors to the concert hall are opened. Events hosted there are of many different types, and the events taking place during the time of our recordings were two classical concerts, a movie previewing and a body-building convention. In this study, we concentrate on the four gatherings, which took place either in the late afternoon or in the evening; participants are members of the general public, many of whom are older adults.

While people were slowly gathering, the robot was driving around offering water to people sitting or standing. At the beginnings of our recordings, there were rather few people around, while towards the end, shortly before people were let into the concert hall, the robot was immersed in crowds of people.

3.1 The Robot

The SMOOTH robot (see Fig. 1) [25] is a large service robot developed to take over several tasks in elderly care facilities, including transporting laundry and guiding residents. It was thus optimized for economic feasibility on the one hand and for transport on the other. It carries its load on the back, which is probably appropriate for laundry and garbage transportation, but which may have disadvantages in a drink serving task [26] since the robot needs to turn around a bit in order to provide people with access to the water it is serving.

The robot is equipped with autonomous navigation and dialog capabilities, but to ensure participants' safety and to be able to adapt the dialog to the circumstances arising, the robot was controlled by two wizards, one for navigation and movement, the other for the dialog (see Sect. 3.2). The robot's head includes a microphone, speakers, cameras and two touch screens, one in the front and one in the back. The front touchscreen displays a pair of simulated eyes, with a white sclera and black pupils on a gray background. Given the size of the robot, its eyes are slightly below those of a person sitting on a chair. The touchscreen in the back was not used.

3.2 Robot Dialog

The dialogs were scripted and played according to a dialog model, with some flexibility for the wizard. In particular, a set of functionally equivalent utterances was defined from which the wizard could choose in order to vary the robot output so that overhearers would not witness the same dialogs over and over again. These were:

- five different greetings (*hi, hello, hi there, sorry to bother you, but…, and sorry to disturb you, but…*),
- six different robot utterances to offer some water (*How about some water?, Would you like something to drink?, You are probably thirsty – please take a drink, can I offer you some water, I wonder if you would like something to drink, may I offer you some water*),
- three different persuasive utterances we were testing (*Research shows that it is important to drink enough water during the day* and *Most women/men do actually take something to drink*),
- five different humorous utterances (e.g. *What did the ice cube say to the water? I was water before it was cool*),
- a request to take the water,
- a toasting utterance (*skål*), and
- five different closings (*Bye bye, Enjoy your drink, Goodbye, It was nice meeting you, Have a lovely day*).

Jokes were generally told after greetings or after offers to take something to drink, whereas the toasting utterance "skål" was typically uttered when the participants had accepted an offer to take a drink and had taken a glass of water from the robot's tray; however, there are also a few cases in which participants were not already equipped with glasses.

Most of the time, the phrase "please take your water" ("tag venligst din vand") was uttered before "skål", together with a slight turn so that participants could reach the glasses on the robot's back more easily, but in some cases, the participants reached out for the water on the tray without being directly encouraged by the robot. In all of these situations, the risk that people lose the mutual gaze with the robot was high. Mutual gaze was either regained by participants moving around to look into the robot's face or by the robot turning back, but in many cases, mutual gaze was not re-established. The example shown in Figs. 2a and 2b illustrates a typical interaction with the robot.

1. Robot initiates: *"I don't mean to interrupt, but..."* *("Nu vil jeg ikke afbryde, men...")* Both participants look at the robot, participant on the right has her back turned		
2. Robot repeats: *"I don't mean to interupt, but..."* *("Nu vil jeg ikke afbryde, men...")* Both participants turn towards the robot, circular arrangement (F-formation) develops		
3. *Robot: "... But would you like something to drink?"* *("...Kunne I tænke jer noget at drikke?")* Participant on the left answers: *"Yes, we actually would"* *("Ja, det kunne vi da godt")*		
4. Robot utters: *" Please take your water"* *("Tag venligst din vand")* and turns. Participant on the left utters: *"Wow..." ("Nej...")* Both participants reach for glasses on the tray		

Fig. 2a. Example interaction (1–4)

3.3 Data Collection

Two wizards controlled the robot from a deck one floor above the experiment site, having a good overview of the experiments the entire time while not being noticed by the participants (see Fig. 1). The wizards had an audio connection to the robot and thus could hear the participants. They could see the interaction from above but not from the robot's perspective.

Three to four additional researchers were engaged in observing, interviewing and gathering consent forms from participants after the short-term interactions with the robot, as well as making sure that the robot's tray was filled with fresh beverages. These researchers also put the GoPro cameras in place around the experiment site and made sure that the GoPro mounted on top of the robot was turned on.

5. Both laugh and take a glass *Participant on the left responds: "Okay, then... We will then... Thank you."* *(Okay, så... Jamen det gør vi da så... Tak.")* Both participants thank the robot, and look towards the robot's front as it turns back		
6. Robot turns back towards the participants and utters: *"Cheers"* *("Skål")*		
7. Participant on the right look to the participant on the left, as they both respond: *"Cheers!"* *("Skål!")* to the robot		
8. The participants then look at each other and raise their glasses The participants both drink as the robot turns Robot drives away, while uttering: *"Enjoy the show"* *("Nyd forestillingen")*		

Fig. 2b. Example interaction (5–8)

3.4 Data Analysis

For the analysis of the data, first all camera data from the robot's head were scrutinized for instances of "skål" and of the joke uttered by the robot; the number of occurrences of “skål” across the four evening events was 40, while the joke was told 19 times. Then, these interactions were copied into separate video files for subsequent analysis.

The data were then categorized into those interactions in which the target utterance was uttered under mutual gaze and those which were told without mutual gaze. Mutual gaze was identified by analyzing if the participant was visible in the head-mounted camera data and was orienting towards the robot’s face (i.e. who was perceived as looking into the camera). For those interactions during which gaze was lost, the videos from the external cameras were consulted to analyze participants’ behavior.

Fig. 3. Results of the analysis between robot gaze and people’s responses to the robot toasting

The analysis then identified whether the utterance of “skål” led to behaviors in the participants that are typical of the toasting ritual, namely lifting the glass, replying “skål” and drinking in response to the robot’s actions, that is, within a timeframe of 300–1000 ms. Similarly, the analysis of the joke determined whether people laugh and whether they drink in response to the robot’s utterance. Figures 2a and 2b illustrates the data analysis of a typical interaction involving the use of toasting (“skål”).

4 Results on Toasting

Our analysis reveals that in 20 interactions, mutual gaze was re-established, mostly by participants moving around the robot to take a glass and moving back to interact with its front. In four of these 20 interactions with mutual gaze, participants do not have anything to drink. Interestingly, in one interaction, participants toast to each other as soon as they have their glasses of water.

In 13 of the remaining 16 interactions, participants fulfill the toasting ritual by lifting the glass and saying “skål”; of these, 10 participants drink right away; of those who have toasted to the robot, two do not drink right away but rather take their glasses to their seats to drink them there, and the remaining participant has already started drinking when the robot utters “skål.”

The remaining four participants who have water, who experience mutual gaze with the robot when the robot utters “skål” and who do not enter into the ritual comprise a person walking past to find a seat, one participant who is busy taking pictures, and one pair of young kids.

In contrast, in the 20 interactions in which there is no mutual gaze, only 8 participants drink in response to the toasting utterance; two do not drink because they do not have a glass when the robot utters “skål.” Thus, 18 participants could have drunk from the water. Only four participants lift their glasses, while five reciprocate the robot’s utterance and say “skål.” Figure 3 illustrates the different distributions based on mutual gaze.

A chi-square test of independence shows that the difference in water consumption is not significant ($\chi^2(1,34) = 1.108$; $p = .292$), but that people lift their glasses ($\chi^2(1,34) = 11.806$; $p = .001$) and say “skål” ($\chi^2(1,34) = 9.722$; $p = .002$) significantly more often in the mutual gaze condition. Table 1 below presents an overview of the data.

Table 1. Means (and standard deviations) of participants drinking, lifting their glass and saying skål in response to the robot’s utterance

	N	Drinks	Lifts	Says skål
No gaze	20	0.36 (0.49)	0.18 (0.39)	0.32 (0.48)
Gaze	20	0.55 (0.48)	0.65 (0.49)	0.70 (0.47)

5 Results on Joking

In the second study, we address to what extent two very similar jokes about carbonated water (‘tickle water’ in Danish) are responded to if told by a robot by those the robot is gazing at, in comparison with bystanders with whom no mutual gaze is established. Both jokes directly address the interaction partner, and they have a similar two-part structure. The two jokes are the following:

- I have something to make you laugh: tickle water!
- Do you know how to make a fish laugh? You put it into tickle water.

Because the two jokes are so similar, we treat them as the same kind of joke in the following analysis.

In total, the robot uttered the two versions of the joke 19 times (9 times in the first version and 10 times in the second); two interactions could not be analyzed because the robot was not in the view of one of the external cameras, or people were blocking the view on the interaction. This leaves us with 17 interactions with altogether 35 participants. We count as participants a) people in the field of view of the robot and b) people in close proximity to the robot who direct their attention to the robot; for example, they may be behind the robot to pick up some water. Similarly, we count as mutual gaze when a person is in view of the robot’s head-mounted camera and is looking at the robot’s ‘face’ (Fig. 4). AQ2

The results of a chi-square test of independence show significant differences between people’s laughing behavior depending on whether or not there is mutual gaze between the participant and the robot ($\chi^2(1,35) = 13.895$; $p = .001$), while regarding drinking and

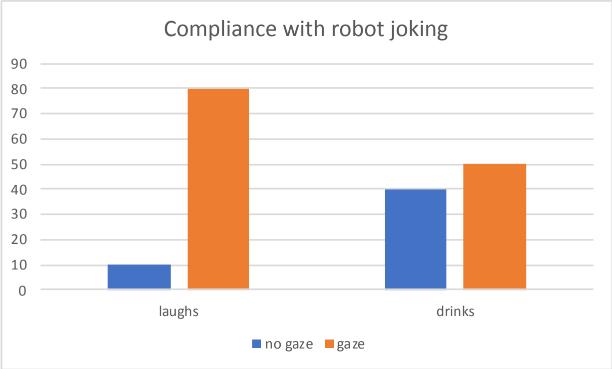

Fig. 4. People's responses to the robot joking (in percent)

Table 2. Means (and standard deviations) of participants laughing and drinking in response to the robot's joke

	N	Laughs	Drinks
No gaze	9	0.10 (0.33)	0.40 (0.53)
Gaze	26	0.80 (0.41)	0.50 (0.51)

mutual gaze the difference does not reach significance ($\chi^2(1,35) = 0.0005$; $p = .982$). We can conclude that the jokes are more effective such that participants will laugh more often when mutual gaze is established. Regarding water consumption, the connection between drinking and mutual gaze is less direct (Table 2).

6 Discussion

In the current investigation, we analyzed the persuasiveness of two robot behaviors in relationship with its other behaviors, in particular, a verbal utterance in relationship with the robot's body orientation. The toasting utterance was found to be extremely effective in getting the participants to drink and toast with the robot if the robot was also gazing at the participant. This finding is interesting because 1) it is obvious that the robot is not able to carry out the ritual of toasting with them besides providing a verbal utterance (but it cannot lift a glass and drink itself), and 2) it crucially depends on perceived mutual gaze. In particular, if the robot gazes at the user while saying *skål*, 62.5% of the users drink immediately, and further 15% join the toasting ritual with the intention to drink afterwards (when reaching their seats), whereas only 44.5% of the people drink if the robot is looking elsewhere. This results is remarkable since the fact that the robot is turning away is clearly functionally motivated and could also be understood as a polite behavior that is part of the continued interaction.

In contrast to people's participation in the toasting ritual, their drinking behavior is not directly predictable because of many additional context factors; still, if there is mutual gaze, the robot's utterance is very effective in encouraging them to drink.

We can thus conclude that the particular toasting ritual requires gaze coordination, which cannot be substituted by other social robot behaviors (such as friendly or polite previous interactions), though such previous interactions increase the probability that people drink the water later. Thus, our findings suggest that gaze and speech behavior need to be coordinated to improve the robot's persuasiveness in the wild.

The same observations have been made with respect to the robot's jokes, where the jokes reliably elicited laughter if they were uttered under mutual gaze, whereas they were significantly less effective when the robot was not looking at the participant. And like "skål", the jokes were moderately effective in eliciting drinking behavior by the participants.

Since this was a qualitative analysis of data elicited not in experimental scenarios but in an unstructured environment, the data base was necessarily rather small; the whole data set comprises 40 instances of the toasting ritual, 20 instances uttered with mutual gaze, 20 without. Regarding the jokes, the situation was even worse with 19 instances of the two jokes and 35 participants in total. Nevertheless, with the exception of young kids, almost all participants who had water already and thus for whom the basic preconditions for the success of the toasting ritual were fulfilled, irrespective of whether they were alone, in groups or in a family context, engaged in the ritual and drank their water; only if they were engaged in important other business, such as handling a camera or serving water to someone else, the toasting utterance failed to have its intended effect, whereas the variation is much higher in the situation in which the robot does not look at the participant. The same is true for the joke telling, where 80% of the participants responded with laughter if the robot gazed at them at the same time. Thus, even though the data basis is small, the fact that such a broad range of users respond so consistently to the persuasive robot behavior under mutual gaze suggests that toasting and jokes serve as persuasive strategies if coordinated with robot gaze.

Another possible limitation could be that toasting is an integral part of Danish culture, but may be less conventionalized in other cultures and hence less effective. However, since we could replicate the effect with respect to joke telling, it is likely that the coordination between persuasive utterance and robot gaze will also apply to other utterances and across cultures. The current findings are also compatible with the only other study [23] on the relationship between gaze behavior and the persuasiveness of robots.

7 Conclusions

The analysis of interactions in which the robot uttered "skål" or jokes in unstructured interactions with heterogeneous groups of participants, who were free to move in relation to the robot as they pleased, reveals significantly different responses to the robot's persuasive utterances depending on mutual gaze. Consequently, in spite of the uncontrolled setting, results on the effectiveness of robot utterances could be gathered. Thus, it seems not only possible to study robot persuasiveness "in the wild," it could also be shown that in spite of the contingencies of in-the-wild situations, robots can be persuasive social agents.

The study has furthermore shown that robots' gaze behavior influences significantly the effectiveness of persuasive utterances in human-robot interaction – even in the wild. While the contingency of the effectiveness of persuasive strategies on their interactional circumstances had previously been underestimated, our results show clearly that persuasion crucially depends on the coordination with other behaviors of the agent that produces it. Robot behavior should thus be designed in a holistic fashion, paying attention to the tight coupling between different robot behaviors, such as gaze and dialog behavior.

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Chapter 14

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