“Enjoy, but Moderately!”: Designing a Social Companion Robot for Social Engagement and Behavior Moderation in Solitary Drinking Context

YUGYEONG JUNG, KAIST, Korea
GYUWON JUNG, KAIST, Korea
SOOYEON JEONG, Purdue University, USA
CHAEWON KIM, KAIST, Korea
WOONTACK WOO, KAIST, Korea
HWAJUNG HONG*, KAIST, Korea
UICHIN LEE*, KAIST, Korea

(a) Social engagement (b) Accepting ‘cheers’ interaction (c) Drinking moderation

Fig. 1. Three main interactions with the companion robot. (a) Social engagement: The robot suggests clinking to make it more enjoyable, (b) Accepting ‘cheers’ interaction: When the user offers a toast, the robot accepts it and the user can clink the glass with the robot, (c) Drinking moderation: The robot also regulates drinking when the user drinks too fast by talking and shaking its body.

Socially assistive robots can support people in making behavior changes by socially engaging in or moderating certain behaviors, such as physical exercise and snacking. However, there has not been much work on designing social robots that aim to support both social engagement and behavior moderation, i.e., offering

*Corresponding author

Authors’ addresses: Yugyeong Jung, KAIST, School of Computing, Korea, yugyeong.jung@kaist.ac.kr; Gyuwon Jung, KAIST, School of Computing, Korea, gwjung@kaist.ac.kr; Sooyeon Jeong, Purdue University, Department of Computer Science, USA, Indiana, West Lafayette, sooyeonj@purdue.edu; Chaewon Kim, KAIST, Graduate School of Culture Technology, Korea, chaewonkim.uvr@gmail.com; Woontack Woo, KAIST, Graduate School of Culture Technology, Korea, wwoo.kaist@gmail.com; Hwajung Hong, KAIST, Industrial Design, Korea, honghwajung@gmail.com; Uichin Lee, KAIST, School of Computing, Korea, uclee@kaist.ac.kr.

2573-0142/2023/10-ART237 $15.00
https://doi.org/10.1145/3610028

social interactions for engaging in behaviors without over-engagement. This work explores how social robots can moderate alcohol consumption while socially engaging them in a solitary drinking context. As alcohol consumption can have benefits when done in moderation, this companion robot aims to guide the user toward moderate drinking by using social engagement (i.e., creating an enjoyable atmosphere) and drinking moderation (i.e., regulating the drinking pace). Our preliminary user study (n=20) reveals that the robot is perceived as a friendly companion, and its human-likeness is partly attributed to the robot's intervention. Most participants followed the robot's guidance and perceived it as an intelligent friend due to its social interactions and behavior tracking features. We discuss the benefit of physical interactions for social engagement, utilizing interaction rituals for enjoyable but moderate commensality, and ethical considerations in solitary drinking contexts.

CCS Concepts: • **Human-centered computing** → **Interaction paradigms**; **Interaction design**.

Additional Key Words and Phrases: social companion robot, social engagement design, behavior moderation, solitary drinking

ACM Reference Format:
Yugyeong Jung, Gyuwon Jung, Sooyeon Jeong, Chaewon Kim, Woontack Woo, Hwajung Hong, and Uichin Lee. 2023. "Enjoy, but Moderately!": Designing a Social Companion Robot for Social Engagement and Behavior Moderation in Solitary Drinking Context. *Proc. ACM Hum.-Comput. Interact.* 7, CSCW2, Article 237 (October 2023), 24 pages. https://doi.org/10.1145/3610028

1 INTRODUCTION

Research has been actively conducted in the fields of human-computer interaction (HCI) and computer-supported cooperative work (CSCW) on how humans interact with social robots as partners in our daily lives [48]. Social robots are designed to provide companionship and social support to mitigate loneliness with a physical presence [12]. Furthermore, various design goals also consider facilitating behavioral changes, such as promoting physical exercise for older people [16] or recommending healthy foods to children [76].

Depending on their design goals, social robots may take different approaches, from socially engaging users to push them to do something desirable or moderating users to help them avoid doing something undesirable. For instance, social robots with a physical presence can help users socially engage in healthy habits such as exercising more [16, 61] or consuming nutritious food and drink [75, 81]. Such robots speak and act in a human-like manner and socially engage users by establishing a social rapport. Social companion robots may also be designed to help users regulate unhealthy habits, such as bad snacking [76] by warning users if they do not adhere to expectations.

However, the design of a social companion that both promotes and moderates certain behaviors has not been well explored. One unexplored area of social robots providing only social engagement is that it needs to carefully consider the potential negative consequences when the user is over-engaged in the target behavior. For example, a jogging companion can engage users in enjoyable physical activities, but if a user exercises excessively following the companion's advice (e.g., "*Run more!*") or has an excessive desire to exercise, they can suffer from fatigue or injury. Moreover, a dining companion can share meals with users and socially engage them in eating (e.g., "*Try this food.*"), but if they overly follow the robot, this can lead to overeating or binging on food. Likewise, if social robots simply offer social engagement and take users to enjoyable activities, users can become over-engaged in target behavior [10]. In everyday social contexts, these unregulated or excessive behaviors can be urged to maintain their behaviors at appropriate levels via nudging from family members or friends. Similar to human companions, a social companion robot can also be designed to provide balanced social support through behavioral moderation, not to be over-engaged.

This work explores social robot design in the context of solitary drinking, which requires both social engagement and behavior moderation. Our work belongs to existing HCI scholarship that aims to design technologies for supporting [34, 42] or augmenting [57] eating and drinking experiences; this area is known as computational or digital commensality [64, 82]. In particular, assistive technologies such as socially assistive robots offer social support for dining [42, 55] or guide healthy dietary choices [74, 75]. Similarly, social robots can assist people in solitary drinking contexts, those who drink alone at home and consume alcohol based on their preferences (e.g., choice of liquor, the drinking pace) [78]. For instance, social robots can help mitigate loneliness by offering an enjoyable atmosphere, such as clinking glasses and chit-chatting. However, an enjoyable atmosphere derived from a robotic companion can lead to overly fast or heavy drinking. Even if not because of the robot, they can meet negative consequences if they lack decision-making competence or have alcohol-abuse experiences. In solitary drinking contexts, we should be aware of the harmful health consequences, and thus, it is important for the robot as an ethical machine [88] that can provide balanced social engagement and behavior moderation.

In this work, we consider a social robot that offers and tracks 'cheers' interactions, a physical-social interaction occurring in social drinking. Drinking is typical of commensality: people usually drink and eat with others to feel a sense of belonging and build social bonds [23, 47, 68]. In particular, the 'cheers' interaction (i.e., clinking glasses) is important in social drinking because it builds a sense of *togetherness.* In celebrations or consolations, people often toast by clinking their glasses and saying "*Cheers!*" Particularly in Asian countries, which often value collectivism, these interactions are considered a social norm representing togetherness. In South Korea, 'cheers' interactions frequently occur during social drinking, and almost every drinking occasion involves clinking glasses. Using the social interaction that is already familiar to people, we expect to create solitary drinking in which people can be guided to drink moderately while mitigating their loneliness.

Thus, we designed a robotic companion to mimic a human friend who engages in physical interactions (such as clinking glasses), using verbal and non-verbal cues to implement persuasive interactions by the robot. In particular, we chose the form of a physical robot rather than a virtual avatar to perform actual physical interactions similar to those of social drinking contexts. However, designing a drinking companion requires careful ethical considerations because creating a joyful drinking environment may lead to binge drinking. Therefore, the companion was designed to refuse to continue drinking when the user's drinking pace exceeded a certain threshold and thus guided the user to moderate drinking.

We conducted a preliminary user study with 20 participants with the robot companion. This user study explored (1) perception toward drinking companion and (2) user experiences of adhering to companion's interventions, both in social engagement and behavior moderation. Especially in the latter case, we investigated how well the users accepted the two kinds of intervention and how these interventions affected their drinking behavior. Participants perceived the robot as various social beings due to its *physical and verbal* interactions. Participants tended to follow the robot's recommendations when both engagement and moderation interventions were provided. Furthermore, providing both interventions helped users perceive the robot as human-like, and consider the robot a smart friend capable of behavior tracking and moderation. Our findings highlight the benefits of physical interactions for facilitating social engagement in solitary drinking and suggest design implications for enjoyable but moderate commensality by utilizing socially-appropriate engagement and moderation interventions.

The main contributions of this work can be summarized as follows:

- We designed a social robot supporting social engagement and drinking moderation in solitary drinking contexts.

- We shared our empirical findings from a preliminary user study (N=20) on user perception and experiences interacting with the robot through qualitative analysis.
- We presented design implications on how designers can leverage social robots to support enjoyable but moderate behavior: (1) adopting socio-physical interactions to build social rapport with users, (2) using interaction rituals of social engagement and behavioral moderation by tracking and learning users' behaviors in computational commensality, and (3) considering ethical issues in solitary drinking contexts.

2 BACKGROUND AND RELATED WORKS

2.1 Social Robots and CSCW Research

Social robots have been spotlighted as 'close companions' in everyday life. As the term 'social robot' implies, these robots help with diverse tasks and utilize social communications to support people [17]. In particular, because how they act 'socially' may affect user responses and interactions between robots and users, researchers tried to classify the robots based on several properties (e.g., form, modality, social norms, autonomy, and interactivity) [6] and suggest design guidelines to help users build long-lasting relationships with the robots [19, 51].

The CSCW community has shown a steady interest in socially assistive robots [24] because these robots will play increasingly crucial roles in assisting people with diverse everyday tasks as collaborative social companions (e.g., in elderly care scenarios) [12]. Social robots can provide education/information to complete certain tasks and offer socio-emotional support via companionship and behavioral reinforcement in various contexts, e.g., promoting physical exercise [16], serving as receptionists [50] or outdoor guides [22], engaging in creative tasks [2, 40], assisting in medication intake [60], and coaching presentations [84]. PARO [86] and AIBO [5] help users reduce loneliness and sometimes entertain users with movements and their pet-like appearances. Also, social robots can assist people in diverse contexts, e.g., serving as co-players at children's playgrounds [90], or helping with transport in semi-public hospitals, supporting collaborative staff activities [52]. These works suggest that, beyond chore services, social robots, via their ability to offer enjoyment, sociability, and companionship, have the potential as more than "tools" and can act as "helpful companions" in people's daily lives [18]. This social phenomenon could also be viewed using CASA (Computers Are Social Actors) framework [62] in that users give more meaning to the system similar to a living being rather than regard it as a machine.

Social robots can leverage their unique properties (e.g., physical embodiment and presence) to provide users with an enjoyable and engaging experience, which may be challenging for other virtual agents (e.g., avatars or voice-only systems). For instance, users perceived that an agent was more engaging, credible, and enjoyable to interact with, and they were more motivated to sustain behavior change efforts when interactions were provided via a physically embodied robot rather than a virtual agent [43, 44]. In addition, physically embodied agents are perceived as more socially attractive and yield higher social presence than virtually embodied agents [39].

In this study, we leveraged the properties and advantages of a physical robot. Here, we consider the robot's physical movement to deliver the 'cheers' interaction (i.e., clinking glasses) and mimic the feelings of drinking with friends. There are course alternatives, such as on-screen avatars or voice-only agents (e.g., smart speakers): such social agents could offer a 'safe and anonymous space' for social interaction [4]. However, virtual social agents are not suitable for mimicking the physical interactions we observe in typical drinking contexts. Also, we could connect users online for enjoyable drinking (e.g., video chat), but this would eliminate one of the key reasons for drinking alone: having a full rest without being conscious of others [8]. Accordingly, a robot companion could leverage its advantages in interacting with the user, being an entertaining friend and behavioral coach through multiple types of interaction, including physical interaction, thereby securing the user's time alone and facilitating responsible drinking.

2.2 Monitoring Systems for Responsible Drinking

Many people drink alcoholic beverages at social events, but the popularity of solitary drinking is increasing. According to a study conducted in 2016, 15% of young Canadian adults engaged in solitary drinking [41]. Another survey in Korea (2018) showed solitary drinking peaked for those who were in their 30s (18.5%), whereas social drinking peaked for those in their 50s (68.1%). We posited that the global COVID-19 pandemic had further aggravated the situation because the ratio of people spending time alone at home has increased from 22.4% to 81.9% [59]. These surveys suggest that solitary drinking appears to be a popular trend. Prior studies have warned, however, that when people are alone and without social support, they are more likely to suffer loneliness and depression than engaging in social drinking [31]. Heavy solitary drinkers are exposed to the risk of over-drinking [41] and thus suffer from alcohol-related problems. Therefore, it is important to understand these solitary drinkers and design tools to help them maintain responsible drinking behaviors.

Researchers have actively explored the design of new technologies to track drinking behaviors and promote responsible drinking. Definitions of 'responsible drinking' may vary, but the term generally refers to adhering to safe drinking limits and avoiding harmful consequences [33]. Recent advances in mobile and wearable technologies have brought new opportunities for tracking drinking episodes. Wang et al. [87] designed a Bluetooth-enabled breathalyzer for alcohol-dependent patients; a device greatly lowers the burden of self-tracking. Smartphone sensor data can be leveraged to build a machine learning model that can classify heavy drinking episodes of young adults [3, 69], contexts of alcohol consumption [56, 70]. Similar to food intake detection [83], smartwatches [25] or optical sensors [54] can be used to detect drinking activities.

These studies have laid a foundation for detecting hazardous drinking events via behavioral sensing. However, there is a lack of intervention systems to guide users toward responsible drinking through proper context-aware interventions. Since solitary drinkers are challenged to control their drinking behavior, providing appropriate interventions for behavioral moderation would be beneficial. Thus, our work on social robots builds on existing studies in that we not only track users' drinking behaviors by detecting 'cheers' interactions but also provide nudging interventions to help users drink moderately.

2.3 Intervention Design for Social Engagement and Behavior Moderation

Behavior change interventions are 'coordinated sets of activities to change specified behavior patterns' [58]. They support changing users' behaviors that are considered difficult for users to change by themselves. In fact, providing intervention to change behaviors can be complicated because diverse contexts and components are involved [15].

Depending on the types of behavior intervention, research has been conducted in either *engaging in* desirable behaviors or *moderating* over-engagement that can lead to negative consequences. First, by providing social companionship, the robot interventions can encourage desirable behaviors, such as physical activities [16, 27, 32] that are difficult for users to continue with only self-motivation. Also, some studies have utilized interventions to moderate behaviors so that people are not over-engaged in target behaviors such as excessive smartphone usage [45], binge drinking [28], and bad snacking [76].

Interestingly, behavioral interventions that consider both engagement and moderation have yet to be well explored in prior HCI studies. Existing interventions for behavior engagement have mostly considered less engaging target behaviors, such as those related to health and education.

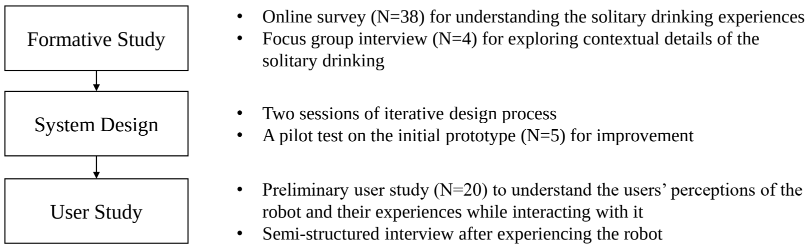


Fig. 2. Overall study procedure. Our study consists of a formative study, a system design, and a preliminary user study

Using techniques such as goal setting and gamification (e.g., badges, points, and financial rewards), agents play the role of content recommenders and behavior reinforcers. However, there is a class of behavior intervention that requires both engagement and moderation. When a social agent is used for behavioral interventions, its engaging features (e.g., gamification and incentives) or target behaviors (e.g., drinking, gaming, and media) may induce and reinforce features that lead to excessive or addictive behaviors (e.g., binge drinking or binge watching) [35, 49]. Intelligent social agents such as drinking buddies use social interactions for behavior engagement; however, in real-world contexts, ethical design should guide users to self-regulate their behavior through appropriate moderation mechanisms. As a case where engaging features and ethical design can be applied, we chose solitary drinking contexts and designed a social robot.

3 FORMATIVE STUDY

Figure 2 illustrates the overall procedures of our study. It consists of (1) a formative study including an online survey and focus group interview, (2) a system design process consisting of iterative design sessions with a pilot test, and (3) a preliminary user study to understand user perception and experiences of interacting with the social robot.

We began with a formative study to understand the context of solitary drinking and determine the system requirements. First, at a large university in South Korea, we conducted an online survey of 38 students (17 women, 21 men; age: $M = 26.2$, $SD = 1.7$) who had experienced solitary and social drinking activities. As shown in Table 1, the survey asked: (1) Why do you drink alone? (2) What are the disadvantages of drinking alone? and (3) What are the advantages of drinking alone? The first had four options, and the second and third were open-ended questions. The responses to the open-ended questions were categorized using affinity diagramming. The results showed that 47% of participants voluntarily chose to drink alone because they wanted to enjoy their time alone; this was the main reason for solitary drinking. In contrast, for some participants, drinking alone was not a choice. For 26% of the participants, mingling and drinking with others became difficult due to their busy schedules. Among the participants, 42% reported feeling lonely while drinking alone, which was the main disadvantage. On the other hand, 49% of participants reported they could drink anytime without scheduling with others, which was the main advantage of solitary drinking.

We then conducted a focus group interview with four participants (2 women, 2 men age: $M = 25.8$, $SD = 2.99$) to understand contextual details. We asked (1) in what context they drink alone, (2) what the differences were between solitary drinking and social drinking, and (3) what they expected from a social companion in a solitary drinking context. We recorded all interview sessions after

Questions	Options / Responses
Why do you drink alone? (Predefined options)	To enjoy my time alone (47%) It is difficult to meet others due to the busy schedule (26%) It is reluctant to drink outside because of COVID-19 (19%) Others (8%)
What are the disadvantages of drinking alone? (Open-ended question)	I feel lonely while drinking alone (42%) I do not have any friends to interact with (26%) It is difficult to control my drinking pace (19%) No response (13%)
What are the advantages of drinking alone? (Open-ended question)	I can drink anytime without scheduling with others (49%) I can hoose drink and food without caring about others (38%) No response (13%)

Table 1. Questions, options, and responses of the online survey

obtaining consent from participants, and the transcribed sentences were grouped using affinity diagramming.

There were various reasons and situations for solitary drinking. They usually drank beer to “*spend time alone at home*” (P01, P02, P03) and “*do leisure activities such as watching video content*” (P02). Also, solitary drinking could “*refresh their mood after a stressful day*” (P02, P04). One of the reasons they started drinking alone was COVID-19. P01 mentioned, “*I enjoyed drinking with my friends, but after COVID-19, I drank alone at home.*” They thought solitary drinking differed from social drinking in that there were no social interactions such as conversation or clinking glasses. P02 felt lonely while drinking alone due to the absence of such social interactions, saying: “*If I drink alone on a stressful day, I feel more lonely because I do not have anyone to talk with.*” P01 thought that the absence of interactions made it difficult to control drinking: “*When I drink with my friends, I can have conversations and perform ‘cheers’ interactions. However, solitary drinking makes me keep drinking without any interaction, so I cannot easily control my drinking.*”

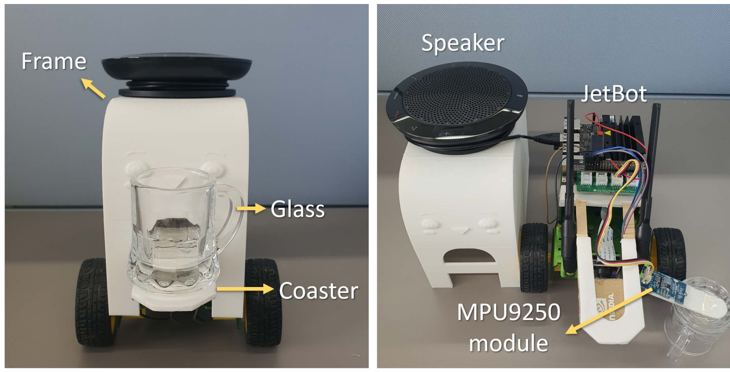
Our participants expected solitary drinking companions to have social interactions similar to those of their friends. For instance, P01 mentioned, “*I wish the robot could clink glasses with me and say ‘cheers!’ Then I may feel as if I were drinking with friends, which will create a social bond.*” P04 was concerned about situations in which she would drink too much with the companion, so she expected that “*the companion would moderate me, pushing me not to drink too much,*” just as her friends did. However, they did not want these companions to be too intrusive. P02 said, “*It would be good if the companion talked to me or clinked glasses, but I would prefer just a simple interaction.*” As for the robot’s appearance, they expected a small companion so as not to be disturbed even when drinking at a table.

4 SYSTEM DESIGN

We conducted two iterative design sessions based on our formative study result to design our social companion robot. To design the initial prototype, we set up the following design rationale.

4.1 Design Rationale

First, the robot can create enjoyable social interactions while moderating the user’s drinking pace. As the formative study results suggested, solitary drinking can induce feelings of loneliness, exacerbated by the absence of social interaction. However, if the robot only focuses on creating



(a) Appearance **(b) Components**

Fig. 3. Hardware setup of the robot; (a) Appearance and (b) Components that make up the system

an enjoyable atmosphere to lessen the user's loneliness, the user may overly engage with robot interaction, leading to over-drinking. Second, the robot can deliver a speech similar to social settings. Participants in the formative study expected the robot to engage in dialogue, just as their friend did.

To persuade users toward enjoyable but moderate drinking, we referred to persuasive system design principles [66], which consists of primary task support, dialogue support, system credibility support, and social support. Primary task support involves helping users perform primary tasks, e.g., guiding users through a process to persuade them along the way. Second, dialogue support, using reminders or suggestions, help users move toward the target behaviors. Third, system credibility helps to build credible systems, such as showing truthful information. Finally, social support motivates users using social influences, such as social comparison.

Among the above, our social robot focuses on (1) primary task support and (2) dialogue support. The primary task our robot pursues is enjoying the moderate pace of drinking. Our robot guides users with a process of 'cheers' interactions and drinking moderation (e.g., it refuses 'cheers' interaction or says 'drink slowly!'). The robot provides proper support dialogue so that users move toward enjoyable but moderate drinking. We investigated what people do in social drinking settings to design the initial dialogue and make the robot a realistic drinking buddy. Our interviews identified several social behaviors: suggesting "Cheers!" and clinking glasses, and sometimes reminding "Slow down!" when their friends drink too quickly. We implemented these conversations and behaviors in the prototype.

After the initial prototype design, we performed a pilot test with five students (2 women, 3 men; age: $M = 29.2$, $SD = 4.7$) with solitary drinking experiences and determined how to improve our initial design. Participants spent 30 minutes interacting with the robot and provided feedback on its appearance and interactions; feedback was eventually applied to our final prototype. In the following, we describe the final prototype's hardware setup and social interaction design and review the major changes that occurred in iterative prototyping.

4.2 Hardware Setup

4.2.1 Appearance. The robot was designed as a character resembling a small pet to give a friendly impression of drinking together at the table, as shown in Figure 3 (a). The robot frame was created using a 3D printer with polylactic acid; its dimensions were 19.3 cm × 14.5 cm × 9.2 cm. This design reflected the opinions of pilot test participants. The initial version was shaped like a simple white box holding a glass. However, participants indicated that, the robot should have a friendly appearance to act as a drinking companion. We redesigned the appearance to include eyes and a mouth to deliver a friendly character.

4.2.2 Robot platform. The body inside the frame was based on JetBot [65], an open-source robot using NVIDIA Jetson Nano (Figure 3 (b)). All interactions with the robot were programmed inside JetBot. We aimed to mimic the gestures of (1) someone reaching out their hand holding a glass for clinking ('cheers' interaction) and bringing their hands back afterward and (2) someone shaking their head to say 'no.' We made the robot move forwards or side by side using its two wheels to implement this.

4.2.3 A Glass and Coaster. On its front side, our robot has a coaster for glass so that it can perform the 'cheers' interaction with the user using real glass, allowing for realistic interaction. Using the MPU9250 motion processing module attached beneath the glass, the robot can detect whether the user made a 'cheers' interaction (Figure 3 (b)). When the user's glass collides with that of the robot and the x, y, and z values of the accelerometer sensor exceed a pre-set threshold, that event is detected as a 'cheers' action by the program in JetBot.

4.2.4 Speaker. A speaker (Jabra Speak 510) connected to JetBot enables simple dialogue between the user and the robot. Using a microphone, it transmits the user's speech to JetBot and enables the robot to recognize simple sentences. When the user calls the robot (e.g., "*Shall we cheers?*"), resulting data is transferred to Picovoice [71] speech-to-intent engine saved in JetBot. The engine infers the spoken words and conveys the detected results to a program running in JetBot, which initiates the 'cheers' interaction. The speaker also delivers the robot's response in verbal form. We used TypeCast [63], a commercial speech-to-text service, to convert the robot's predefined responses (in text) to speech. This service provided various types of voices; we chose one that was friendly (a male character named *Changu*).

4.3 Social Interaction Design

Based on the hardware setup, we designed interactions to help users experience an enjoyable drinking atmosphere (i.e., social engagement) while drinking at a proper pace (i.e., behavior moderation). Our system provides three main interactions people usually engage in the social drinking context: (1) 'cheers' interaction, the clinking of glasses between user and robot, (2) robot gestures of shaking its body for drinking moderation or moving back and forth to suggest 'cheers' interaction, and (3) robot's voice feedback. These three interactions were used to guide users to maintain a moderate drinking pace. In particular, when designing the robot's responses, we considered the time interval of any two consecutive 'cheers' interactions. Each 'cheers' interaction was used as a point at which the user tried to drink, and the robot accepted or refused to clink based on the determined time interval. From our pilot test results, we set 2.5 minutes as the minimum interval the robot would allow a user to drink; thus, it functions as a criterion for 'moderate drinking.' If we assume a user takes a normal sip of a can of beer and that it takes approximately ten sips to finish that can, then it takes at least 25 minutes per can, which would be considered an acceptable pace that is not too fast. In addition, if the user does not do anything for 5 minutes after the last 'cheers' interaction, the robot comes to the user and suggests a 'cheers' interaction. This is based on our pilot test result that the robot should not only wait for the user's suggestion but also initiate interactions.

Figure 4 shows the interaction flow with the robot, and Table 2 shows sets of corresponding voice feedback. In each situation, one of three types of voice feedback is delivered randomly to user. As described in Figure 4 and Table 2, we have three cases (i.e., situation (a), (b), and (c)) depending on when user attempts a 'cheers' interaction with robot and a reaction (i.e., situation (d)) after user

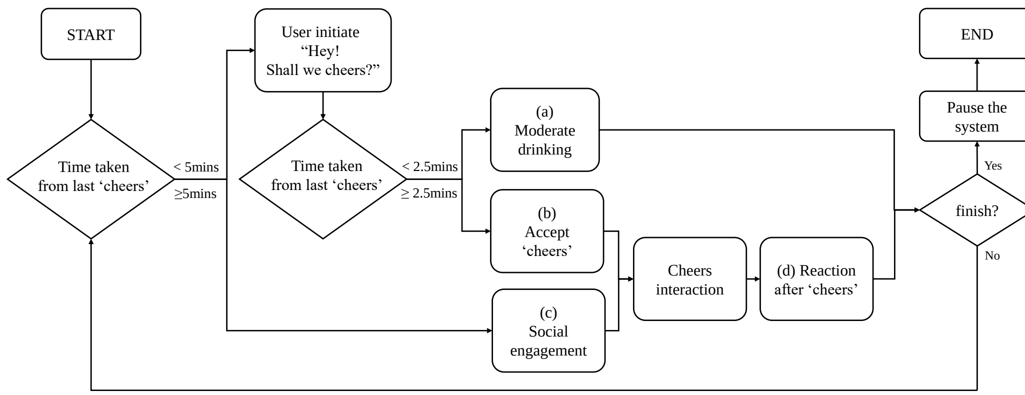


Fig. 4. Interaction diagram of the robot

Situation	Description	Voice feedback
(a) Moderate drinking	If the user tries 'cheers' within 2.5 mins from the last interaction; the robot says 'no' by shaking its body	"*Drink slowly!*" "*It is too fast. Please wait.*" "*Aren't you drinking too fast?*"
(b) Accept 'cheers'	If the user tries 'cheers' between 2.5 to 5 mins from the last interaction; the robot says 'yes' with moving toward the user	"*Sure. Cheers!*" "*Okay. Come on.*" "*Great. Cheers with me!*"
(c) Social engagement	If the user does not do 'cheers' more than 5 mins from the last interaction; the robot initiates 'cheers' interaction and moves toward the user	"*Shall we cheers?*" "*Please have cheers with me.*" "*I'm bored. Cheers with me!*"
(d) Reaction after 'cheers'	After the 'cheers' interaction, the robot goes back to where it was while showing a simple reaction	"*Cheers!*" "*Wow, good.*" "*So cool!*"

Table 2. Sets of voice feedback of the robot

and robot clink their glasses. The robot can moderate interaction with a warning message and a short body shake as a gesture (like people shaking heads to say 'no') if a user tries again within 2.5 minutes of the last interaction (a). If the user suggests clinking glasses between 2.5 and 5 minutes (b), the robot will accept, provide a gesture of moving toward the user, and perform 'cheers' with a simple reaction (d). If the robot waits more than 5 minutes from the last 'cheers' (c) since the user does not attempt any interaction, the robot initiates 'cheers' and shows the reaction described in (d).

In our initial design, we focused on regulating the amount of drinking, assuming that user is drinking too much if the number of 'cheers' interaction exceeds a pre-set threshold. However, all participants in the pilot study mentioned that focusing on the drinking pace would be better. Based on their solitary drinking experiences, they first decided how much they wanted to drink (e.g., two cans or bottles of beer) and took that quantity from the refrigerator. They could easily check how much they had drunk by looking at the amount of beer left in the cans or bottles. On the other hand, they wanted to check their drinking pace through our robot companion because they sometimes got drunk without knowing how fast they were drinking. Thus, our robot's final design guides user based on drinking pace.

5 PRELIMINARY USER STUDY

We conducted a preliminary user study to understand (1) users' perceptions of robot and (2) user experiences of engaging and moderating interventions. In the following, we introduce our user study procedure.

5.1 Method

5.1.1 Participants. We recruited 20 participants (7 women, 13 men; age: M = 23.9, SD = 2.3) through an online campus community. We targeted participants who had previously engaged in solitary drinking; they reported they drank alone 2.7 times per month on average. We administered the Alcohol Use Disorders Identification Test (AUDIT) [67] questionnaire to screen out those who might have risky alcohol consumption behaviors. According to the WHO guideline [67], only participants with low-risk consumption (test scores of 7 or lower) were recruited (score: M = 3.45, SD = 2.16). We checked the amount of alcohol they usually drank and ensured there was no problem with drinking a can of beer.

5.1.2 Study Setup. We provided participants with brief introductions to the robot and what they should do during the experiment. We introduced our robot as a drinking companion that could create an enjoyable atmosphere via 'cheers' interaction while moderating overly-fast drinking. Subsequently, as shown in Figure 5, we conducted a user study at a place that represents where they regularly engage in solitary drinking (i.e., at home). The participants drank a can of beer (5% alcohol, 500mL) and were given a glass to perform the 'cheers' interaction. They were asked to say "Shall we cheers?" whenever they wanted to drink. We asked them to drink only after engaging in a 'cheers' interaction with the robot. To make the environment natural, we placed a tablet on the desk where they could watch a video (Netflix: Our Planet) while drinking. The user study lasted 40 minutes.

5.1.3 Data Collection and Analysis. During the user study, the interactions were recorded after obtaining consent from the participants. After this drinking session, we conducted a 30-minute-long semi-structured interview to understand users' experiences with the robot. All interview sessions were recorded and transcribed. We performed thematic analysis [9] to analyze the transcribed interview data. Each interview sentence was given a code representing its meaning, and codes with similar meanings were clustered into themes. To analyze the results, we prioritized the themes mentioned by their frequency, and two researchers performed all review and revision processes.

5.1.4 Compensation and Safety Rules. The participants were paid 89 USD as compensation for their participation. We chose to offer a high compensation owing to the difficulties in recruiting participants to attend offline user studies (because of the COVID-19 situation) and the risk of drinking alcohol during the user study. Following Institutional Review Board (IRB) recommendations, we informed them in advance that they were allowed to quit the study at any time if they felt unwell. We minimized the risk of drinking alcohol by letting participants go home only after verifying their blood alcohol concentration (BAC) was < 0.03%. We checked the BAC using a breathalyzer (Sentech AL8000), and it took a few hours for participants to be able to leave the lab.

5.2 Result

5.2.1 Impact of physical and social interactivity on perceived companionship. To determine what robot companion meant to users when they drank with it, we first analyzed participants' perceptions of robot. Owing to the main functions of the robot, (1) participating in a 'cheers' interaction and (2) providing verbal responses, eleven participants responded they felt as if they were drinking with their "friends". The participants reported they frequently performed the 'cheers' interaction

Fig. 5. Preliminary user study setup

when drinking with friends in social settings, such as “*at the very beginning of drinking*” (P03), “*to suggest a drink together in the middle of the party*” (P15), and “*to lighten up the mood*” (P07). Eight participants regarded physically clinking glasses with the robot as ‘cheers’ interactions with their friends, which made them recall their prior experiences of social activities. P02 mentioned, “*This ‘cheers’ interaction created a mood similar to a party’s.*” As a result, the participants performed ‘cheers’ with the robot “*to accelerate an exciting atmosphere like that when they drink with friends.*” (P16) Among the eight participants, three mentioned that the physical collision of glasses seemed to be important in creating a feeling similar to that of the social drinking context; P11 mentioned, “*The cheerful sound of clinking glasses was so good to me; it was just like having a drink with my friends.*” Sometimes, the participants favored the physical interaction itself, as P02 stated, “*I enjoyed a pleasant feeling when I clinked glasses with the robot.*”

Additionally, six participants said the robot’s verbal responses made them feel as if there were with friends. P06 talked about the robot’s response after the cheers interaction, saying “*After clinking glasses, the robot said something like ‘Cheers!’, which reminded me of when I was drinking with my friends.*” Four participants were impressed with the robot-initiated interaction, which they said resembled their friends’ responses. “*When I was doing nothing for a while, the robot asked me to drink together. It was just like my friends who wanted to drink with me.*” (P14) They found these robot-initiated interactions created a more enjoyable atmosphere because “*it was interesting to guess what the robot would say next time.*” (P10) From these results, we found that the physical interactions and verbal responses helped the participants enjoy the time even when alone.

Five participants described the robot as someone other than a friend because of its unique appearance and behavior. P11 recalled his pet and stated, “*It was like a pet coming up and tapping me as if it wanted my attention.*” Similarly, P03 said, “*I thought the robot being nearby was quite similar to how my pet would be next to me.*” Alternatively, P20 described the robot’s behavior as like that of “*a bartender who only listens to me while staying quiet.*” As such, the participants regarded the robot as various companions. This kind of anthropomorphism or zoomorphism [21] regarding the robot partly made the participants emotionally attached when interacting with it. P09 said, “*I bet I will get more attached to it if I use it in my everyday life.*” P14 also acknowledged she would become attached to the robot, saying “*I think I felt affection in that we did something together, right next to each other.*”

Furthermore, when they regarded the robot as a drinking buddy, they began expecting more functions such as diverse conversations (seven participants), physical interactions (four participants), and gestures (six participants) that resembled the context of drinking with real friends. For instance, they wanted more sophisticated conversations so as “*to build a bond of sympathy through conversations*” (P12) and “*to be comforted by the emotional state*” (P07), that may be commonly found in interactions among humans. However, two participants sometimes preferred the robot’s simple and limited set of conversations, as P01 said: “*I often get tired of having a conversation when I drink with friends. In that sense, it made me relaxed not to have to talk much with the robot.*” They were impressed with the physical interactions and gestures of the robot, but their expectations got higher, seeking more realistic interactions, like those possible with human counterparts (e.g., “*more cheerful or stronger clinking of glasses*” (P03, P15) or “*stretching its arm toward the user to perform a ‘cheers’ interaction*”(P13)).

In summary, the participants perceived the robot as a friendly social companion because of its physical, auditory, and gesture interactions. They had higher expectations of the robot, believing certain tweaks could create more engaging experiences like those possible when drinking with friends.

5.2.2 Interactions for social engagement and drinking moderation.

Compliance Rates and Number of Interactions for Social Engagement and Drinking Moderation Interventions. Based on video recorded (except for one participant with missing recording) during the user study, we examined how many times participants complied with the robot’s social engagement and drinking moderation. Generally, there were 207 interaction events with robot, and 125 of them were cases in which the robot accepted the ‘cheers’ when the user suggested it first. The remaining 82 events were composed of cases in which the robot (1) socially engaged in drinking (i.e., when the robot initiated interaction by saying “*Shall we cheers?*”) and (2) moderated drinking (i.e., when the user initiated a ‘cheers’ interaction but the robot refused it); these occurred 43 and 39 times, respectively. As described in Table 3, the participants followed the robot’s interventions in most cases: 39 out of 43 events for engagement (90.7%) and 29 out of 39 events for moderation (74.3%). This shows that participants were more likely to follow robot intervention when it was engaging than when it was moderating.

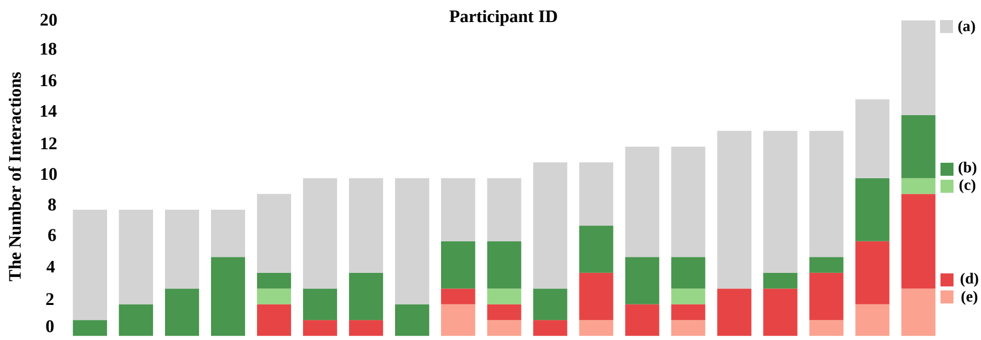
When participants interacted with the robot, there were cases in which the robot did not recognize users’ words (speech-to-intent engine detection error) or the interaction of clinking glasses (accelerometer sensor detection error). In our study, the error rate of the speech-to-intent engine was 7.64%, and that of the accelerometer sensor was 5.56%. To cope with errors, participants kept calling the robot (P01, P04, P16, P17, P18, P20) or attempted to ‘cheers’ several times (P01, P04, P07, P13, P14, P16, P17, P19). However, three participants (P06, P09, P19) gave up calling the robot and drank beer alone.

Figure 6 describes interactions that occurred for each user; it shows the different interactions experienced by users and how they responded to them. They either experienced a few monotonous interactions, such as those of P06 or P10 (i.e., one intervention type with the following only), or numerous diverse ones, such as those of P04 and P19 (i.e., two intervention types with both following and not). It should be noted that, in the figure, the darker green/red ratio for each user is greater than that of lighter ones, indicating that in most cases, participants responded well to the robot’s engaging and moderating interventions.

Reasons for Complying with Each Intervention. We analyzed the interview results to understand what made participants follow the robot’s recommendations. They reported how they came to follow the interventions for each behavior engagement and moderation. When the robot engaged the participants, 90.7% of participants accepted the suggestion. As stated earlier, they perceived these robot-initiated interactions as analogous to their friends’ behavior and reacted naturally (i.e., clinking glasses and drinking) as they would when they were with their friends. P14 explained, “*Although it was not human, I felt like I was interacting with someone else. I always take a sip after a ‘cheers’ interaction with other people, and I did the same naturally when I drank with the robot since it*

	User, Follow intervention	User, Not follow intervention	Total
Robot, Socially engaging	39 (case (b))	4 (case (c))	43
Robot, Moderate drinking	29 (case (d))	10 (case (e))	39
Total	68	14	82

Table 3. Distributions of robot-initiated engaging/moderation interactions. There were 207 interactions in total, and 125 cases omitted in this table were user-initiated and robot-accepted cases (i.e., the user first suggested drinking together, and the robot took it)



	P06	P08	P02	P05	P09	P11	P07	P14	P18	P01	P16	P15	P12	P04	P10	P20	P17	P13	P19
(a)	7	6	5	3	5	7	6	8	4	4	8	4	7	7	10	9	8	5	6
(b)	1	2	3	5	1	2	3	2	3	3	2	3	3	2	0	1	1	4	4
(c)	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1
(d)	0	0	0	0	2	1	1	0	1	1	1	3	2	1	3	3	3	4	6
(e)	0	0	0	0	0	0	0	0	2	1	0	1	0	1	0	0	1	2	3
Sum	8	8	8	8	9	10	10	10	10	10	11	11	12	12	13	13	13	15	20

Fig. 6. The number of interactions with the robot for each situation; (a) users suggested ‘cheers’ interaction and the robot accepted it (b) the robot proactively engaged users in ‘cheers’ and users followed it (c) the robot proactively engage users in ‘cheers,’ but users did not follow it (d) users suggested ‘cheers’ interaction and the robot moderated, and users followed it (e) users suggested ‘cheers’ interaction and the robot moderated, but users did not follow it.

acted like a human being.” From the recorded video, we also observed participants’ responses to the engagement intervention; they became amused and laughed or talked with robot. For instance, participants laughed out loud (P15, P17) or smiled (P01, P03, P06, P08, P17, and P19) while looking at the robot. In addition, they responded to the robot’s suggestion, saying, “*Come on, let us clink glasses right away!*” (P15) or “*Okay, cheers!*” (P01, P20). These results indicate that the robot’s socially engaging intervention helped make participants’ solitary drinking enjoyable by using interactions that were familiar to them.

Conversely, the participants responded that the robot’s behavior-moderating interventions helped them not to drink too fast, especially from two perspectives: (1) by making them reflect on their drinking pace and (2) by persuading them as a trustworthy social companion. Six participants reported they did not care about their drinking pace when they drank alone. P20 commented, “*I usually drink alcoholic beverages as fast as if I were drinking water. I would have drunk more if* *the robot had not rejected my cheers suggestion.*" (P12) However, in this study, participants found themselves drinking quite fast and tried to follow the pace suggested by the robot. "*I usually drink fast; however, when the robot told me not to drink, I slowed, realizing my fast drinking pace.*" (P09) This reflection not only made them aware of their drinking pace but also allowed them to consider what would happen if they kept drinking too fast. "*As I listened to what the robot said, I thought, 'Will tomorrow not be a tough day if I drink in this way?' and complied with the robot's message.*" (P20) Moreover, five participants regarded the robot as a persuasive social companion and cared a lot about what it said during their drinking. They trusted and followed the robot's interventions because they thought it utilized objective measures. They expected "*It would have criteria for a proper drinking pace which may be beneficial to follow*" (P04) and "*their pace would be evaluated objectively, not in an ad-hoc way.*" (P20) Further, the robot's friendly appearance and reaction affected the user's decision to follow the intervention, as two participants stated: "*I would be sorry if I ignored the robot's message,*" (P17) and "*If I had not followed the robot, I would have felt I was bothering this cute friend.*" (P15) In summary, our robot helped participants moderate their drinking by nudging them to rethink their drinking behavior and persuading them with data-driven and reliable messages.

Benefits of Combining Both Interventions. In addition to the benefits from each engaging and moderating intervention, we found certain advantages from providing both together. Nine participants experienced human-like characteristics from the robot, which made interventions more persuasive. They found a human-likeness to the robot in that it did not keep repeating the same intervention but showed different ones according to the situation. "*It would have been like a robot if it had simply said 'Drink slowly!', but it felt more like a human being when the robot responded flexibly in different directions (sometimes allowing my drinking).*" (P10) Similarly, P01 stated, "*I knew this robot did not always suggest a 'cheers' interaction. This also happens when I drink with other people. Thus, I felt it was more like a human, making me feel that the robot was psychologically close to me.*" This human-like aspect also helped users reduce their reluctance toward the robot's interventions. P07 stated: "*If it keeps telling me not to drink, I would say, 'Why don't you just tell me to quit drinking for good!' and abandon using it. However, because the robot intervened in both engaging and moderating ways, I thought it really cared about me, considering the situation and trying to guide me to moderate drinking, not simply forcing me to stop drinking.*" P17 also mentioned, "*People do not always make the same decision, and I think the robot's choices resemble human judgment. As a result, I felt less reluctant to follow the robot's interventions.*"

Six participants even believed the robot was a smart friend who carefully considered the user's situation. P07 mentioned, "*The method of alternating between engagement and moderation seemed to maintain the behavior at a certain level, like 'homeostasis,' and I thought this robot was intelligently helping me!*" P20 referred to the robot's advantages over human friends, adding, "*If I drink with friends, we may drink fast unconsciously, owing to the pleasant and buzzy feelings. However, the robot seems so helpful that it can always suggest the right pattern considering my health or context.*"

Moreover, four participants mentioned that they considered the robot's interventions important messages that could not be easily ignored. P11 mentioned, "*If my friend keeps asking me not to drink, I will not take it seriously, thinking he will repeat the same thing. However, the robot seemed to value the importance of both enjoying and drinking in moderation, which was more rational to me. Therefore, I followed the messages.*" Providing both types of intervention aroused participants' curiosity, helped them to be more concerned about it, and caused them to follow the robot's advice as much as possible. P09 compared the intervention to a guessing game about moderate drinking behavior: "*I was curious about how the robot would react because it was like a roulette game. When the robot accepted my suggestion, I counted it as a success, but it was a failure if it rejected me.*" P20 tried to find the proper drinking pace to perform the 'cheers' interaction with the robot successfully. "*At first, I was rejected because I called the robot too frequently. However, I tried my best to find the optimal pace so as not to be rejected by the robot.*"

Reasons for Ignoring the Robot's Interventions. In most cases, participants followed the robot's interventions; however, the robot was likely to be ignored when users' preferred drinking pace and intervention criteria did not match well. Eight participants sometimes did not follow the robot's suggestions because either "*the pace of the robot's suggestion was faster than their pace.*" (P04) or "*they wanted to drink faster than the robot's rule.*" (P10) The robot's intervention criteria were also fixed, indicating it may not consider changing drinking speed over time. "*I drank fast at the beginning and got slower as the trial continued; however, it seemed the robot did not properly keep up with my pace.*" (P01)

Even when users ignored interventions, the robot was still advantageous, keeping up its intervention while not forcing anything. Participants who did not drink when the robot suggested drinking clinked their glasses only, which may not have been easy if they were drinking with others. "*When I am with others, I am worried they will feel bad if I refuse to drink. However, when I drink with the robot, I do not need to think about that; thus, it is comfortable.*" (P09) Similarly, P17 stated, "*I thought it was not mandatory to follow when the robot prohibited drinking because it was just a guideline, and choosing to drink or not was entirely up to me.*" Consequently, the robot can lessen the burden of caring about what others feel and provide a mild interaction to guide users by leveraging social norms.

6 DISCUSSION

6.1 Physical-Social Interaction Support for Persuasive Engagement Design

In this study, we designed and developed a social companion robot in the context of solitary drinking and explored users' perceptions and experiences. Our robot aimed to guide users toward moderate drinking by providing (1) physical interaction, (2) gestures, and (3) speech. Our results show that most participants followed the interventions for the following reasons. They perceived the robot as various social entities owing to its physical-social interactions. In addition, they believed the guidance provided by the robot was reliable, based on objective measures. Therefore, our findings show that the robot was perceived as a persuasive companion.

In particular, the major physical interaction ('cheers') provided by the robot played an important role in persuasion by building social rapport with users; they considered the experience similar to that with human friends in the context of social drinking, even though the "robot" companion delivered it. Clinking glasses with other people has a special meaning of *togetherness*, and most participants were familiar with this social norm. Following this social norm, they regarded the robot as a familiar friend who could physically clink a glass with them; however, for future work, they hoped that this interaction would be delivered in a more realistic way, as they would do with their friends. Similar to research on social robots performing handshaking [73], physical interactions can play a role in eliciting well-known social norms such as greetings or agreements [72] and building close relationships with users [85].

Building social rapport with robots has, as a result, made robots more persuasive companions. These findings are consistent with prior research, which has found that social robots' behaviors such as whispering [80] or dialogue [53] can elicit user compliance by building social rapport. Especially in our context, physical interaction ('cheers'), as it helps to build social rapport and elicit normative behaviors, may play an important role in persuading users to moderate their drinking. Following previous research, our findings show the importance of physical interaction in building social rapport and further contribute to the field of persuasive social robots.

6.2 Leveraging Social Engagement and Behavior Moderation for Computational Commensality

As a technology probe [37] providing social engagement and behavior moderation, our social robot design can contribute to ongoing social robot studies. Social robots have been designed with single-phase intervention, such as helping users socially engage in a target behavior [16, 36, 55]. In contrast, our robot provides multi-phase interventions, balancing social engagement and behavioral moderation to guide users toward target behavior (e.g., enjoyable but moderate drinking). Thus, our robot differs from previous studies in that it provides companionship by socially engaging while moderating the over-engagement *together*.

In our preliminary study, one of the key findings about a social robot providing multi-phase interventions was that the robot was perceived as having human-like features. The two interventions can be interpreted using the concept of *interaction rituals* that describe the ceremonial nature of everyday social interactions [13, 30]. In particular, Goffman's presentational rituals elaborate on an action of deference and are concerned with how an entity regards or treats the *recipient* to communicate meaning such as care, esteem, or togetherness [26, 29]. Presentational rituals include social behaviors such as greetings, salutations, or gestures that are expected in specific social situations. For example, when a serving robot navigating a narrow corridor encounters a human, it may follow interaction rituals of human-human crossing behaviors by rotating its body or performing sliding motions [77]. Similar to how people behave during social settings, our social robot included interaction rituals of engagement and moderation: social engagement like '*Cheers*' can be a sign of togetherness, and moderation such as '*Drink slowly*' can be a sign of caring. Providing such interaction rituals was regarded as how a human coach or a friend suggests healthy behaviors by considering the negative consequences of over-drinking. This kind of human-likeness can be explained through the lens of intentional stance [11], which guides people to interpret the behavior of an entity as a rational agent that makes choices based on its desires with consideration. Our participants interpreted the robot as having persuasive intent; its healthy choices came from the desire to help users moderate their drinking. In this process, the ability to think, reason, and act like a human was projected onto a non-human rational agent [20], which helped to make the robot more persuasive.

This persuasive human-like aspect (e.g., providing engagement and moderation together) can be applied to social companions in commensal settings. In computational commensality, there are two possible scenarios: to enhance (1) human-human interaction and (2) interaction between a human and an artificial companion [64]. As the artificial companion, our robot was mainly designed to facilitate the 'commensal drinking' of solitary drinkers. In further steps, this can be extended to other commensal scenarios, and there are diverse design spaces for enabling computational commensality. Similar to our social robot design, we can use socially-appropriate interaction rituals for behavior engagement and moderation. Let us assume a dining companion sitting in front of a solitary diner. For social engagement, a robot can engage in diverse rituals using physical-verbal behaviors similar to those people usually engage in. It can say '*Enjoy your meal.*' or suggest '*Cheers*' before the meal, or mimic the eating gestures and sometimes say '*Yummy!*' during the meal, as a sign of togetherness. At the same time, the robot can be used to moderate any negative results caused by an enjoyable atmosphere or the users' problematic habits. With signs of caring and consideration, it can provide rituals in diverse dimensions, like (1) eating pace, (2) kinds of food, and (3) eating amount. For instance, for a user who enjoys a meal with a robot but eats only pizza, the robot could say, "*I am worried that you are only eating high-calorie food. Why don't you stop eating that and try the salad?*"

To moderate users in diverse dimensions, the social robot needs to track and learn their eating behaviors (e.g., kinds of food, how quickly or how much they eat). Food detection [1, 38] or eating activity recognition [7] technologies, discussed in the computational commensality field, can be utilized to detect these behaviors. Additionally, if a robot can calculate users' recommended daily energy intake based on weight or sex and learn their health status (e.g., obesity or diabetes), it may be possible to provide a personalized level of engagement and moderation. As a result, we envision that social companion robots that provide behavioral moderation based on behavior tracking with social engagement can create 'enjoyable but moderate commensality' in our daily lives.

6.3 Ethical Considerations for Responsible Drinking Companion Design

Excessive alcohol consumption can cause several negative consequences. Thus, we acknowledge the need for careful ethical considerations when designing a social robot that engages people in such a context. In the study, our robot was designed to guide users to drink at a moderate level. However, there still is a possibility that users may misunderstand the system's intention (i.e., to drink moderately) and think as if the robot *only* promotes their drinking. Positive social interactions or emotional bonding with the robot could also reinforce or encourage some people to consume more alcohol than usual, resulting in negative health outcomes.

To prevent these undesired consequences, it is critical for the robot to communicate its role and purpose to users. For example, the robot could start interacting with the user by introducing its objective clearly, so that the user could perceive this robot as a responsible drinking companion. As in navigational warning systems, it should notify that its purpose is to build an enjoyable atmosphere with emotional support (e.g., not feeling lonely) but not to promote risky drinking behaviors.

In addition, the system could provide educational information regarding possible negative consequences of alcohol consumption and resources for self-assessment for those needing more professional help. For example, the robot could raise users' awareness of their health by providing warning messages (e.g., "Excessive drinking may harm your health."), an approach similar to that used in online video games [89]. The system should monitor user's drinking behavior and offer resources based on their risk of an alcohol use disorder, such as a gentle warning message to forcibly restrict the activity [46] or social support [87]. In our future work, we plan to monitor users via self-reported assessments (e.g., the AUDIT questionnaire [14]) and behavioral measures (e.g., the amount of alcohol consumed) to identify potential risks and provide health education and resources. Exploring responsible companion system design that protects users from potential ethical concerns while providing a novel user experience will be a future research direction.

6.4 Limitations and Implication for Future Research

In this study, we recruited college students in South Korea to design and evaluate our drinking companion robot. We acknowledge there was a lack of diversity in the participants. Their similar background may have resulted in a cultural-specific response, affecting robot design and evaluation. For generalizability, follow-up user studies are required in which participants from diverse backgrounds are recruited, considering such factors as age, job, and culture.

As a preliminary user study, we explored how users react to a social robot in a solitary drinking context. The design of controlled experiments will be required to gain a deeper understanding of the effects of robot companions. For example, we can compare users' drinking behaviors (1) when they are with/without the robot or (2) when robots with different intervention styles are used (e.g., engagement only, moderation only, or combinations of both). Also, the pace of intervention provided by the robot was constant, without considering individual characteristics (e.g., weight or sex). To better design interventions, we can use a systematic approach to calculate the proper drinking pace; the Widmark formula, which estimates blood alcohol content by considering body mass index, can be used in one possible approach.

Due to IRB restrictions, we conducted an in-lab user study that simulated a solitary drinking experience at home. The study may not represent people's solitary drinking behavior well because it was conducted in an unfamiliar space, and the participants knew that the researchers were observing their behaviors. Since this was not a long-term study, the novelty effect of the robot might also have influenced how users engaged with the robot. Our follow-up study will be conducted in a real-world setting, deploying this robot in users' homes. This in-the-wild experiment will require careful ethical scrutiny because of possible risky drinking behaviors that may harm participants' health during their engagement with the social robots. In field studies, we should also be cautious about potential confounders or other variables affecting user interactions with robots. Possible alternative approaches will be to set up semi-naturalistic environments where users can participate in field studies at home, but researchers mediate sessions remotely.

In future work, social robots providing engagement and moderation can also be applied to other scenarios. For example, exercising with a jogging companion robot [32] can encourage users to keep exercising; however, moderation can also be considered to prevent harmful consequences like over-exercising ("*You look tired. Let's wrap up today's exercise.*"). Furthermore, a social robot can play a card game with a child [79] for entertainment, but it can also provide moderation so that the child does not become addicted to playing enjoyable games with the robot ("*You played too many games with me. Let's take a break and do it again later!*"). As such, we envision that these social robot designs can help to make enjoyable but moderate behaviors in our daily lives.

7 CONCLUSION

We presented a social robot that offers enjoyable drinking experiences while avoiding over-engagement by providing both social engagement and behavior moderation in a solitary drinking context. Our goal was to explore how the users perceive the companion robot and their experiences when interacting with the robot. Results from our study showed that the robot's behaviors, such as clinking glasses, voice feedback, and gestures, reminded the users of the context when they drank with their friends. They tended to trust the robot or became emotionally attached to it so that they would eventually follow the interventions for moderate drinking. Moreover, participants experienced human-like features from the robot because of its physical presence as well as its intervention style, and they were more persuaded partly due to these features. In this sense, our approach showed the feasibility of utilizing a social robot combining social engagement and behavior moderation to guide users' behavior to be enjoyable but in moderation. However, further studies are needed to examine its effect on the user's behavior in a more natural, real-world setting.

Based on the findings, we discussed the benefit of supporting physical-social interactions for persuasive social companion design and suggested design implications toward enjoyable but moderate commensality. We expect that our findings can be extended to other domains on health-related behaviors, and it can be further studied in the HCI and CSCW fields to better guide user behavior moderately as a "smart and caring companion."

ACKNOWLEDGMENTS

This research was supported by LGE-KAIST Digital Health Research Center (DHRC) and by the Institute of Information communications Technology Planning Evaluation (IITP) grant funded by the Korean government (MSIT) (No. 2022-0-00064, Development of Human Digital Twin Technologies for Prediction and Management of Emotion Workers' Mental Health Risks). SJ was supported by the T32MH115882 grant from the National Institute of Mental Health (NIMH).

REFERENCES

[1] Eduardo Aguilar, Marc Bolaños, and Petia Radeva. 2017. Food recognition using fusion of classifiers based on CNNs. In *International Conference on Image Analysis and Processing*. Springer, Springer International Publishing, Cham, 213–224.

[2] Safinah Ali, Tyler Moroso, and Cynthia Breazeal. 2019. Can Children Learn Creativity from a Social Robot?. In *Proceedings of the 2019 on Creativity and Cognition* (San Diego, CA, USA) *(C&C '19)*. Association for Computing Machinery, New York, NY, USA, 359–368. https://doi.org/10.1145/3325480.3325499

[3] Sangwon Bae, Denzil Ferreira, Brian Suffoletto, Juan C Puyana, Ryan Kurtz, Tammy Chung, and Anind K Dey. 2017. Detecting drinking episodes in young adults using smartphone-based sensors. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 1, 2 (2017), 1–36.

[4] Petter Bae Bae Brandtzæg, Marita Skjuve, Kim Kristoffer Kristoffer Dysthe, and Asbjørn Følstad. 2021. When the Social Becomes Non-Human: Young People's Perception of Social Support in Chatbots. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 257, 13 pages. https://doi.org/10.1145/3411764.3445318

[5] Marian R Banks, Lisa M Willoughby, and William A Banks. 2008. Animal-assisted therapy and loneliness in nursing homes: use of robotic versus living dogs. *Journal of the American Medical Directors Association* 9, 3 (2008), 173–177.

[6] Christoph Bartneck and Jodi Forlizzi. 2004. A design-centred framework for social human-robot interaction. In *RO-MAN 2004. 13th IEEE international workshop on robot and human interactive communication (IEEE Catalog No. 04TH8759)*. IEEE, 591–594.

[7] Yin Bi, Wenyao Xu, Nan Guan, Yangjie Wei, and Wang Yi. 2014. Pervasive eating habits monitoring and recognition through a wearable acoustic sensor. In *Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare*. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), Brussels, BEL, 174–177.

[8] Brian Borsari and Kate B Carey. 2001. Peer influences on college drinking: A review of the research. *Journal of substance abuse* 13, 4 (2001), 391–424.

[9] Virginia Braun and Victoria Clarke. 2012. *Thematic analysis.* American Psychological Association.

[10] Massimiliano L Cappuccio, Eduardo B Sandoval, Omar Mubin, Mohammad Obaid, and Mari Velonaki. 2021. Can robots make us better humans? *International Journal of Social Robotics* 13, 1 (2021), 7–22.

[11] Daniel Clement. 1996. *Kinds of Minds: Toward an Understanding of Consciousness.* Basic Books.

[12] Simon Coghlan, Jenny Waycott, Amanda Lazar, and Barbara Barbosa Neves. 2021. Dignity, autonomy, and style of company: dimensions older adults consider for robot companions. *Proceedings of the ACM on human-computer interaction* 5, CSCW1 (2021), 1–25.

[13] Randall Collins. 2014. Interaction ritual chains. In *Interaction Ritual Chains*. Princeton university press.

[14] Katherine M Conigrave, Wayne D Hall, and John B Saunders. 1995. The AUDIT questionnaire: choosing a cut-off score. *Addiction* 90, 10 (1995), 1349–1356.

[15] Peter Craig, Paul Dieppe, Sally Macintyre, Susan Michie, Irwin Nazareth, and Mark Petticrew. 2008. Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ* 337 (2008), 1–6. https://doi.org/10.1136/bmj.a1655 arXiv:https://www.bmj.com/content/337/bmj.a1655.full.pdf

[16] Dagoberto Cruz-Sandoval, Christian I. Penaloza, Jesús Favela, and Allan P. Castro-Coronel. 2018. Towards Social Robots That Support Exercise Therapies for Persons with Dementia. In *Proceedings of the 2018 ACM International Joint Conference and 2018 International Symposium on Pervasive and Ubiquitous Computing and Wearable Computers* (Singapore, Singapore) *(UbiComp '18)*. Association for Computing Machinery, New York, NY, USA, 1729–1734. https://doi.org/10.1145/3267305.3267539

[17] Kerstin Dautenhahn. 2007. Socially intelligent robots: dimensions of human–robot interaction. *Philosophical transactions of the royal society B: Biological sciences* 362, 1480 (2007), 679–704.

[18] Maartje MA De Graaf and Somaya Ben Allouch. 2013. Exploring influencing variables for the acceptance of social robots. *Robotics and autonomous systems* 61, 12 (2013), 1476–1486.

[19] Maartje Ma De Graaf, Somaya Ben Allouch, and Tineke Klamer. 2015. Sharing a life with Harvey: Exploring the acceptance of and relationship-building with a social robot. *Computers in human behavior* 43 (2015), 1–14.

[20] Brian R Duffy. 2003. Anthropomorphism and the social robot. *Robotics and autonomous systems* 42, 3-4 (2003), 177–190.

[21] Noah Duncan, Lap-Fai Yu, Sai-Kit Yeung, and Demetri Terzopoulos. 2015. Zoomorphic design. *ACM Transactions on Graphics (TOG)* 34, 4 (2015), 1–13.

[22] Vanessa Evers, Nuno Menezes, Luis Merino, Dariu Gavrila, Fernando Nabais, Maja Pantic, and Paulo Alvito. 2014. The Development and Real-World Application of FROG, the Fun Robotic Outdoor Guide. In *Proceedings of the Companion Publication of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing* (Baltimore, Maryland, USA) *(CSCW Companion '14)*. Association for Computing Machinery, New York, NY, USA, 281–284. https://doi.org/10.1145/2556420.2557638

[23] Catharine E Fairbairn and Michael A Sayette. 2014. A social-attributional analysis of alcohol response. *Psychological bulletin* 140, 5 (2014), 1361.

[24] David Feil-Seifer and Maja J Mataric. 2005. Defining socially assistive robotics. In *9th International Conference on Rehabilitation Robotics, 2005. ICORR 2005.* IEEE, 465–468.

[25] Simon Flutura, Andreas Seiderer, Ilhan Aslan, Chi-Tai Dang, Raphael Schwarz, Dominik Schiller, and Elisabeth André. 2018. DrinkWatch: A Mobile Wellbeing Application Based on Interactive and Cooperative Machine Learning. In *Proceedings of the 2018 International Conference on Digital Health* (Lyon, France) *(DH '18)*. Association for Computing Machinery, New York, NY, USA, 65–74. https://doi.org/10.1145/3194658.3194666

[26] Noah Franken. 2010. *Honest but Hurtful Messages in Romantic Relationships*. Ph. D. Dissertation. University of Wisconsin-Stevens Point, College of Fine Arts and Communication.

[27] Prathik Gadde, Hadi Kharrazi, Himalaya Patel, and Karl F MacDorman. 2011. Toward monitoring and increasing exercise adherence in older adults by robotic intervention: a proof of concept study. *Journal of Robotics* 2011 (2011), 1–11.

[28] Claire Garnett, David Crane, Robert West, Jamie Brown, and Susan Michie. 2019. The development of Drink Less: an alcohol reduction smartphone app for excessive drinkers. *Translational behavioral medicine* 9, 2 (2019), 296–307.

[29] Erving Goffman. 1956. The nature of deference and demeanor. *American anthropologist* 58, 3 (1956), 473–502.

[30] Erving Goffman and Joel Best. 2017. *Interaction ritual: Essays in face-to-face behavior.* Routledge.

[31] Vivian M Gonzalez and Monica C Skewes. 2013. Solitary heavy drinking, social relationships, and negative mood regulation in college drinkers. *Addiction Research & Theory* 21, 4 (2013), 285–294.

[32] Eberhard Graether and Florian Mueller. 2012. Joggobot: A Flying Robot as Jogging Companion. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems* (Austin, Texas, USA) *(CHI EA '12)*. Association for Computing Machinery, New York, NY, USA, 1063–1066. https://doi.org/10.1145/2212776.2212386

[33] Heather M Gray, Rhiannon C Wiley, Pat M Williams, and Howard J Shaffer. 2021. A scoping review of "responsible drinking" interventions. *Health communication* 36, 2 (2021), 236–256.

[34] Catherine Grevet, Anthony Tang, and Elizabeth Mynatt. 2012. Eating alone, together: new forms of commensality. In *Proceedings of the 17th ACM international conference on Supporting group work*. Association for Computing Machinery, New York, NY, USA, 103–106.

[35] Mark Griffiths. 1995. Technological addictions. *Clinical Psychology Forum* 76 (01 1995), 14–19.

[36] Arzu Guneysu and Bert Arnrich. 2017. Socially assistive child-robot interaction in physical exercise coaching. In *2017 26th IEEE international symposium on robot and human interactive communication (RO-MAN)*. IEEE, 670–675.

[37] Hilary Hutchinson, Wendy Mackay, Bo Westerlund, Benjamin B Bederson, Allison Druin, Catherine Plaisant, Michel Beaudouin-Lafon, Stéphane Conversy, Helen Evans, Heiko Hansen, et al. 2003. Technology probes: inspiring design for and with families. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. Association for Computing Machinery, New York, NY, USA, 17–24.

[38] Wenyan Jia, Yuecheng Li, Ruowei Qu, Thomas Baranowski, Lora E Burke, Hong Zhang, Yicheng Bai, Juliet M Mancino, Guizhi Xu, Zhi-Hong Mao, et al. 2019. Automatic food detection in egocentric images using artificial intelligence technology. *Public health nutrition* 22, 7 (2019), 1168–1179.

[39] Younbo Jung and Kwan Min Lee. 2004. Effects of physical embodiment on social presence of social robots. *Proceedings of PRESENCE* 2004 (2004), 80–87.

[40] Peter H. Kahn, Takayuki Kanda, Hiroshi Ishiguro, Solace Shen, Heather E. Gary, and Jolina H. Ruckert. 2014. Creative Collaboration with a Social Robot. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (Seattle, Washington) *(UbiComp '14)*. Association for Computing Machinery, New York, NY, USA, 99–103. https://doi.org/10.1145/2632048.2632058

[41] Matthew T Keough, Roisin M O'Connor, and Sherry H Stewart. 2018. Solitary drinking is associated with specific alcohol problems in emerging adults. *Addictive behaviors* 76 (2018), 285–290.

[42] Rohit Ashok Khot, Eshita Sri Arza, Harshitha Kurra, and Yan Wang. 2019. FoBo: Towards Designing a Robotic Companion for Solo Dining. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, 1–6. https://doi.org/10.1145/3290607.3313069

[43] Cory D Kidd and Cynthia Breazeal. 2004. Effect of a robot on user perceptions. In *2004 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)(IEEE Cat. No. 04CH37566)*, Vol. 4. IEEE, 3559–3564.

[44] Cory D Kidd and Cynthia Breazeal. 2008. Robots at home: Understanding long-term human-robot interaction. In *2008 IEEE/RSJ International Conference on Intelligent Robots and Systems*. IEEE, 3230–3235.

[45] Jaejeung Kim, Joonyoung Park, Hyunsoo Lee, Minsam Ko, and Uichin Lee. 2019. LocknType: Lockout Task Intervention for Discouraging Smartphone App Use. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI '19)*. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3290605.3300927

[46] Orsolya Király, Mark D Griffiths, Daniel L King, Hae-Kook Lee, Seung-Yup Lee, Fanni Bányai, Ágnes Zsila, Zsofia K Takacs, and Zsolt Demetrovics. 2018. Policy responses to problematic video game use: A systematic review of current measures and future possibilities. *Journal of Behavioral Addictions* 7, 3 (2018), 503–517.

[47] Emmanuel Kuntsche, Ronald Knibbe, Gerhard Gmel, and Rutger Engels. 2005. Why do young people drink? A review of drinking motives. *Clinical psychology review* 25, 7 (2005), 841–861.

[48] Cliff Lampe, Bob Bauer, Henry Evans, Dave Robson, Tessa Lau, and Leila Takayama. 2016. Robots As Cooperative Partners... We Hope.... In *Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion* (San Francisco, California, USA) *(CSCW '16 Companion)*. Association for Computing Machinery, New York, NY, USA, 188–192. https://doi.org/10.1145/2818052.2893360

[49] Robert LaRose. 2007. Uses and gratifications of Internet addiction. *Internet addiction: A handbook and guide to evaluation and treatment* (2007), 55–72.

[50] Min Kyung Lee, Sara Kiesler, and Jodi Forlizzi. 2010. Receptionist or Information Kiosk: How Do People Talk with a Robot?. In *Proceedings of the 2010 ACM Conference on Computer Supported Cooperative Work* (Savannah, Georgia, USA) *(CSCW '10)*. Association for Computing Machinery, New York, NY, USA, 31–40. https://doi.org/10.1145/1718918.1718927

[51] Iolanda Leite, Carlos Martinho, and Ana Paiva. 2013. Social robots for long-term interaction: a survey. *International Journal of Social Robotics* 5, 2 (2013), 291–308.

[52] Sara Ljungblad, Jirina Kotrbova, Mattias Jacobsson, Henriette Cramer, and Karol Niechwiadowicz. 2012. Hospital Robot at Work: Something Alien or an Intelligent Colleague?. In *Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work* (Seattle, Washington, USA) *(CSCW '12)*. Association for Computing Machinery, New York, NY, USA, 177–186. https://doi.org/10.1145/2145204.2145233

[53] Gale M. Lucas, Jill Boberg, David Traum, Ron Artstein, Jonathan Gratch, Alesia Gainer, Emmanuel Johnson, Anton Leuski, and Mikio Nakano. 2018. Getting to Know Each Other: The Role of Social Dialogue in Recovery from Errors in Social Robots. In *Proceedings of the 2018 ACM/IEEE International Conference on Human-Robot Interaction* (Chicago, IL, USA) *(HRI '18)*. Association for Computing Machinery, New York, NY, USA, 344–351. https://doi.org/10.1145/3171221.3171258

[54] Hidenori Matsui, Takahiro Hashizume, and Koji Yatani. 2018. Al-Light: An Alcohol-Sensing Smart Ice Cube. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* 2, 3, Article 126 (sep 2018), 20 pages. https://doi.org/10.1145/3264936

[55] Derek McColl and Goldie Nejat. 2013. Meal-time with a socially assistive robot and older adults at a long-term care facility. *Journal of Human-Robot Interaction* 2, 1 (2013), 152–171.

[56] Lakmal Meegahapola, Florian Labhart, Thanh-Trung Phan, and Daniel Gatica-Perez. 2021. Examining the Social Context of Alcohol Drinking in Young Adults with Smartphone Sensing. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 5, 3 (2021), 1–26.

[57] Yash Dhanpal Mehta, Rohit Ashok Khot, Rakesh Patibanda, and Florian'Floyd' Mueller. 2018. Arm-a-dine: towards understanding the design of playful embodied eating experiences. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*. Association for Computing Machinery, New York, NY, USA, 299–313.

[58] Susan Michie, Maartje M Van Stralen, and Robert West. 2011. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation science* 6, 1 (2011), 1–12.

[59] Ministry of Food and Drug Safety, Republic of Korea. 2020. *The spread of COVID-19 reduces overall drinking but increases 'drinking alone' and 'home drinking' (in Korean)*. https://www.mfds.go.kr/brd/m_99/view.do?seq=44892 (accessed: 2022-02-15).

[60] Tamanna Motahar, Md. Fahim Farden, Md. Atiqul Islam, Rahat Jahangir Rony, and Dibya Prokash Sarkar. 2018. Mini Nurse-Bot: A Healthcare Assistance for Elderly People. In *Proceedings of the 2018 ACM International Joint Conference and 2018 International Symposium on Pervasive and Ubiquitous Computing and Wearable Computers* (Singapore, Singapore) *(UbiComp '18)*. Association for Computing Machinery, New York, NY, USA, 170–173. https://doi.org/10.1145/3267305.3267662

[61] Florian 'Floyd' Mueller and Matthew Muirhead. 2015. Jogging with a Quadcopter. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) *(CHI '15)*. Association for Computing Machinery, New York, NY, USA, 2023–2032. https://doi.org/10.1145/2702123.2702472

[62] Clifford Nass, Jonathan Steuer, and Ellen R. Tauber. 1994. Computers Are Social Actors. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Boston, Massachusetts, USA) *(CHI '94)*. Association for Computing Machinery, New York, NY, USA, 72—-78. https://doi.org/10.1145/191666.191703

[63] Neosapience. 2022. *Typecast*. https://typecast.ai/ (accessed: 2022-02-15).

[64] Radoslaw Niewiadomski, Eleonora Ceccaldi, Gijs Huisman, Gualtiero Volpe, and Maurizio Mancini. 2019. Computational Commensality: from theories to computational models for social food preparation and consumption in HCI. *Frontiers in Robotics and AI* 6 (2019), 119.

[65] NVIDIA. 2022. *JetBot*. https://jetbot.org/master/index.html (accessed: 2022-02-15).

[66] Harri Oinas-Kukkonen and Marja Harjumaa. 2009. Persuasive systems design: Key issues, process model, and system features. *Communications of the association for Information Systems* 24, 1 (2009), 28.

[67] World Health Organization et al. 2001. *AUDIT: The alcohol use disorders identification test: Guidelines for use in primary health care.* Technical Report. World Health Organization.

[68] Patrick M O'Malley, Lloyd D Johnston, and Jerald G Bachman. 1998. Alcohol use among adolescents. *Alcohol health and research world* 22, 2 (1998), 85.

[69] Thanh-Trung Phan, Florian Labhart, Skanda Muralidhar, and Daniel Gatica-Perez. 2020. *Understanding Heavy Drinking at Night through Smartphone Sensing and Active Human Engagement.* Association for Computing Machinery, New York, NY, USA, 211–222. https://doi.org/10.1145/3421937.3421992

[70] Thanh-Trung Phan, Skanda Muralidhar, and Daniel Gatica-Perez. 2019. Drinks & crowds: Characterizing alcohol consumption through crowdsensing and social media. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 3, 2 (2019), 1–30.

[71] Picovoice. 2022. *Picovoice: Edge Voice AI Platform.* https://picovoice.ai/ (accessed: 2022-02-15).

[72] Vignesh Prasad, Ruth Stock-Homburg, and Jan Peters. 2021. Human-robot handshaking: A review. *International Journal of Social Robotics* (2021), 1–17.

[73] Vignesh Prasad, Ruth Stock-Homburg, and Jan Peters. 2021. Learning Human-like Hand Reaching for Human-Robot Handshaking. In *2021 IEEE International Conference on Robotics and Automation (ICRA).* IEEE, 3612–3618.

[74] Natasha Randall, Swapna Joshi, and Xiaohang Liu. 2018. Health-e-eater: dinnertime companion robot and magic plate for improving eating habits in children from low-income families. In *Companion of the 2018 ACM/IEEE international conference on human-robot interaction.* Association for Computing Machinery, New York, NY, USA, 361–362.

[75] Hannes Ritschel, Andreas Seiderer, Kathrin Janowski, Ilhan Aslan, and Elisabeth André. 2018. Drink-O-Mender: An Adaptive Robotic Drink Adviser. In *Proceedings of the 3rd International Workshop on Multisensory Approaches to Human-Food Interaction* (Boulder, CO, USA) *(MHFI'18).* Association for Computing Machinery, New York, NY, USA, Article 3, 8 pages. https://doi.org/10.1145/3279954.3279957

[76] Nicole L Robinson, Jennifer Connolly, Leanne Hides, and David J Kavanagh. 2020. Social robots as treatment agents: Pilot randomized controlled trial to deliver a behavior change intervention. *Internet Interventions* 21 (2020), 100320.

[77] Emmanuel Senft, Satoru Satake, and Takayuki Kanda. 2020. Would You Mind Me if I Pass by You?: Socially-Appropriate Behaviour for an Omni-based Social Robot in Narrow Environment. In *2020 15th ACM/IEEE International Conference on Human-Robot Interaction (HRI).* IEEE, Association for Computing Machinery, New York, NY, USA, 539–547.

[78] KO Seungduk and SOHN Aeree. 2018. Behaviors and culture of drinking among Korean people. *Iranian journal of public health* 47, Suppl 1 (2018), 47.

[79] Suleman Shahid, Emiel Krahmer, and Marc Swerts. 2014. Child–robot interaction across cultures: How does playing a game with a social robot compare to playing a game alone or with a friend? *Computers in Human Behavior* 40 (2014), 86–100.

[80] Masahiro Shiomi, Kayako Nakagawa, Reo Matsumura, Kazuhiko Shinozawa, Hiroshi Ishiguro, and Norihino Hagita. 2010. "Could i have a word?": Effects of robot's whisper. In *2010 IEEE/RSJ international conference on intelligent robots and systems.* IEEE, 3899–3904.

[81] Elaine Short, Katelyn Swift-Spong, Jillian Greczek, Aditi Ramachandran, Alexandru Litoiu, Elena Corina Grigore, David Feil-Seifer, Samuel Shuster, Jin Joo Lee, Shaobo Huang, et al. 2014. How to train your dragonbot: Socially assistive robots for teaching children about nutrition through play. In *The 23rd IEEE international symposium on robot and human interactive communication.* IEEE, 924–929.

[82] Charles Spence, Maurizio Mancini, and Gijs Huisman. 2019. Digital commensality: Eating and drinking in the company of technology. *Frontiers in psychology* 10 (2019), 2252.

[83] Edison Thomaz, Irfan Essa, and Gregory D. Abowd. 2015. A Practical Approach for Recognizing Eating Moments with Wrist-Mounted Inertial Sensing. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing* (Osaka, Japan) *(UbiComp '15).* Association for Computing Machinery, New York, NY, USA, 1029–1040. https://doi.org/10.1145/2750858.2807545

[84] Ha Trinh, Reza Asadi, Darren Edge, and T Bickmore. 2017. Robocop: A robotic coach for oral presentations. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 1, 2 (2017), 1–24.

[85] Mohamed Yacine Tsalamlal, Jean-Claude Martin, Mehdi Ammi, Adriana Tapus, and Michel-Ange Amorim. 2015. Affective handshake with a humanoid robot: How do participants perceive and combine its facial and haptic expressions?. In *2015 International Conference on Affective Computing and Intelligent Interaction (ACII).* IEEE, 334–340.

[86] K. Wada, T. Shibata, T. Saito, and K. Tanie. 2003. Effects of robot assisted activity to elderly people who stay at a health service facility for the aged. In *Proceedings 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2003) (Cat. No.03CH37453)*, Vol. 3. 2847–2852 vol.3. https://doi.org/10.1109/IROS.2003.1249302

[87] Kuo-Cheng Wang, Yi-Hsuan Hsieh, Chi-Hsien Yen, Chuang-Wen You, Yen-Chang Chen, Ming-Chyi Huang, Seng-Yong Lau, Hsin-Liu (Cindy) Kao, and Hao-Hua Chu. 2014. SoberDiary: A Phone-Based Support System for Assisting Recovery

from Alcohol Dependence. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication* (Seattle, Washington) *(UbiComp '14 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 311–314. https://doi.org/10.1145/2638728.2638847

[88] Alan F Winfield, Katina Michael, Jeremy Pitt, and Vanessa Evers. 2019. Machine ethics: The design and governance of ethical AI and autonomous systems [scanning the issue]. *Proc. IEEE* 107, 3 (2019), 509–517.

[89] Shumaila Yousafzai, Zaheer Hussain, and Mark Griffiths. 2014. Social responsibility in online videogaming: What should the videogame industry do? , 181–185 pages.

[90] Cristina Zaga, Alejandro Moreno, and Vanessa Evers. 2017. Gotta Hatch 'em All!: Robot-Supported Cooperation in Interactive Playgrounds. In *Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing* (Portland, Oregon, USA) *(CSCW '17 Companion)*. Association for Computing Machinery, New York, NY, USA, 347–350. https://doi.org/10.1145/3022198.3026355

Received July 2022; revised January 2023; accepted March 2023