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The Robot Tangy Facilitating Trivia Games: A Team-based User-Study with Long-Term Care Residents

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***Abstract*—Robot facilitated cognitive interventions for older adults have mainly focused on one-on-one interactions or with groups of people each individually playing. In this paper, we present the design of the socially assistive robot, Tangy, for autonomously facilitating the team-based cognitively stimulating activity of Trivia with older adults which encourages users to interact with each other. A pilot study at a local long-term care facility with older adult residents demonstrated that Tangy could successfully facilitate Trivia games. In general, the participants were engaged in the activity, complied with the robot's requests, and had positive attitudes towards Tangy during the games. The Trivia game scenario also promoted cooperation and interactions between teammates. Furthermore, we compared the results in this study with the results of our previous study on the individually played game of Bingo. The comparison results showed that participants complied with the robot and were engaged during both activities, however, the team-based Trivia had higher levels of engagement and player interaction.**

Keywords—Socially Assistive Robots, Cognitively Stimulating Activities, Human-Robot Interaction, Team-based Games

I. Introduction

Aging is associated with a natural decline in cognitive abilities and presents the greatest risk factor for mild cognitive impairments and Alzheimer's disease [1]. As older adults age, they are also more likely to reside in residential facilities as they require support with activities of daily living (ADL) [2]. These ADLs include instrumental (i.e., personal hygiene and housekeeping) and recreational (i.e., games, reading a book) activities to maintain/improve quality of life. Participating in recreational activities is important as it can aid in improving an individual's overall cognitive and physical abilities, allow him/her to function independently, maintain social connections and lead to a reduction in mortality [3].

Cognitive stimulation programs that focus on recreational activities for older adults have been shown to provide both functional and behavioral benefits [4],[5]. Functional benefits have included increased speed of processing, reduced memory decline, and an increased capacity to independently conduct ADL (e.g. money management, travel, and health). Behavioral benefits have included increased participation in cognitively stimulating activities, and decreased behavioral disturbances (e.g. anxiety, apathy, and irritability). Furthermore, such organized recreational activities can provide older adults with a structured setting for social engagement with others. Improving an elderly individual's social network has been shown to reduce mortality, reduce the risk of isolation and depression, and delay age-related health decline [6].

To implement and facilitate such programs requires a considerable amount of time from caregivers. However, due to high staff-to-resident ratios, caregivers already lack the time to facilitate recreational activities as they spend a significant amount of their time focusing on assisting older adults with instrumental activities of daily living [7]. As a result, there is an insufficient number of such recreational programs in residential facilities; therefore, residents feel under-stimulated and bored [7]. The use of autonomous socially assistive robots to provide cognitive training to older adults via recreational activities can lessen the burden placed on staff and provide the needed stimulation to the residents.

In this paper, we present the design and implementation of the socially assistive robot, Tangy, for the novel application of autonomously facilitating the team-based group recreational activity of Trivia with older adults living in long-term care (LTC). We selected Trivia since it is a cognitively stimulating activity which promotes the training of the working memory, provides information about a variety of topics, and promotes social interactions between players [9]. A pilot human-robot interaction (HRI) study was conducted to investigate engagement and compliance as well as attitudes and acceptance of the residents towards the robot and the facilitated Trivia games. We then compared these results to HRI study results obtained with Tangy autonomously facilitating the group-based activity, Bingo [10], in which residents individually played the game. The objective of this comparison was to investigate the impact of team-based play with a robot facilitating the activity.

II. Robot Facilitated Activities

In this section, we discuss robots which were designed to perform one-on-one question and answer games as well as facilitate individual-based group activities.

A. One-on-One Question and Answer Games

A handful of robots have been developed to facilitate question and answer type games with individual participants [11]-[13]. For example, in [11], a teleoperated Nao robot was used to facilitate three different single-player games with children to investigate how the children adapted their verbal and expressive behaviors while engaging with the robot. The robot conducted a dance, imitation or quiz game based on the preference of the user. The results showed the children would

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adapt and align their responses to match how the robot would move and speak with them.

In [12], a teleoperated Nao robot was used to facilitate a single-player diabetes themed quiz game with children with diabetes. For half of the children, the robot lacked expression and emotional response, while for the other half it would remember their names and respond when they answered a question using body language and positive speech. The children found the expressiveness of the robot positively correlated with their learning during the game.

In [13], a comparison study was conducted comparing an autonomous telepresence robot, a virtual female avatar, and a laptop. Elderly participants played a single player trivia game with each technology. Questionnaire results showed the robot and virtual agent did not add enjoyment to the game; however, participants would choose the robot over the other two because of its physical presence.

B. Individual-Based Group Activities

In addition to the robots designed to facilitate single player activities, a small number of robots have also been developed to facilitate individual-based group games, specifically with older adults [10], [14]-[18]. For example, in [14], a teleoperated robotic dog, AIBO, was used to facilitate card and ball games to improve the memory and emotional control of a group of older adults with dementia. Studies at a LTC facility showed that residents had noticeable improvements in their memory, as well as their emotional control.

In [15], the autonomous character-like robot Ifbot was used to facilitate group games to test if elders with dementia would enjoy robot assisted activities like quiz style games, sing-alongs and tongue twisters in their LTC facility. Results from the experiments showed that most participants favored having the activities facilitated by a robot.

In [16], the autonomous character-like robot Matilda facilitated group activities like bingo, hoy and quiz games with elderly residents in a LTC facility. The robot used voice and facial recognition to interpret the participants' responses and emotions. The results showed that the participants felt relaxed while talking to Matilda and that playing the quizzes had a positive impact on their mental activity.

In [17], a NAO robot autonomously facilitated a group exercise session by asking LTC facility staff members and elderly residents living with mild cognitive and physical impairments to imitate its gestures. Results from video recordings and a questionnaire suggested staff members were supportive of the robot coach and that the residents moderately accepted the robot as an exercise coach.

In [18], a mobile robot autonomously facilitated group mobility games with elderly participants where the goal was to have the robot follow you for as long as possible. Post-game interviews showed the robot was well-received by the participants and could be used for rehabilitation purposes.

In [10], a robot with a human-like upper body, Tangy, was used to autonomously facilitate a multi-player Bingo game in a LTC facility with seven elderly residents. The robot would autonomously call out bingo numbers and check players' individual cards to provide help or let them know if they had won Bingo. The results showed that they had high levels of compliance and engagement during the robot facilitated game.

The aforementioned research shows the potential for socially assistive robots to be incorporated into LTC facilities to provide cognitively stimulating recreational activities, while promoting the overall well-being of residents. Furthermore, question and answer style games facilitated by robots were engaging for a variety of different users. However, these studies have been mainly focused on single users or groups of individuals who are independently interacting with the robot during an activity. To the authors' knowledge, the impact of robot facilitated team-based games with older adults has not yet been explored. In this paper, we present the development and implementation of the autonomous robot Tangy for team-based Trivia games. A pilot study was conducted with the robot and older residents in a LTC facility to uniquely investigate team-based interactions with a robot.

III. TRIVIA ACTIVITY SCENARIO WITH TANGY

The Tangy robot autonomously facilitates Trivia games with two teams of players. Both the robot and the Trivia game scenarios are discussed in this section.

A. The Tangy Robot

We have designed the socially assistive Tangy robot, Fig. 1, to facilitate socially and cognitively stimulating activities in LTC settings with older adults [19]-[21]. Tangy has a head and two arms integrated onto a torso with a screen. Tangy can interact via speech, arm gestures, and by displaying text/visuals on its screen. Tangy can autonomously navigate its environment using its differential drive mobile base and a combination of a laser range finder and optical encoders.

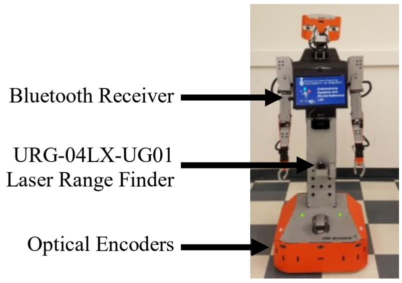


Fig. 1: Tangy the Trivia Facilitator

B. Trivia Games

For each Trivia game, two teams sit behind a row of tables facing Tangy, who is located at the front of the room, Fig. 2(a). We have designed the game to include a variety of different categories of questions, including General Knowledge, Animals, History, Science, Movies, and Food. The teams can choose the categories for each game. Once a category is chosen, Tangy presents questions to the teams in a multiple-choice format, with three possible answers A, B, or C, of which only one is correct. Teams compete to be the first to correctly answer each question within a 1-minute time interval. If they need assistance, teams can request for a hint from Tangy. The following scoring system is used: 1) Incorrect answers receive 0 points, 2) correct answers with no hint provided receive 2 points, and 3) correct answers after a hint is provided receive 1 point. The team with the most points wins the game.

To play the Trivia game, each team is provided with an input device, Fig. 2(b). The device has four large buttons to press. The A, B, and C buttons are used to input the answers to questions, and the Help button is used to request a hint from Tangy. We have custom designed and 3D printed the input devices which require minimal force to press the buttons to accommodate players with limited physical strength. The buttons are labeled in large letters to accommodate players with low visual acuity. A Bluetooth transmitter and receiver provide signals from the input device to the robot.

(a) Scenario at Long-term Care Facility (b) Trivia Input Device

Fig. 2 Trivia Scenario Set-up

IV. TANGY-TRIVIA SYSTEM ARCHITECTURE

We have developed a system architecture for Tangy to autonomously facilitate Trivia games, Fig. 3. The architecture identifies the state of the game to determine Tangy's corresponding behaviors. Sensory information, received from Tangy's sensors, Fig. 1, is used by the architecture for: 1) generating a map of the environment to localize the robot via the laser range finder and odometry, and 2) receiving answers and help requests from each team via the Bluetooth receiver.

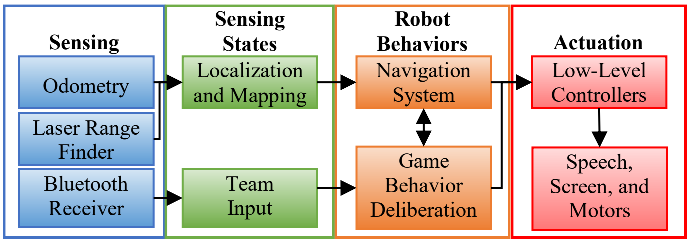


Fig. 3: System Architecture

A. Localization and Mapping

Tangy generates a 2D map of the environment using the Simultaneous Localization and Mapping Gmapping technique [22]. To estimate the joint posterior distribution of the map and robot's trajectory within the map Gmapping uses a Rao-Blackwellized particle filter and an adaptive resampling technique. Given the map, a Monte Carlo localization technique [23] is used during the Trivia games to localize and determine Tangy's angular orientation.

B. Team Input

As previously mentioned, teams provide an answer to a question or request a hint by pressing the buttons on their input device, Fig. 2(b). The robot receives the team's input via a Bluetooth receiver, along with the ID of the input device which identifies the team which has requested assistance.

C. Navigation System

At the start of the game Tangy is positioned at the front of the room, facing both teams. During the game, when a team provides input, Tangy localizes to face that team. Pose goals are sent to the low-level motor controller to compute the motor commands for the differential drive base.

D. Game Behavior Deliberation

The objective of the Game Behavior Deliberation module is to determine the appropriate behaviors for Tangy to facilitate the Trivia game. This module utilizes the overall finite state machine (FSM) presented in Fig. 4(a), and requires inputs from both the Team Input and Navigation modules. The FSM used to determine the appropriate assistance behaviors of the robot is also shown in Fig. 4(b). Examples of the robot behaviors are presented in Table I, and Fig. 5.

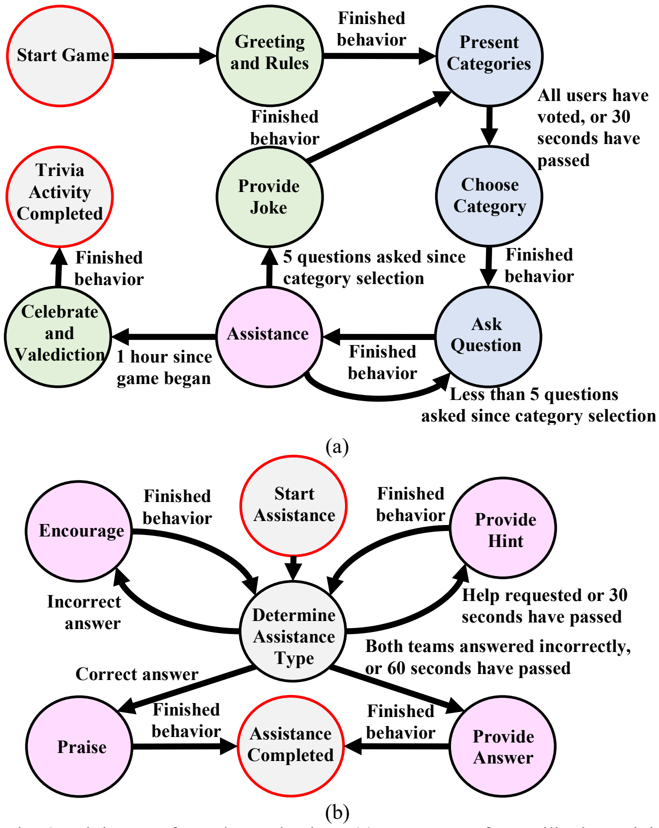


Fig. 4: Trivia FSM for Robot Behaviors: (a) FSM Layer for Facilitating Trivia, and (b) FSM Layer for Assistance

Tangy starts a Trivia session by greeting players and explaining the game rules. The robot then requests that the teams vote for a Trivia category. The category with the highest votes is selected, and in the case of a tie a category is randomly selected from among the categories in the tie. If no team votes, after 30 seconds the robot chooses a category. Tangy then asks questions related to the selected category, while providing three possible answers (e.g. A, B, or C). Teams respond using their input device. Each team may only answer each question once. The teams may also request a hint for a question.

If a team answers the question correctly, Tangy praises them. If they answer incorrectly, Tangy will let them know that the answer is incorrect and will provide encouragement. Tangy then lets the other team also provide an answer if they choose to. If a hint is requested, Tangy provides them with a hint related to the question. Tangy will also provide a hint if 30 seconds have passed after the question has been asked and at least one of the

(a) Greeting (b) Present Categories (c) Ask Questions (d) Provide Hint (e) Provide Joke (f) Celebrate

Fig. 5: Example Robot Behaviors for Trivia

teams has not provided an answer. Tangy will only provide a single hint per question. If both teams have answered incorrectly Tangy provides the correct answer and continues by asking a new question in the same category.

After 5 questions are asked, Tangy tells a joke and provides the teams with an opportunity to change the category. After an hour of playing, the Trivia session comes to an end, and the team with the most points wins. Tangy celebrates with the winning team, thanks both teams for playing and performs a valediction.

TABLE I. EXAMPLE ROBOT BEHAVIORS FOR TRIVIA

Behavior Type	Example Behavior
Social Utterances	
1) Introduction	
a) Greeting	"Hello! My name is Tangy. I am so excited to play trivia with you today!" (Robot waves at players, and displays its name on the screen)
b) Rules	"I will call out a series of categories. Once a category is selected, I will ask a question, and then present three possible answers. You can use your input device to choose categories, provide answers, and ask for hints." (Text is also displayed on the screen)
2) Provide Joke	"What is the best way to carve wood? Whittle by whittle." (Robot covers its mouth and laughs, displays question and then answer on the screen)
3) Celebrate	"Congratulations to team 1! You're the winner today!" (Robot raises arms straight up and sways in a celebration dance, displays 'Congratulations' on the screen)
4) Valediction	"I had a great time playing with everyone today. Have a great day." (Robot waves at players, displays 'Good-bye!' the on screen)
Trivia Game	
1) Category Selection	
a) Present Category	"The categories are: a) General Knowledge, b) Food, c) Science. Which would you like to play?" (Robot points to categories displayed on the screen)
b) Choose Category	"The next category is General Knowledge." (Robot points to the category displayed on the screen).
2) Ask Question	"Who is a British Prime Minister? a) Justin Trudeau, b) Theresa May, c) Barack Obama." (Robot points to question, and displays question on the screen)
Assistance	
1) Provide Answer	"The answer is b." (Robot points to answer displayed on the screen)
2) Provide Hint	"She is married to Phillip May." (Robot faces team that requested the hint, displays hint on the screen)
3) Encourage	"Unfortunately, that answer is not correct. Great try though!" (Robot faces team that answered and shakes head, displays text on the screen)
4) Praise	"Great job!" (Robot faces team that answered and nods its head, displays text on the screen)

E. Low-Level Controllers

Low-level controllers are used to perform verbal/non-verbal behaviors. Google™ powered text-to-speech is used to synthesize Tangy's voice. Non-verbal actions include displaying text on Tangy's screen, head and arm gestures, and navigating via the mobile base. The Open Motion Planning Library [24] creates collision free motion plans for Tangy's arm gestures.

V. TRIVIA HRI STUDY

An HRI study was conducted at a local LTC facility to evaluate Tangy's performance facilitating Trivia with teams of older adult residents. The study also evaluated participant engagement, compliance, and attitude and acceptance towards the autonomous robot facilitating a team-based game. Six female participants, aged 66-96, participated in the study. They had the opportunity to play in two Trivia sessions with Tangy. The inclusion criteria for the participants were: 1) residents lived at the facility for at least one year, 2) over 60 years of age, 3) fluent in English, 4) can hear normal levels of speech, and 5) cognitively intact or with mild cognitive impairment (less than 3 on the MDS Cognitive Performance Scale [25]).

A. Methods

Prior to the start of the Trivia sessions, written informed consent was obtained from all participants. Four members of our research team then demonstrated Tangy's capabilities during a Trivia game and how to play the game. After the demonstration, participants were given an opportunity to ask questions regarding the robot and the activity.

One-hour Trivia sessions were held in a general-purpose activity room in the LTC facility, Fig. 2(a). Sessions were video recorded for post-session analysis to evaluate robot performance, and participant engagement and compliance. Namely, the measured study variables were: 1) robot performance as defined by the percentage of correctly executed robot behaviors with respect to the expected robot behavior; 2) participant engagement as defined by visual focus of attention towards Tangy or the Trivia input device; 3) number of utterances as defined by the number of instances participants spoke to each other; and 4) participant compliance as defined by responding to Tangy's questions and choosing categories.

A post-interaction questionnaire, adapted from the Almere model [26], was also given to participants after the Trivia sessions to investigate attitudes and acceptance towards Tangy. Participants indicate their agreement with the statements using a 5-point Likert scale (1-strongly disagree, 3-neutral, 5-strongly agree). Additionally, open-ended questions were asked about Tangy and the game scenario.

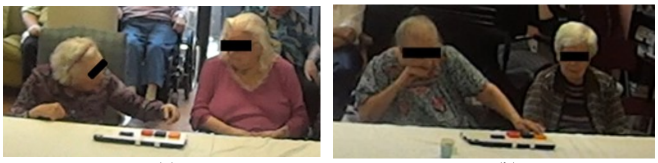
B. Robot Performance

The robot behaviors all executed with a 100% success rate. However, during the interactions, there was an issue with the buttons on one of the input devices sticking when a player would press the edges of the button rather than the center of the button (it worked when they pressed the center). This resulted in the input device only transmitting 74.4% of answers. To resolve this issue in the future, the 3D printed parts will be further sanded and finished to provide a smoother surface.

C. Engagement and Compliance

During the sessions, average participant engagement towards: 1) Tangy was 88.7%, 2) the input device was 6.9%, and 3) team members was 2.4%. During the interactions with teammates, over 16 inter-team utterances occurred in a single session, Fig. 6(a). Although the percentage of the overall visual focus of attention as defined by engagement was not high towards other team members, they did speak to each other as evident by the frequent utterances. In particular, they discussed the questions while looking at the robot. Most utterances were discussions of questions and which team member wanted to answer. Such team-based activities have been shown to promote cooperation and social interactions [27].

Average participant compliance towards Tangy was 91.3%. An example is shown in Fig. 6(b). It is interesting to note that when Tangy asked participants to choose a category, they usually waited for the robot to choose for them, rather than actively choosing it. We postulate that this was due to user's indifference to the categories, and so were fine with Tangy selecting for them.



(a) (b)

Fig. 6: Example Team Engagement and Compliance: (a) Team Discussing a Question, and (b) Team Answering a Question

D. Open Ended Questions

The responses to the open-ended questions were categorized into enjoyability, user experience/interaction, and game design. Participants enjoyed the game and appearance of Tangy the most. They thought it was important for Tangy to use both speech and display for communication. With respect to game design, four participants stated that the questions could be asked faster. We had designed this behavior to allow the participants enough time to read the full questions on the robot's screen.

E. Questionnaire Results

The statistics for the questionnaire results are presented in Table II. The questions are presented with respect to their corresponding constructs defined by the Almere model. The reliability of each construct was determined using Cronbach Alpha values [28]. The alpha value for the Perceived Enjoyment, Perceived Usefulness, and Attitude Towards were all above the accepted level of 0.5 for short tests [29], with values of 0.83, 0.57, and 0.56, respectively. The remaining constructs were below this level. Further statement analysis was performed on the remaining constructs to determine whether removing statistically weak statements would improve the scores [30]. However, the alpha values remained below 0.5; so, the remaining statements were analyzed individually.

The Perceived Enjoyment, Perceived Usefulness, and Attitude Towards constructs all had positive scores. The participants also strongly agreed that they would play Trivia with Tangy again. Furthermore, all participants liked Tangy's appearance, which matched the responses to the open-ended questions. It has been found that the extent to which a robot's appearance matches its functionality and portrays usefulness positively correlates with the robot's acceptance by older adults [31]. The positive scores for these constructs also support the engagement results we observed in the videos.

Tangy is developed to be expressive with human-like social features including speech, gestures, and body pose. In general, participants did not find Tangy intimidating and were comfortable interacting with the robot. Studies have shown that social robots with such characteristics have a positive impact on an elder user's enjoyment [32]. Only half of the participants felt that Tangy was looking at them directly during Trivia, because Tangy is designed to face an entire team instead of individuals.

TABLE II. QUESTIONNAIRE RESULTS

Construct	Statement	Median	Frequency				
			1	2	3	4	5
Perceived Enjoyment	I enjoyed playing Trivia with Tangy	4.5	1	0	1	1	3
	I enjoyed the categories that Tangy provided	4.5	0	0	0	3	3
	I found Tangy's jokes enjoyable	3.5	2	0	1	1	2
	I enjoyed the Trivia questions that Tangy gave	4.5	0	0	1	2	3
Perceived Usefulness	I thought it was helpful when the robot pointed to its screen	4.5	2	0	0	1	3
	Tangy displaying the question and choices on his screen was helpful	3.0	2	1	0	1	2
Intent to use	I would play Trivia with Tangy again	5.0	0	1	0	0	5
Attitude Towards	I think Tangy should host Trivia games again	5.0	0	0	1	0	5
	I think Tangy makes the Trivia game interesting	4.0	1	0	1	2	2
Social Presence	I liked Tangy's appearance	5.0	0	0	0	0	6
	I feel like Tangy is looking at me when I am playing the game with it	2.5	3	0	0	1	2
Anxiety Towards	I am comfortable interacting with Tangy	5.0	0	1	0	1	4
	I find Tangy intimidating*	1.0	4	1	1	0	0

*Statement is negatively worded and was reverse-scored during analysis

F. Comparison of Team Based Trivia vs. Single Player Bingo

We compared the team-based Trivia study results with study results from the individual-based group activity of Bingo presented in [10]. Tangy facilitated both studies.

The average overall engagement was higher during Trivia sessions (98%) than during Bingo sessions (90%). This is expected as people tend to show higher engagement levels in team activities than individual activities, as the former provides a structured social environment for participants [33]. Based on the analysis of the video footage of the residents during both the Trivia and Bingo sessions it was observed that participants were also actively engaged in significantly more social interactions with each other during Trivia due to the team-based play.

Compliance during the Bingo sessions (98%) was higher than during the Trivia session (91.3%). The participants complied when the robot asked them to provide an answer in

Trivia or mark their cards in Bingo. However, when asked to choose a category in Trivia they relied on Tangy to make the decision for them, hence Trivia had a lower compliance rate.

The questionnaire results for Trivia and Bingo were comparably positive with respect to enjoyment and interest when playing with Tangy. The response to Tangy's gestures also scored positively, however, the screen was found to be more helpful for Bingo than for Trivia. During Bingo, numbers were mainly displayed on the screen, whereas in Trivia more information was displayed, as the questions and the corresponding potential answers were displayed at the same time. This may have been more difficult for the older adult participants to view, and therefore, they relied more on Tangy's speech. This design choice was initially made to avoid having players remember information displayed on multiple screens. In general, participants liked playing Trivia and Bingo with Tangy and wanted it to facilitate both games in the future.

VI. CONCLUSION

In this paper, we present the design of the socially assistive robot, Tangy, to autonomously facilitate team-based Trivia games with older adults. A pilot study was conducted at a local LTC facility with residents to investigate user engagement, compliance, and attitudes as well as acceptance towards the robot and the activity. In general, participants enjoyed playing Trivia with Tangy and would participate in future robot facilitated Trivia sessions. They also had high levels of engagement and compliance during the game. A comparison study with Tangy facilitating individually played Bingo games showed that participants were more engaged in the Trivia games. They also engaged in more social interactions with each other as evident by the number of utterances spoken during the team-based Trivia activity. However, they found both activities enjoyable and would play them again with the robot.

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