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# *Computational Awareness in a Tactile-Responsive Humanoid Robot Comedian*

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*Abstract*—**In the future, humans will have robot friends that will need to have social and computational awareness for intuitive human-robot interactions. In this paper, we demonstrate a method for incorporating computational awareness in a humanoid robot comedian scenario that uses tactile feedback to respond to the audience. Our findings indicate that incorporating computational awareness in a humanoid robot must also take into account the users' ability to detect responsiveness in a robot.**

***Keywords- robotics; humanoid robotics; human-robot interaction; computational awareness; robot entertainment; engineering; programming; artificial intelligence***

## I. INTRODUCTION

In the future, robots will continue to play a larger role with respect to humans. They will be able to engage in conversation and respond to users, and not simply follow a pre-programmed script. In this paper, we focused on a situation where a humanoid robot is a comedian with a dynamic routine that changes based on audience response. Future applications of this include robots that can spend time with elderly people and keep them company. This could be accomplished by robots programmed with computational and social awareness.

Computational awareness is defined as the collection of information that enables humans or machines to make decisions or take actions [12]. Donald A. Norman talks about how machines with emotions are more comfortable for humans to interact with [8]. Communication plays an extremely important role in human-human relationships. When a human feels like a robot counterpart is capable of actually responding in an intelligent way, there is a greater potential for human-robot friendship. If the number of robots in our society continues to grow, having friendly robots will benefit all involved. Robots need not be scary machines; they might as well become friends with their "users." In this article, we address computational aware companion robots, but more specifically humanoid robot comedians.

The rest of this article is organized as follows. First, we discuss previous work on computational awareness in entertainment robots and related research in human behavior. Next, we discuss our approach to developing a responsive humanoid robot using tactile feedback for computational awareness. Then we describe how we evaluated our approach with human subjects. Finally, we discuss our results and conclusions and describe future directions for this work.

## II. RELATED WORK

The field of computational awareness in robots benefits from research in human behavior and autonomous entertainment robots. In her paper *Entertainment Robotics*, Manuela Veloso describes the three main characteristics of autonomy: perception, action, and cognition [11]. This is important to consider as robots have increasing roles in entertainment, as they need to use perception and cognition of their audience to determine actions that entertain. The robot used in our research used perception to gather data about the audience, namely, a positive or negative reaction to a given joke. Based on the perceived response, the robot will either act or continue with a script. The robot demonstrated cognition with the basic choice that it made between continuing with the current set of jokes and trying a new set.

Donald Norman spoke about Sony's Aibo, which was a "pet robot dog" [8]. The dog acts like a real dog, and displays emotions typical of a household pet. This is an example of a robot that displays emotions "in a way that people can interpret" [8]. This article aims to develop a humanoid robot that is fun and enjoyable for humans to interact with because it displays human-like behavior.

This article builds on ideas from previous research in human behavior. Salah *et al.* describe the importance of recognizing and understanding human behavior [9]. They explain that the challenges include not only recognizing visual actions but also interpreting complex social signals. By applying some of these concepts to robots, we believe that human-robot interaction will be more effective and enjoyable. In addition, the human can even come to appreciate a robot as a friend, rather than simply a mechanical beast. According to Salah *et al.*, facial expressions and gestures are evident of habits that are socially formed [9]. A robot that is effective in social situations needs to understand human social habits.

Cynthia Breazeal talks specifically about interpreting social cues of humans. Specifically, she mentions praise and how human cues can reinforce robot behavior. Over time, this feedback can be used to train the robot and refine its behavior [3]. Likewise, this project aims to program a humanoid robot

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that will behave in a different way for each user by actively responding to feedback.

Heather Knight conducted similar research on the use of real-time human feedback to maximize an audience's enjoyment level of a robot performance [6]. Knight programmed the robot to use visual and audio feedback to respond to an audience. Our work differs from Knight's in that we compare people's perceptions of a responsive robot comedian to their perceptions of one that does not respond to their feedback.

Several major assumptions went into the programming of the Nao humanoid robots [4]. Initially, it was assumed that users would laugh out loud at jokes that were thought to be funny. Pre-study experiments revealed that this was not often the case [5]. Laughter can be silent and hard to detect. Some people show more emotion through sound, while others reveal their enjoyment of jokes through facial expressions. It proved to be quite a challenge to determine how to best ascertain whether or not a user liked a given joke.

As Baldwin and Baird would suggest, facial expressions themselves are surface behaviors that do not always reveal what a person's reaction truly means [2]. For example, someone might laugh at a joke to be polite, or stifle laughter when they feel it is inappropriate to laugh. This further indicates that facial recognition is not the best path for this research. A better path would be to determine a course of action that removes the abstract difficulty that is "discerning intentions in dynamic human action" and makes it obvious to the robot *exactly* what a human is trying to communicate [2].

The final related work that we will be discussing is a paper written by John Lasseter about 3D computer animation [7]. Although this article does not involve computer animation *per se*, the physical motions and behaviors exhibited by the Nao humanoid robot are just like 3D animations. In fact, the programming environment for the Nao robots has a 3D rendering of what the robots are doing. Since this is the case, Lasseter's paper is extremely relevant. Lasseter discusses the concepts of anticipation and staging. When the Nao robot waves to the user and introduces itself, the user can anticipate the interaction to flow like a conversation. Likewise, many of the jokes set the stage and build up anticipation for the punch lines. The humanoid robot also exhibits the concept of *appeal* that Lasseter describes as "creating a design or an action that the audience enjoys watching." The idea of this article is to promote friendliness and enjoyment when interacting with robots. By having the robot say "it is nice to meet you" and asking for the user's name, we create a design that is appealing [7].

## III. MOTIVATION

We believe that a professional comedian could use this technology to test their ideas for new jokes. Currently comedians try new jokes in smaller markets and cheaper comedy clubs. However, as a particular comedian becomes more popular this gets more and more difficult to do, since many audience members will already know the name and expect a polished show, no matter the price. We believe that a comedian could use a variation of our robot to test the effectiveness of jokes. The robot can remember which jokes are better than others and will be able to respond to the audience well enough that the audience still gets an enjoyable show, no matter how good the experimental jokes actually are.

Another application that has served as a motivation for performing this research was the use of a friendly, joke-telling robot for scenarios involving a need for interaction. For example, children in hospitals or elderly people in nursing homes could use such a humanoid robot as a companion when nobody else is around. In other words, robots can bring joy to the world instead of simply performing jobs that humans find dangerous or undesirable.

On a higher level, the spirit of our approach may be applied in many other ways. A robot that acts as a counselor or teacher will be better able to perform its job if it gets feedback from the user based on positive or negative response. For example, if a teacher hears a student say "I don't understand" or sees them raise a hand, the teacher can adjust their teaching style to better accommodate that particular student. A counselor can also ask different questions or respond in different ways to a patient depending on how they have responded to different techniques.

## IV. APPROACH

In this article, we provide a proof-of-concept model for determining the effectiveness of a humanoid robot that is capable of actively responding to user input using computational awareness. Our method consisted of volunteers interacting with two different robots after watching a video of a human comedian. The comedian video provided the control against which the robots telling jokes could be tested. One robot demonstrated an entirely scripted routine. The other robot performed a variable routine that was modified based on user response, which was gauged by tactile inputs.

The human subject participants were shown the video of the comedian, and then had the chance to interact with each of the robots individually. Fig. 1 shows the experimental setup with one volunteer interacting with one of the two robots. After they were finished, the volunteers were given a survey to provide feedback on each of the demonstrations as well as overall impressions.

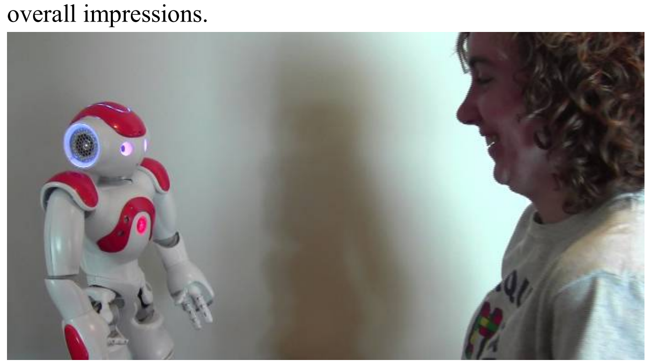

Fig. 1: Experimental setup with humanoid robot comedian with tactile hand sensors and speech generation/recognition turn-taking dialogue with human subject audience member. Photo by Paul Kaefer, used with permission from Christine Matheney.

The initial hypothesis was that the robot with the variable routine would be better liked by the audience. The thought was that a routine that responds to user feedback is more entertaining. A robot with computational awareness should appear more human-like and autonomous.

In this paper, tactile response was used as it yielded consistent results in initial testing. Tactile response provided discrete data for audience favorability of the robot's behavior.

At several points during the interaction, the robot waited for the user to respond, or take their turn at the conversation. This is called perspective-taking, and it plays an important role in the experiment. Trafton *et al.* ran experiments in which various statements such as questions or vague instructions were studied [10]. In order to create a robust experiment that accounts for users who do not have experience with robots, the researchers had to incorporate perspective-taking. It would seem that most people respond to knock-knock jokes with "who's there?" However, sometimes the user's response is vague or pronounced in a different manner. To incorporate perspective-taking, the robots were programmed to recognize a variety of potential responses whenever asking a question that requires user speech input.

After incorporating perspective-taking, there were two main tasks for programming the robot. First was the collection of a large variety of jokes with several different styles, including pun-based one-liners and knock-knock jokes. These were then grouped into categories and programmed into the Nao robots. Second was the development of a way to measure the audience's response to a given joke.

The first approach in measuring audience response was to attempt to measure the amount of audience laughter after each joke. Unfortunately, we were not able to accurately measure the audience response using audio alone. People have different styles of laughter, and sometimes jokes simply evoke a smile, which is impossible to hear. So we decided to implement a touch-based feedback system where an individual audience member can touch either the robot's hand or head to indicate how they felt about the joke.

Gathering user feedback via touch was decided to be an acceptable substitute for volume of laughter. Dare Baldwin and Jodie Baird [2] wrote that "one can carry out a variety of actions to fulfill a given intention." Although humans do not normally tap each others' heads or wrists during typical conversation, doing so while interacting with a robot is done only to communicate intention. The human is able to tell the robot that they do not intend to hear this kind of joke, and the robot is able to recognize that intent.

Fig. 2 illustrates the process taken in this implementation of computational awareness. After telling a joke, the robot determines the audience or user response to the joke based on tactile sensors. If a negative response is detected, the humanoid robot will immediately try a different set of jokes. On a positive response, a weighted random choice is made. It is most likely that the robot will tell a joke from the same set, but there is a small chance that the robot will move on to a different set. This was implemented to encourage continuity. If the user finds every joke humorous, the show will not continue in an infinite loop. In the case that the audience does not respond at all, the default choice is the positive route. This will take advantage of the random choice and will not result in a short show that would happen if the default path was a negative response to each joke.

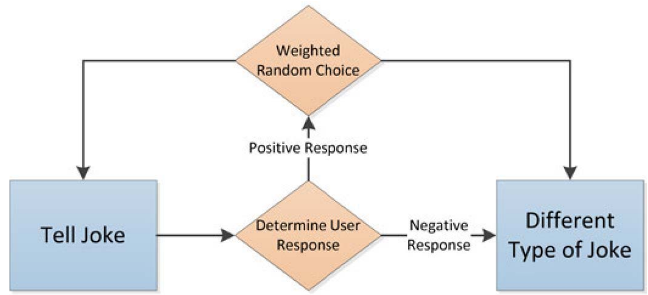


Fig. 2: Flow diagram for responsive humanoid robot comedian with computational awareness.

Using Choregraphe software [1], the set of jokes was encoded and the text-to-speech (TTS) functionality of the robot was employed to tell the jokes to the audience. Initial dry-run tests revealed that in many cases, the TTS software did not correctly pronounce a word. Additionally, many of the jokes were poorly timed. As a result, it was decided to record all of the jokes with human speech, which solved both issues.

John Lasseter from Pixar explains the importance of movement and timing, especially in regards to traditional (two dimensional) animation [7]. These techniques played a big role in the programming of the Nao humanoid robots for the experiment. When the timing of the speech and motions was off, it was immediately obvious and even made the audience uncomfortable. Adding motion, even if it was robotic motion, gave the humanoid robot much more personality. This was important to include so that the experiment was not just about recorded jokes, but rather a robot that was performing a routine involving recorded jokes.

## V. Evaluation and Discussion of Results

Volunteers who participated in the research were asked to fill out a brief questionnaire in response to their interactions. There was a mix of open-ended and quantitative questions, which provided the researchers with data that could be analyzed using statistics as well as qualitative data about the study.

Participants were asked to rate the quality of the jokes and the performer as a whole on a scale of one to five, with five being the best. This was done for each of two humanoid robot demonstrations as well as the comedian video. Participants were asked whether or not they felt the robots understood their reactions, and whether or not they would watch the robot demonstrations again. They were also asked to rank the shows and answer open-ended questions about what they did or did not like about each of the experiences.

A total of 15 volunteers participated in the study. Summary tables of their responses are displayed below.

TABLE I. DID THE ROBOT UNDERSTAND YOU?

| **Demonstration** | **Did you feel that the robot understood your response to its jokes?** | | |
|---|---|---|---|
| | ***Yes*** | ***No*** | ***Other*** |
| Scripted | 12 | 2 | 1 |
| Variable | 7 | 7 | 1 |

The results in Table I show the number of human participants that felt that the robots could understand their responses. This was an important feature of the experiment, as computational awareness depends on the robot having some level of understanding of its audience.

Two things should be noted regarding Table 1. One is that the robot running the variable routine experienced several technical difficulties during the course of the study. This will be further explained later in this article. The second thing to note is what this data reveals that was not discussed by any hypotheses.

The data in Table I indicates that the audience had no idea whether or not the robot was actually responding to the user input that was given. The users may have approached the scripted demonstration thinking that the robot would react to their feedback, which was incorrect. In both cases, the robot encouraged the user to respond to jokes by tapping the robot's head after an enjoyable joke or tapping the robot's wrist after a "bad joke." In the case of the scripted robot, having the user tap the head or wrist may have acted as a placebo action.

TABLE II. WOULD YOU WATCH THE PERFORMANCE AGAIN?

| **Demonstration** | **Would you watch the performance again?** | | |
|---|---|---|---|
| | ***Yes*** | ***No*** | ***Other*** |
| Scripted | 12 | 3 | 1 |
| Variable | 9 | 6 | 1 |

Table II shows results similar to Table I. In this case, the users responded favorably to both routines. They were more likely to want to re-watch the scripted routine, which produced no technical difficulties. Perhaps they were optimistic that a second viewing would go more smoothly.

The researchers also recorded notes about each of the volunteers and how they interacted with the robots. The observations closely matched the results from the surveys.

Fig. 3 shows the average scores that the users assigned to each of the shows as a whole. The approval rating for the human comedian and the robot with the scripted demonstration were not statistically different. The ratings for the robot with the variable script were lower by a statistically significant amount.

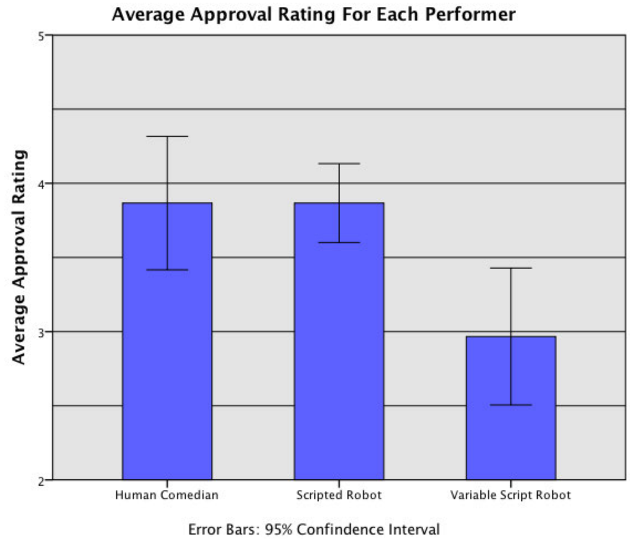


Fig. 3: Average participant approval ratings for each performer, on a scale of 1 to 5. A repeated-measures ANOVA shows a statistically significant difference between the two robot performers' ratings ($p < 0.001$).

It had been expected that the robot with the variable script would receive higher ratings. However, due to technical difficulties or perhaps the order in which the shows took place, the opposite occurred. Each participant saw the three routines in the same order. The human comedian video was first, the scripted robot was second, and the robot with the variable script was seen third. This order may have impacted their overall impressions. Several of the participants commented that the robot routines were too similar. Sometimes they heard the same exact jokes from both of the robots. This may have also contributed to the results discussed previously.

Fig. 4 is consistent with the previous analysis. Both the comedian and the robot with the scripted routine received many first and second place rankings from users. The robot with the scripted routine only received second and third place rankings. The robot with the scripted routine received the largest number of first place rankings.

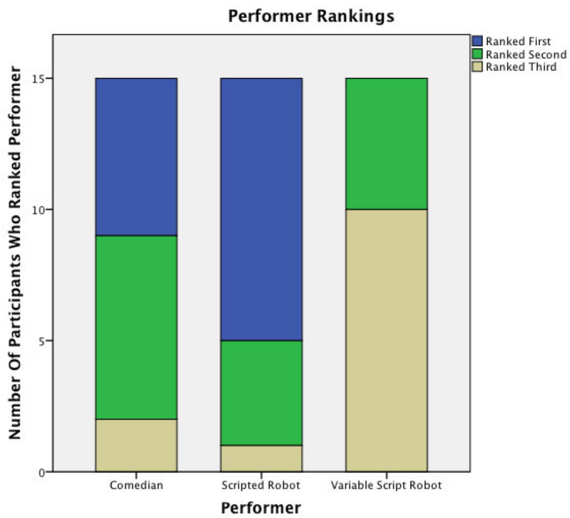


Fig. 4: Performance rankings by routine.

The participants' comments reflect our above analysis. They remarked that there were good jokes in all of the shows, but delivery could have been better, repetition was annoying, and the interaction could have been smoother. Positive comments seemed to suggest that interaction with the robot involved unexpected laughter. Some of the jokes were new to the audience, and it seems the chance to interact with a joke-telling robot was a positive experience overall.

The robot with the variable demonstration experienced several technical issues during the performances. On several occasions, the robot ceased to communicate with the user after telling a few jokes. A couple of times, the robot gave an automated error message along the lines of, "no question received." This not only baffled the researchers, but also annoyed the study participants who only wanted to be entertained. In one instance, the humanoid robot began telling several jokes simultaneously, which was comical, but this also made it difficult to discern what was being said.

The researchers attributed these issues to insufficient testing. Future research will involve more rehearsals before the robot goes before a live audience.

## VI. Conclusions

In conclusion, the results of this study did not support the original hypothesis that a tactile-responsive humanoid robot with computational awareness performs a better comedic routine, but produced important results. Even if a robot does not *actually* respond to user input, making the user feel like they have some control over the robot's actions gives them a better experience. At this point it seems that humans are generally wary of robotic interaction, and maintaining a feeling of control leads to more comfort. At one point, one of the volunteers said, "So creepy. It followed [my eyes]" Although maintaining eye contact seems to be an important part of human behavior, it may be unexpected in a robot and cause discomfort to humans.

An unexpected subtlety was revealed during one of the interactions between a volunteer and a robot. The participant repeatedly touched the robot's hand during a particularly long joke that they didn't like. The robots had been programmed to respond to the wrist touching only *after* each joke had been completed. This interaction made the researchers think about the goal of user feedback. If the user feedback is supposed to make the show more enjoyable, response during a joke should be just as important as a response after a joke has been completely recounted. After all, comedians on stage respond to people "booing" even during a story joke.

Another interesting realization was that occasionally the user will not understand a joke. Rather than simply liking or disliking that particular joke, they might be confused or not fully appreciate the joke. Live comedians sometimes just continue on with a show or make a joke about the audience in this situation. It adds an interesting challenge to determine how a robot should interpret a user having an unexpected reaction.

Comments on the surveys revealed that one reason the comedian video stood out was the presence of jokes related to current events. This hints that not only is variation in joke types preferred, but also that successful comic routines change with the times. A really successful comedian–robot or otherwise–would watch the news or find some other source of new material.

Certain jokes, notably the knock-knock jokes, required vocal user response. We found that including interactive dialogue led the volunteers of the study to think that the robot responded to their feedback. Although one of the robots did not actually respond to tactile input, the fact that the robot did respond to the voice of the audience led the users to believe that tactile feedback was effective as well.

The results of the study show that more work needs to be done in order to determine more conclusively whether or not computational awareness of an audience's response will noticeably affect human-robot interaction. It is likely that, at least in some cases, the audience will be able to determine that the robot has computational awareness, and this will allow the interaction to go more smoothly.

## VII. Future Work

While working on this article, it was realized that the programs used could easily be adapted for riddles or puzzles as opposed to jokes. In this experiment, the robots did most of the talking. The users' primary contribution to the interaction was responding to jokes. If the robot challenged the user to solve a riddle or a puzzle, the human could interact by asking clarifying questions (asking for a hint or responding, "Could you explain…?"). This would give the user more reason to talk and interact. The robot would have to follow a different course based on whatever potentially unpredictable responses the user produced.

In addition to adapting the robot for more purposes, this work could be furthered by improving upon the existing program. It is likely that programming error led to the technical difficulties described above. Perhaps the robot misinterpreted user input, or the preprogrammed path was unclear, leading the robot to behave in unexpected ways.

Whatever the case may be, this study provided the researchers with many perspectives and ideas that may be applied to future work. These ideas include anticipating how the audience will respond to the robots as well as conducting tests to ensure that all use cases are accounted for.

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