Designing Interactions for Artificial Commensal Companions

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Abstract

Eating with others offers several health and social benefits, which could potentially be preserved through the use of robotic companions when dining with another person is not an option. This study examined enjoyment of interaction, social connection, desired features, and concerns regarding a lunchtime commensal interaction between a human and a social robot. Participants were asked to eat lunch, unexpectedly accompanied by a NAO robot capable of conversing with them, and to participate in a qualitative study afterward.

Twenty-two users took part in interviews focused on their experience with a robot and their thoughts on the ideal functionalities an artificial commensal companion should have. Users unanimously enjoyed the interaction, and stated that they would prefer eating with a robot to eating alone. They also suggested novel applications and specific improvements, including stronger personalization and the ability to discuss personal topics and interests as well as show empathy.

CCS Concepts

• **Human-centered computing** → *Human computer interaction (HCI)*; Empirical studies in HCI; • **Computing methodologies** → *Intelligent agents.*

Keywords

Commensality, Social Robotics, Behavioral Modeling, Multimodal Interaction, User Experience

ACM Reference Format:
Hunter Fong, Selim Soufargi, Maurizio Mancini, and Radoslaw Niewiadomski. 2025. Designing Interactions for Artificial Commensal Companions. In *Designing Interactive Systems Conference (DIS '25 Companion), July 05–09, 2025, Funchal, Portugal.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3715668.3736351

ACM ISBN 979-8-4007-1486-3/25/07
https://doi.org/10.1145/3715668.3736351

1 Introduction

Commensality, or eating together, is an age-old practice that has shown to provide a number of health and social benefits, such as, improved mental health, mood, and eating habits [4, 13, 27], group cohesion [6, 9, 11, 15], and the creation of social bonds and identity [10]. Currently, opportunities to eat in the presence of others are less frequent than in the past [10] due to increasing work commitments, remote living, and a general shift toward more solitary lifestyles, especially in Western culture.

Some approaches addressing this gap in human social needs have been proposed by Human-Computer Interaction researchers, such as i) novel interfaces for human-human remote interaction and ii) artificial commensal companions (ACCs) [22]. The former includes, among others, tele-dining [3] and interactive smart tables [1, 5, 20], which facilitate new forms of connection. The latter includes virtual [16, 17, 28, 29] and augmented reality [30] characters, diet coaches [2, 25], and robotic dining companions [8, 14, 18, 19]. In this line, we propose a novel system based on an existing robotic platform that allows for a rich multi-modal interaction with humans during meals. In this paper, we focus mainly on the interaction design and evaluation study. While the literature postulates potential advantages of using such technology, the design choices are challenging, and little is known about how interactions with such companions might unfold. Previous works on this topic propose a range of solutions, starting from speculative designs [14], through pet-like robots with very limited interaction skills and no verbal communication [22], to robots specialized in serving and feeding [21]. An example of such design choices is the ongoing debate on whether artificial companions should simulate food consumption when interacting with humans. On the one hand, preliminary work using robots and AR shows promising results with a small number of participants [7, 8]. On the other hand, questionnaire-based research with potential users revealed strong skepticism toward this idea [12]. Other open choices concern the type of interaction, the use of verbal communication, the topics of conversation, the ability to interact with objects (spoons, mugs, etc.), and even embodiment. Regarding the last point, according to recent study [12] people expect commensal robots not to be overly realistic (humanoid) in appearance.

To address various design questions, we decided to put our users (without notice) face-to-face with the example ACC implementation. Instead of relying solely on theoretical considerations, as proposed in other works (e.g., previously mentioned [12]), we provide users the opportunity to interact with a real companion, enabling them to better understand how such interactions might ideally function. Our robotic companion is able to recognize and interpret human nonverbal behaviors, discuss a variety of topics, and follow social norms of interaction. User experiences are collected through post-experiment interviews. We believe that the unexpected experience with an ACC may provide valuable insights into how such interactions should be designed. This study aims to explore i) the user reception of our robotic companion, as well as ii) the features and conversation topics preferred by potential users of such technology in general. The latter will shape the interactions in subsequent studies potentially enhancing the overall user experience.

2 Research Questions

To explore the potential of robotic companions, our research focuses on the following questions:

- RQ1) Does our commensal robot provide a more enjoyable eating experience than eating alone?
- RQ2) Can our system be viewed as a social dining companion? If so, in which circumstances?
- RQ3) What capabilities do users believe an ideal robotic dining companion should have?
- RQ4) What concerns do users have regarding robotic eating companions?

To address them, we propose a series of qualitative interview questions that the users complete immediately after at least 15 minutes of interaction with the system.

3 System

Our system is able to engage in multi-modal interactions with the user during meals. It conducts conversations on various topics, complemented by gestures and other nonverbal behaviors. The system comprises a *NAO* robot, human activity recognition modules using an RGB camera to collect data about the user, a speech recognition module, and a dialog management system integrated with an LLM model. This specific robot platform was chosen because it is humanoid in appearance, but not overly-realistic–which was a preference of users found in prior research [12]. The robot detects user behaviors, such as when they are speaking, intaking food, chewing, or the direction of their gaze. To detect the user behavior from the video, we use existing datasets of human commensal interactions to train machine learning models, and adapt the existing approaches [23, 31] to operate in real-time in this specific context. Speech recognition is based on existing solutions that is *Google's Speech-Recognition* [32] library. Finally, the robot's behaviors are controlled by a simple yet efficient model based on state machines, an approach that has also been successfully used by other researchers (e.g., [18]). Several rules govern the robot's interactions. For example, the robot, after asking a question, enters an idle state and waits a few seconds for an answer. If no response is received, the robot asks another question after some time. Also, when the robot detects that the user is chewing, it refrains from asking questions and waits briefly before reassessing, and so on. More details on this module can be found in [26].

The prior findings on ACCs [12, 22] showed that potential users of such technology expect a robot to be able to engage in spontaneous conversations on a variety of topics, especially non-personal ones, such as talking about a (current) meal. Unlike other existing ACC implementations (e.g., [18, 23]), our system has the capacity to maintain meaningful dialogues on a variety of topics through the integration of Chat-GPT. It shows proactive verbal behaviors and initiates conversations on new topics. Currently, the system operates only in the English language.

4 Methods

Participants. The participants were 22 volunteers. The majority were male (82%) and between the ages of 18 and 29 (91%), consistent with a university student sample. National origins spanned a range of countries including Italy, Iran, Colombia, Tunisia, China, and Turkey–with 12 participants born in Italy. Over half of the participants (n = 12) reported having previously interacted with a robot, though most noted that these experiences were non-social in nature. The requirements were to be 18 years of age or older and fluent in English.

Materials. (1) A *NAO* robot, connected to ChatGPT via a wireless setup, (2) a computer for running the robot's program and video capturing software, as well as playing the background music, (3) a laptop with a remote desktop to be able to monitor the system during the experiment, (4 and 5) two video cameras: 1 facing the robot, and 1 facing the participant, (6) 1 microphone, (7) an ambient light, (8 and 9) a table and chair for the participant and robot to dine at, and (10) a napkin for the robot to hand the participant were the materials needed for this study.

Procedure. The in-lab portion of the study was scheduled over participant's normal lunch-eating time, and ended when they finished their meal, or after 30 minutes. Upon arrival, participants signed a written consent agreement and information sheet. The participants were told that the study was concerning "how environmental settings affect dining experiences", and true intentions of the study were not revealed before the experiment. To make this statement credible, ambient music and lighting were used during the experiment. It also provided a plausible explanation for why participants would bring their food to the specific room instead of consuming it as they usually would do every day (that is, in the university canteen). We avoided revealing that the experiment involved interaction with a robot to prevent participants from forming strong preconceived notions about the interaction prior to the experiment. It allowed us to avoid recruiting only those interested in robots. Participants were asked not to use their phones or other technology during this lunch. They entered a room set up with a table and a chair facing the robot, which was placed atop the table. A camera was positioned to capture either direction (see Figure 1). A purple light and lo-fi instrumental music were on in the background.

The interaction began with *NAO* powering on and greeting the participant. It asked them to speak in English, and let them know that it sometimes takes a moment to process what they have said and respond. Although the dialog was enhanced with ChatGPT, the robot was proactive, and the initial ice-breaker question always

Figure 1: Top) The setup: the human is sitting in front of the NAO robot, eating the food, and having a conversation with the robot. Two cameras are used to record in sync the robot and human behaviors; bottom) Four participants during their interactions with the robot.

asked by the robot was: "What are you eating today?". After this initial interaction, the robot asked a few more questions about the food's preparation, ingredients, etc.–all the while with ChatGPT facilitating the interaction after the human response, and the robot making periodic gestures. Additionally, the robot could choose to start a new conversation when the user stopped interacting for a period of time from 10 neutral-valence, pre-defined questions concerning things such as hobbies, musical preferences, enjoyment of nature, university life, superpowers that they would like to have, etc. The interaction would end when the user said "Goodbye", and the robot would respond with a friendly sign-off, and power down.

After the study, participants did qualitative interview (via Qualtrics), which involved providing video responses to questions specifically designed in-house for the purposes of this study: 1) Can you see yourself dining with a robot again? Why or why not? 2) In what contexts, situations, or scenarios do you believe this robot as a dining companion would be particularly useful? 3) What capabilities should an ideal robot dining companion possess, according to you? 4) What would your ideal robot dining companion talk about? 5) What can be the disadvantages of introducing such robot dining companions? 6) Do you see any risks or threats or dangers associated with them? 7) How did this last 30 minutes make you feel about your sense of connection to others?

At the end, participants were then given a debriefing revealing the true intent of the study, asked if they had any remaining questions, and informed that they retain the right to withdraw their consent and data at any time.

5 Results

Qualitative responses were analyzed using a grounded theory approach by a single coder, with open coding and thematic categorization used to identify recurring patterns and participant perspectives.

RQ 1: Does our commensal robot provide a more enjoyable eating experience than eating alone? All twenty-two participants stated that they would prefer eating with a robot to eating alone. It is important to note that participants would still prefer to eat with friends or family ("It is definitely more fun to eat in a group of people."), but as one participant described it: "I think that eating alone can be upsetting for a lot of people." Although people would generally agree that eating with a robot is preferable to eating alone, 6 out of 22 participants specifically mentioned that they did not have interest in dining with a robot again unless they could have a deeper and more fluid interaction, and an additional 9 out of 22 participants were potentially interested in an interaction like this in the future, but wished for (1) the interaction to be more "human-like", and (2) for the robot in the interaction to have more advanced features and capabilities. Therefore, if given the option between a robotic commensal companion or eating by oneself, the results suggest that many people would agree with the statement that "Sometimes if I find myself eating alone, it would be a positive, even fun experience to dine with a robot."–but there is room for improvement in both the quality and quantity of the features provided by our ACC.

RQ 2: Can our system be viewed as a social dining companion? If so, in which circumstances? Users truly enjoyed interacting with the robot, and even mentioned it feeling much like human-human interactions, or even more social: "This was my first time dining with a robot…it strangely felt good. It was like I am interacting with my friends." and "While speaking with the robot, I was very conscious of my interactions with humans during my meals. One on one I definitely spoke more with the robot than I do with human counterparts." Feelings of connectedness and a personal interaction are exactly what ACCs should ideally be fostering if we are to reap the benefits of commensality in the absence of other humans. At the same time, multiple users stated that this lunch with an ACC made them reflect on their typical dining companions, and consider that they should eat with their friends and family more. Therefore, supplemental meals with a robot when eating with a human is not possible may actually strengthen human-human bonds. Users mentioned a variety of situations and contexts in which they could see themselves benefiting from this or a similar ACC, but all of them involved solo-dining. Work-time lunches, solo-dining in care-situations, and people who live alone were the circumstances in which our users most readily saw this ACC as a social dining companion.

Finally, several users commented on the pleasant appearance of the robot, with "cute" being a commonly-used descriptor. A dining companion should be designed to look and interact in a manner that puts users at ease. The friendly nature of the interaction, combined with its "cute" appearance, may contribute to the positive perception of our robot as a companion. Further improvements to the system should include ability to display empathy and greater engagement, as suggested by our users. These two features as well as, increased personalization (see RQ3), as postulated by users, might enhance the adoption rates of this technology and deepen the user's sense of social connection with the robot.

RQ 3: What capabilities do users believe an ideal robotic dining companion should have? Participants emphasized service and entertainment features as functional capabilities of the ideal robot, as well as empathetic and social qualities for enhancing conversational interactions.

Capabilities: Multiple users complimented the robot handing them a napkin, but the ability to move drinks, utensils, or other objects on the table was mentioned specifically by four participants. This desire was highlighted by a participant pointing out that without physical capabilities relevant to eating, the robot provides no additional value to a chatbot with similar discussion potential. Interestingly, previous works (e.g., [12]) highlighted user concerns about potential risks related to that functionality, such as the robot dropping objects or accidentally spilling hot food. Additionally, several users specified that the robot does not need to eat, so simulating food consumption might not be a desired feature. Instead, playing videos, music, and providing interesting information (preferably content already attuned to the user's needs) were mentioned as capabilities of an ideal commensal robot companion. Seventeen out of 22 users specifically mentioned wanting their personal interests to be taken into account by the robot to facilitate a more engaging interaction. Integrations with calendar and scheduling apps was a desired feature mentioned by 5 users: "The most important thing for me personally is for it to be able to check future plans while I'm eating. I think it would be more efficient." Additional use cases for a robotic dining companion were identified such as teaching children table manners, encouraging healthy eating choices or assisting with recipes and the preparation of food. The other proposals for commensal robots include being present in the workplace to assist with problems on the job during lunch, and provide news and information on current events, the weather, and other topics of specific interest to the user.

Conversations: Users desired human-like conversation qualities and topics. They mentioned wanting to speak about their current meal, food preparation, current events, etc. All 22 users desired to have conversations about their interests, as opposed to solely small-talk or instructional information. Things such as asking follow-up questions, referencing previous conversations, making comparisons between past and present events, etc. were all mentioned as being ways to improve the fluidity of the interaction, and make it more personal. It was stated that "A dining partner should be able to cover even personal topics." This type of comment is particularly interesting as previous works [12] were suggesting that the ACCs should not address personal topics when interacting with humans. This provides some initial evidence that once people have an actual experience with an ACC, adoption rates and acceptance might be higher and easier to achieve than believed before. This idea of having personal conversations with robots was taken even further by many participants, with explicit suggestions about how the robot might change it's own personality style to adjust to the user's. Users mentioned potential conversation styles based on personality traits such as extroversion and introversion, culture (such as it being common in local culture to discuss food explicitly during meals; 3/22 users), and also on the user's transient moods and feelings: "It depends on my mood [what I would like to speak with a robot about]...maybe sometimes, the robot should just listen to my complaints and problems."

RQ 4: What concerns do users have concerning robotic eating companions? Concerns were that perhaps excessive interaction with ACCs could ultimately lead to more isolation if humans (1) forgot how to interact with one another, or (2) if they began to choose artificial companions over other humans. However, the general feeling was that people will rather prefer human-human interactions, and that the technology is so far from providing better and more fulfilling interactions than a human can, that this is currently a low risk. These concerns align with previous studies on ACC, e.g., [12] highlighted concerns primarily related to: (1) privacy and security, (2) social stigmatization and exclusion, as well as (3) increased social isolation, and other contexts where social robots are introduced [24].

6 Discussion

Users genuinely enjoyed their meal with a robot. The unique nature of this study with its free-form, AI-based conversation, in addition to the qualitative data that were collected has given us the insights necessary to create an improved version of robotic commensal companion. We have gained information about how to improve conversational fluency and tailor conversation topics to users. Most our participants' comments converge on the request for more personalized interaction. While this can be effectively achieved using various automated techniques (e.g., emotion detection, analysis of user profiles, and/or posted social media content), these approaches must be introduced with caution. Personalized interaction requires collecting and processing more personal information, raising important privacy concerns, as noted in previous work [12]. With more data, we will be able to make connections between other variables such as personality, affect, loneliness, and more specific preferences for commensal companion interactions. Furthermore, the free-form nature of the interactions, as confirmed through qualitative interviews, revealed that users experienced a sense of social connectedness to the robot—even though it was a one-time interaction.

Limitations. Improving the robot's skills to increase feelings of shared reality and partner responsiveness during interactions is needed. Furthermore, the perceptions of diverse populations regarding eating with an ACC, as well as their preferences for such interactions (e.g., the elderly, individuals at home, shift workers, etc.), require further investigation, as the current data collection was performed on a rather homogeneous population (mainly young, international, tech-exposed male students). Lyric-less music and dim purple lighting were used during the experiment, however additional configurations were not tested, and thus the specific effects of these environmental cues are unknown.

Future work. We will focus on both (1) improving the robot interaction skills and (2) collecting more quantitative, qualitative, and

behavioral data. Quantitative analyses will be conducted on enjoyment of interaction, feeling of connectedness, and the pace of eating with respect to the variables: personality, general affect, loneliness, commensality habits, and use of technology. Objective behavioral metrics (e.g., response latency, gaze contact duration, smile frequency, eating pace, frequency of interruptions, turn-taking, and so on) will be introduced to further analyze interactions. Many of these measures can be computed automatically from synchronized videos using existing tools, but some may require manual annotation. We also intend to add a solo condition to this experiment and compare enjoyment of the meal with and without a robotic eating companion. Future studies we will also explore the impact of personal vs. impersonal conversations, interactive ACC vs. non-interactive media content, triadic (two humans and one robot) interactions, as well as explore long-term relations to examine novelty effects, relationship development, and emotional resilience over time. The other extension including testing the system in more ecological conditions, including public places such as student canteens.
Conclusions. This work indicates that companions may indeed be a potential social supplement in the absence of human dining companions. Overall, these user quotes sum up this commensal robot interaction best: "It's kind of depressing eating alone", and "This robot is a big advantage for people who don't have that many friends, or are forced to be alone in certain situations". "What could be better than eating with a little cute robot?"

Acknowledgments

This work is supported by the PRIN 2022 project COCOA, PRIN 2022T8ZNNM, funded by the European Union - Next Generation EU (NGEU) Programme, CUP D53D23008850001.

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