















was particularly embarrassing when the robot repeated his/her negative comment about the referent together with precise pointing. No significant difference was found for understandability. One possible reason is that the referents were asked to watch and evaluate the robot, so they were inevitably more aware of the conversation than a typical bystander would be.

#### D. Limitations and Future Work

In this study, the main focus was on generating the deictic behavior that best balances the issues of being polite and being easy to comprehend. This work could be extended to include more detail, such as exploring degrees of casual pointing or other deictic gestures such as chin-pointing. Our study also examined the effect of the use or non-use of descriptive terms, but future work could investigate relative effects of different kinds of descriptive terms or different levels of specificity.

One issue that we did not cover was the effect of gaze and how it relates to politeness and understandability. Gaze cues are a known attention drawing mechanism, and participants in our experiment explicitly noted that the robot's gaze helped them to identify the referents. In our experiment, we implemented the robot's gaze to look at the direction of the referent consistently in both conditions. However, we did not explore what type of roles gaze cues actually play in understandability and politeness.

Pointing behaviors carrying semantic meaning were not fully explored in our study. When a person introduces another person, they usually use an open hand, palm up gesture as an implication for offering. Including more social settings (e.g. introduction) would be an interesting area for future work.

While there are many possible areas for future work, we believe that our model is relatively accurate in representation of the main factors of real human deictic behavior.

## VII. CONCLUSION

In this study, we have empirically confirmed that people's pointing behavior is different when they refer to objects and when they refer to people. From data of real human deictic behaviors, we developed a model for generating deictic behaviors for robot that best balance comprehension and politeness. We compared our model, which considers both understandability and social utility, with an object-reference model that aims to only maximize understandability. We demonstrated that with our model, the robot's behavior was perceived more polite and natural, and therefore the robot's behavior led to a better overall interaction.

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