A User-Study with Tangy the Bingo Facilitating Robot and Long-Term Care Residents

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***Abstract*—Cognitive decline among the elderly decreases their independence and quality of life. Promoting engagement in recreational activities can help reduce this decline as such activities can provide both social and cognitive stimulation. For example, Bingo is a popular recreational activity in long-term care (LTC) facilities. However, activities such as Bingo have significant time and personnel requirements, and are becoming increasingly difficult to facilitate due to the current LTC staff shortages and an increasing demand for other LTC services. To address this problem, our research focuses on the development of the autonomous socially assistive robot Tangy which is being designed to facilitate needed multi-user recreational activities. In this paper, we present a pilot study conducted with Tangy facilitating multiple Bingo sessions with groups of elderly residents at a LTC facility. The study results showed that Tangy was able to autonomously and effectively facilitate Bingo games in real interaction settings by determining its appropriate assistive behaviors. Residents also had high compliance and engagement rates with respect to Tangy and the Bingo games. A post-interaction questionnaire showed that they enjoyed playing Bingo with Tangy, liked Tangy's socially interactive attributes, and would interact with it again in the future.**

Keywords— Multi-User Studies; Elderly Care; Socially Assistive Robots; Human-Robot Interaction

I. Introduction

Cognitive decline among the elderly limit their ability to independently perform activities of daily living such as eating, dressing and toileting [1]. To maintain and improve older adults' quality of life, cognitive training interventions have been proposed to reduce the rate of age-related cognitive decline. Cognitive training includes both specific therapy-based activities that target particular functions in the brain such as memory, reasoning, or speed of processing as well as recreational activities that provide non-specific global cognitive stimulation [2].

A recreational cognitively stimulating activity that is popular among older adults is Bingo. Bingo is an activity commonly used in adult day care programs and assisted living facilities to provide a structured setting for social engagement and community interaction [3]. Bingo also increases cognitive performance by training memory, recall, and recognition functions within the brain [3]. Although Bingo and other recreational programs are common features in long-term care (LTC) facilities, they require considerable time and personnel commitment. Due to the current LTC staff shortages, there are already insufficient recreational programs in these facilities [4].

In order to relieve some of the burden placed on LTC staff, assistive robotic technologies are being developed as potential aids to provide needed services to elderly residents. In this paper, we present the implementation of a socially assistive robot for the novel application of autonomously facilitating Bingo games for multiple older adults. The socially assistive robot Tangy, Fig. 1, is designed to aid healthcare workers in LTC facilities by facilitating recreational cognitively stimulating activities. Herein, we present a human-robot interaction (HRI) pilot study where Tangy facilitates multiple Bingo games for groups of elderly residents. Our HRI study with Tangy has been designed based on feedback from focus groups previously conducted on Tangy with LTC residents, family members, and healthcare professionals [5].

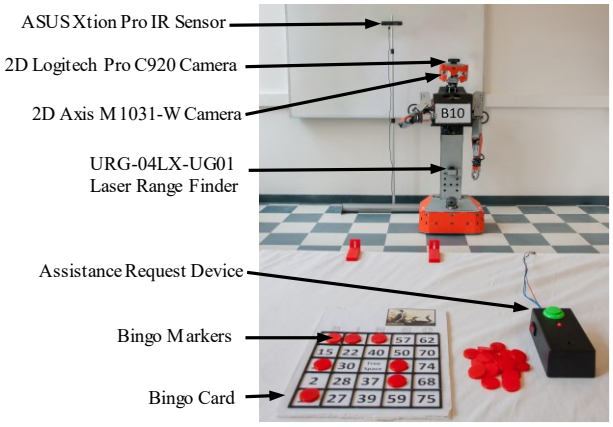

Fig. 1: Tangy the Bingo Facilitator

II. Socially Assistive Robots for the Elderly

To date, only a handful of robots have been developed to interact with multiple elderly residents while facilitating cognitively stimulating recreational activities including educational games [6], a ball catching activity [7], and Bingo and Hoy games [8]. In general, these multi-user robots were able to interact simultaneously with multiple people with some degree of human intervention, ranging from complete robot teleoperation [7] to human mediators and assistants [6],[8] who directed the interaction between the robots and the participants.

Our research addresses the challenge of autonomously facilitating a multi-user recreational activity in the assisted

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living setting using a socially assistive robot. Namely, our contribution lies in the development of the robot features and behaviors which allow a social robot to interact with and facilitate a recreational activity for multiple users without any human intervention. In particular, this pilot study aims to discover the efficacy and acceptance of Tangy's features and behaviors for elderly residents in an assisted living facility during multiple Bingo games.

III. Bingo Activity Scenario

Tangy is able to uniquely facilitate an overall Bingo game for multiple players while also detecting when individual players have requested assistance in order to appropriately respond to each of them. Tangy can offer autonomous individualized assistance to an elderly user through one-on-one assistive behaviors during the activity. This interaction is possible through Tangy's ability to actively sense and move in its environment in order to provide the appropriate assistive behaviors during the Bingo activity.

For each Bingo session, Tangy starts at the front of a room, while the players are seated behind a row of tables facing the robot, Fig. 2. Each player has an assistance request device and a Bingo card, Fig. 1. The session commences with Tangy greeting the residents and introducing itself. A complete Bingo scenario consists of 2-3 games being played over an approximately 1 hour session. A Bingo game begins when Tangy starts calling out Bingo numbers. Players can request assistance from Tangy at any time during the game with respect to correctly marking Bingo numbers on their cards and if they have a winning Bingo card. A Bingo game is finished when a player has a winning card with all numbers in either a row, column or a diagonal configuration marked properly.

Players request assistance from Tangy during Bingo by pressing a large button on the assistance request device. The placement of the button on the table next to a player's card allows players with limited physical arm range to easily press the button without external assistance. The circular Bingo markers are designed with thick profiles in order to allow for ease of tactile manipulation. Likewise, the Bingo cards have a large text font (Fig. 1) to promote accessibility for players who may have lower visual acuity.

Fig. 2: Bingo Scenario Overview

IV. System Architecture for Tangy

A multi-user system architecture is proposed to allow Tangy to facilitate Bingo games and monitor multiple players during the game to provide targeted assistance, Fig. 3. The architecture focuses on determining the appropriate behaviors for Tangy based on the state of the Bingo game and whether a player has requested assistance during the game. Sensory information, obtained by the sensors shown in Fig. 1, is used by the architecture for: 1) assistance identification in order to determine if any players need assistance via an ASUS Xtion Pro IR Sensor that is mounted in the environment, 2) robot navigation and localization within the environment via an URG-04LX-UG01 laser range finder and optical encoders internally mounted on Tangy, 3) localization and tracking of those players who have requested assistance via a 2D Axis M1031-W camera located in the robot's right eye, and 4) Bingo card state detection via a 2D Logitech Pro C920 camera located on top of Tangy's head.

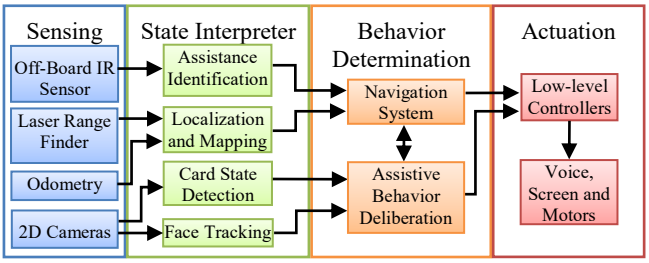

Fig. 3: System Architecture

A. Assistance Identification

As previously mentioned, each player has an assistance request device, Fig. 4. The device comprises of a silver infrared reflective triangle attached to the table in front of the player. By pressing the button, the triangle is revealed through a servo motor. The ASUS Xtion Pro sensor, which is at the front of the room behind the robot's starting position, is used to obtain corresponding infrared images and 3D point clouds of the environment. The infrared images are used to detect when help is needed and from which device help has been requested via detection of the reflective triangles. Namely, we apply a Hough transformation [9] to detect the straight edges of a reflective triangle. Straight edges that form closed contours (intersecting lines that form a polygon) with three vertices are considered a triangle. After a triangle is detected, the position of its centroid in the infrared image is identified and tracked through multiple consecutive images in order to verify that assistance has been requested. The average 3D position of the assistance request triangle is identified using the corresponding point clouds in order for the robot to navigate to the player requesting assistance in the environment. In cases where multiple assistance requests are made to the robot, player requests are queued in the order the buttons are pressed.

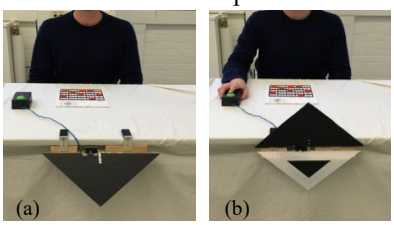

Fig. 4: Assistance request device: (a) Not activated, and (b) Activated.

B. Localization and Mapping

A 2D map of the environment is generated using laser scans from the robot's laser range finder and optical encoder readings via the SLAM (simultaneous localization and mapping) Gmapping technique [10]. Gmapping uses a Rao-Blackwellized particle filter and an adaptive resampling technique to estimate the joint posterior distribution of the map and the trajectory of the robot within the map using the

aforementioned sensory information. This map is then utilized to localize the robot in real-time in the environment during the Bingo sessions using the adaptive Monte Carlo localization technique [11]. Namely, Tangy's pose is determined using a Bayesian filter and updated sensory information.

C. Navigation

Tangy navigates in the environment with the ROS navfn planner [12] based on the use of a costmap. Dijkstra's algorithm is used to plan the lowest cost trajectory of the robot from its current pose to a goal pose using occupancy grids obtained from the map of the environment. The TrajectoryPlannerROS [13] local planner is used to execute this trajectory through a set of local goals while performing obstacle avoidance using the Dynamic Window Approach. The local goals are provided to the low-level controller of Tangy's differential drive base in order to compute the corresponding motor commands needed to navigate Tangy to a player requiring assistance or to the front of the room.

D. Face Tracking

Tangy uses the 2D Axis camera in its right eye to localize a player's face once the robot has approached the player who has requested assistance. The OKAO™ Vision software library [14] is used to localize players' faces within a distance of 2.25m by identifying facial features within the camera's field of view (FOV). A player's face is identified from a direct frontal view within 30º, 20º, and 360º in yaw, pitch and roll rotations, respectively. If there is more than one player in the camera's FOV, the player's face closest to Tangy's direct line of sight (LOS) in the horizontal FOV is determined to be the player who requested assistance. The robot then adjusts its gaze direction towards this player by actuating its neck servos in the pitch and yaw directions.

E. Card State Detection

Tangy uses 2D images from its head mounted webcam to identify the state of the Bingo card of the player who has requested assistance, Fig. 5(a). The card states are defined to be: 1) marked correctly, 2) incorrectly marked and/or missing markers, and 3) winning card. Each card has a unique identifier picture on its top right corner used to distinguish between the different cards, as well as a 5x5 grid of squares containing a unique set of Bingo numbers. The card state is determined via a 3-stage procedure: 1) localize the player's card, 2) identify the card using Speeded-Up Robust Features (SURF) [15], and 3) locate the red markers on the card.

Tangy scans the table in front of it in order to locate the Bingo card. Hough transformations [9] are used to localize the card by detecting the grid lines of the outer 5x5 grid, Fig. 5(b). If multiple cards are located in an image, Tangy isolates the card closest to it via the size of the area that its grid covers in the image frame. Once this card is identified, a top-down projection of the card is constructed by skewing the image using an estimated homography matrix. The identity of the card is then determined by using SURF detection to identify and match features on its unique identifier to a database which contains the SURF features for the unique identifiers of all the Bingo cards, Fig. 5(c). Lastly, the red markers on a card are then found using a red blob filter approach, Fig. 5(d). Only blobs having a large percentage contained within the number grids are defined to represent marked Bingo numbers. Tangy then determines the player's Bingo card state by comparing the marked number grids to the numbers it has already called out during the game.

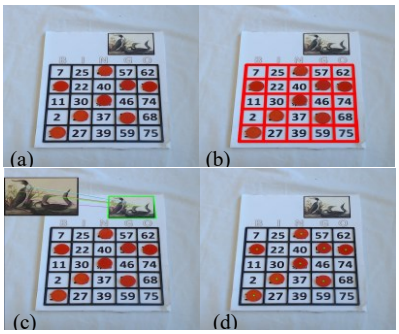

Fig. 5: Bingo Card Detection : a) Captured Bingo card image, b) Detection of grid lines, c) Identification of unique identifier using SURF features, and d) Localization of red markers based on blob centroid. Images are shown from the perspective of the user for visual clarity.

F. Assistance Behavior Deliberation

The Assistance Behavior Deliberation module is used to determine Tangy's appropriate behaviors in order to engage players in the Bingo game and to provide player assistance when requested. This module utilizes the finite state machine (FSM) presented in Fig. 6, which requires inputs from the Navigation, Card State Detection and Face Detection modules in order to determine the robot's effective assistive behavior.

Tangy starts facilitating a Bingo session by greeting the players, and introducing itself as well as explaining the rules of the games, Fig. 7(a). During a Bingo game, Tangy will call out random Bingo numbers and point at its chest mounted tablet screen where each number is also displayed, Fig. 7(b). The robot also plays background music during the number calling process. Tangy will continue calling out Bingo numbers until a player requests for assistance via the assistance request device, at which point Tangy begins transitioning from its multi-user facilitation behaviors to individualized assistive interactions. Namely, the robot will acknowledge the assistance request by a head nod and then navigate towards the player, Fig. 7(c).

After Tangy has navigated to the player, Tangy uses the Bingo card state to either provide corrective assistance, congratulations or encouragement. Tangy provides assistance by repeating the called out Bingo numbers that a player may have not marked and/or by asking a player to unmark Bingo numbers that have been incorrectly marked, Fig. 7(d). The congratulations behavior is executed when Tangy identifies a winning Bingo card, Fig. 7(e). In the case that a player has marked his/her Bingo card correctly, but it is not a winning card, the robot provides encouragement. If a player's card is partially occluded when the robot is trying to provide assistance (identified via the Card State Detection module), Tangy will request that the player move the card closer to the robot. Once the robot has finished providing individualized assistance, the robot will return to the front of the room and continue calling out Bingo numbers. During the game, Tangy will also promote the social dimensions of the group activity by telling jokes or providing Bingo facts after a set of Bingo

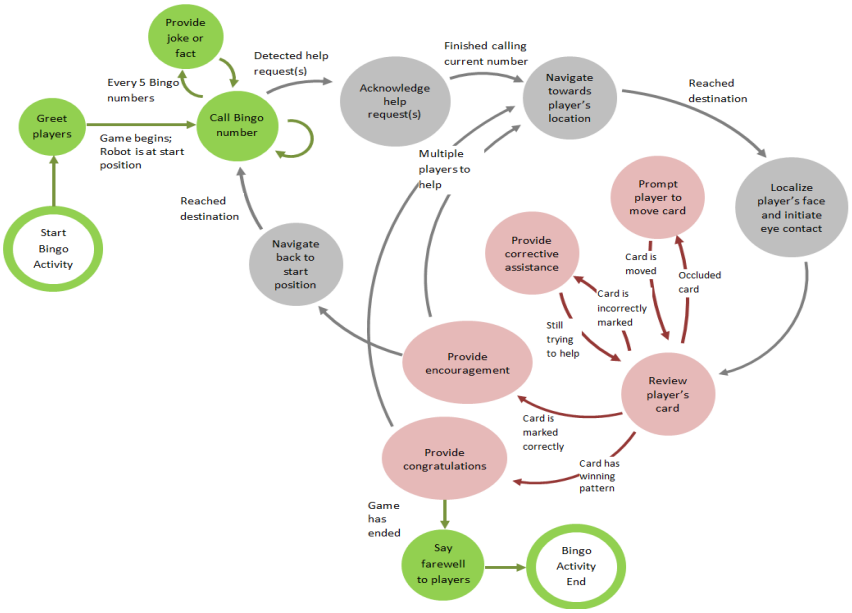

Fig. 6: Tangy's FSM – Multi-user interactions are in green; transition actions are in grey; and the individualized help

numbers have been called. When a Bingo session is over, Tangy will wave and say good-bye to the players, Fig. 7(f).

G. Low-Level Controllers

The assistive behaviors of Tangy are implemented using a combination of both verbal (speech) and non-verbal (e.g. arm and head gestures, mobile base movement, music, and visual display) modes via their respective low-level controllers. Tangy's female voice is synthesized with Google™ powered text-to-speech. Tangy's arm gestures of waving, pointing or celebrating are generated utilizing motion planners in the Open Motion Planning Library [16] which create collision-free trajectories for each joint. A point-to-point trajectory planner is also used for Tangy's head motions of nodding and scanning.

V. Pilot Study with Tangy at an LTC Facility

We conducted a pilot study at a local LTC facility to investigate the efficacy of Tangy in autonomously facilitating the group-based recreational activity Bingo. We investigated the robot's performance during the activity and participant compliance and engagement during the interactions. In addition, we obtained feedback on the residents' attitudes towards and acceptance of Tangy and its capabilities.

A. Participants

Seven residents (6 Female and 1 Male), ages 66-96 years old (μ=79.3, σ=11.7) participated in a total of six 1 hour Bingo sessions facilitated by Tangy. Namely, each resident participated in at least two Bingo sessions. Written informed consent was obtained prior to commencement of the study. Inclusion criteria were: 1) cognitively intact or with mild cognitive impairment (Cognitive Performance Scale level of 2 or less [17]), 2) over the age of 60, 3) fluent in English, and 4) can hear normal levels of speech. Participants' experience with computers ranged from no experience (1 participant) to beginner (2 participants) and advanced level of experience with computers (4 participants). Only one participant had any experience with robots; and that experience consisted of watching robots in a movie.

B. Methods

Prior to commencement of the Bingo sessions, all participants were invited to a robot demonstration session

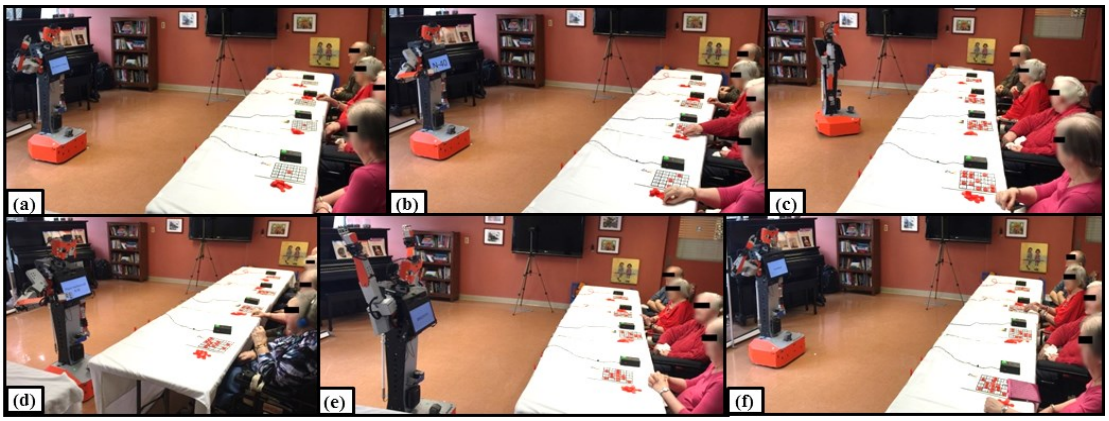

Fig. 7: Tangy Behaviors during a Bingo Game: (a) Greeting and introduction at the beginning of a game; (b) Calling out and pointing to Bingo numbers displayed on its screen; (c) Navigating to player; (d) Giving corrective assistance aurally and visually through its screen; (e) Celebrating a winning card by dancing with its arms swaying from side to side in the air; and (f) Saying and waving goodbye at the end of a session.

TABLE I. ROBOT BEHAVIOR EXECUTION RESULTS

True Interaction State	True Assistance State	True Robot Location	True Facing Tracking State	True Card State	Expected Robot Behavior	Success Rate:
Start of Bingo game	-	At front of room	-	-	Greet players	100%
Call Bingo numbers	Assistance not requested	At front of room	-	-	Call out Bingo number	100%
Call Bingo numbers	Assistance not requested	At front of room	-	-	Provide Jokes and Facts	100%
Call Bingo numbers	Assistance requested	At front of room	-		Acknowledge Player(s) Request(s)	92.68%
Provide Assistance	Assistance requested	At front of room/At another player's location	-	-	Navigate towards location of player	100%
Provide Assistance	Assistance requested	At player's location	Tracking Face	-	Localize player's face and initiate eye contact	63.64%
Provide Assistance	-	At player's location	-	Occluded Card	Prompt player to move card	100%
Provide Assistance	-	At player's location	-	Incorrect markings	Request to remove marker(s) from incorrectly marked numbers	100%
Provide Assistance	-	At player's location	-	Missing markings	Request to mark missing number(s) on the Bingo card	100%
Provide Assistance	-	At player's location	-	Correctly marked	Provide encouragement	100%
Provide Assistance	-	At player's location	-	Bingo	Provide congratulations	100%
End of Bingo game	-	-	-	-	Say farewell to players	100%

which showed Tangy facilitating a Bingo game with four members of our research team. All of the robot's assistive behaviors as well as how a player could interact with the robot were shown. The demonstration was used to introduce Tangy to the residents and to provide them with the opportunity to ask questions prior to the start of the user study.

Each Bingo session was conducted in a multi-purpose activity room on the first floor of the LTC facility, Fig. 2. All sessions were video recorded for post-interaction analysis. The measured variables were: 1) performance of the robot's overall system architecture and its modules during the Bingo sessions, 2) participant compliance as defined by each participant's corresponding actions with respect to the robot's requests, 3) participant engagement in the Bingo session defined by each participant's visual focus of attention towards the robot and his/her Bingo card. Furthermore, participant acceptance and attitudes towards Tangy were measured by administering a post-interaction questionnaire to the participants after they had finished all their Bingo sessions. The questionnaire is adapted from the Almere model [18] and used herein to assess the acceptance and attitude of residents towards Tangy as a Bingo facilitator in the LTC facility. Residents indicated their agreement with the questionnaire statements using a 5-point Likert scale (1 = strongly disagree, 3 = neutral, 5 = strongly agree). We also asked open-ended questions that focused on determining: 1) features of Tangy that residents liked or found helpful, and features they would want the robot to have; and 2) other activities Tangy could assist with in the LTC setting.

VI. STUDY RESULTS

During the Bingo games Tang's behaviors were all executed with 100% success rate with the exception of acknowledging player requests and localizing players' faces, Table I. Acknowledging player requests had a success rate of 92.68% due to the fact that when 2 players simultaneously pressed their buttons, Tangy only acknowledged 1 of the 2 players by nodding in his/her direction and failed to nod at the 2nd player. However, the Assistance Identification Module did detect both requests, and Tangy helped both players regardless of this. We suspect that the error here was caused by 2 commands being sent to the neck motor in quick succession resulting in the 2nd command pre-empting the first.

Localizing participant faces had a success rate of 63.64% due to instances when multiple players' faces were in Tangy's FOV. Participants moved close to each other during the game especially when Tangy came over to help. Since for the individualized help interactions, only a single face was tracked, the addition of more players in the FOV near the LOS would cause Tangy's gaze to also focus on these players. Nevertheless, Tangy was able to detect the card of the player who requested for assistance and determine the card state, since the robot always localized itself in front of this player in a forward-facing pose before moving its head down to detect a Bingo card.

A. Participant Compliance

The total number of requests from Tangy to the participants is shown in Table II. A mean compliance rate of 98% was determined across all the participants. There were 3 distinct occurrences where participants did not comply with Tangy's requests. The first occurrence was when Participant 2 was requested by Tangy to move her card towards the robot, and immediately the participant sitting beside her moved the card for her not giving her a chance to comply with the robot's request. A similar occurrence happened with Participant 6, however, in this case Tangy repeatedly (three times) requested for her to move the card. Eventually, the participant sitting to her right moved her card for her. The second occurrence was when Participant 4 did not mark a called out Bingo number when another participant had activated her assistance request device. We suspect this participant presumed the game was over and thus, did not see the necessity of placing the marker on the Bingo card. The last occurrence was when on five occasions Participant 6 marked the incorrect numbers on the Bingo card when Tangy was calling out Bingo numbers.

TABLE II. PARTICIPANT COMPLIANCE RESULTS

	Participants							Mean
	1	2	3	4	5	6	7	
Total Number of Requests by Robot	141	56	86	74	79	80	24	**77**
Compliant Actions (% of Total Number of Requests)	100	98	100	99	100	90	100	**98**

B. Participant Engagement

It was found that participants had visual focus of attention either towards the robot or the Bingo cards an average of 90% of the total interaction time during Bingo games, Table III. It is important to note that visual focus of attention towards the robot increased when Tangy was providing personalized assistance. During number calling and assistance interactions participants were engaged in the activity 90% and 88% of the time, respectively. The majority of the participants used their assistance request device on multiple occasions, except for Participants 3 and 7. During short intervals of time, players were looking at and talking with other players and looking at the cards of these players, as well as around the room. The participants assisted each other while playing the game, as well as discussed the state of the robot. For example, on one occasion when a participant did not realize she had Bingo, another player informed her: "Bingo. You have Bingo" (Participant 1), "I won?" (Participant 2), "You have to press the button" (Participant 1), "Did I win?" (Participant 2), "Yeah, it will come over in a minute" (Participant 1). Another occasion was when a participant pressed her button: "I pressed my button" (Participant 6), "It's [Tangy] coming to you" (Participant 1), "Oh, it's coming" (Participant 6).

C. Questionnaire Results

The descriptive statistics for the questionnaire results are presented in Table IV. The reliability of the constructs utilized in this study was determined using Cronbach Alpha values. The alpha values were all below the acceptance level of 0.7 [19]. We further performed a statement analysis to determine whether removing statistically weak statements would improve the reliability of the constructs [20]. However, the alpha values remained below 0.7. Therefore, each statement in the constructs was analyzed separately. The low reliability could be attributed to the small participant size which resulted in low covariance among statement responses [21].

TABLE IV. QUESTIONNAIRE RESULTS

Construct	Statement	Mean	Std. Dev.
Perceived Enjoyment	I enjoy playing Bingo with Tangy.	5.00	0.00
Perceived Usefulness	I think Tangy could help me during the game.	4.00	1.73
	Tangy is able to help me.	4.57	0.79
Intent to use	I will play Bingo with Tangy again.	5.00	0.00
	I will ask Tangy for help again.	4.71	0.76
	I will ask Tangy for help in the future.	5.00	0.00
Attitude Towards	I think Tangy should host Bingo games again.	4.86	0.38
	I think Tangy is helpful to other players.	4.86	0.38
	I think Tangy makes the Bingo game interesting.	4.86	0.38
Social Presence	I like Tangy's appearance.	4.71	0.49
	It feels like Tangy is looking at me when I am playing the game with it.	4.00	1.73
Anxiety Towards	I am comfortable interacting with Tangy.	5.00	0.00
	I find Tangy intimidating.*	1.00	0.00
Trust	I trust Tangy's help.	4.86	0.38
	I will follow what Tangy asks me to do in the Bingo game.	5.00	0.00

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

D. Answers to Open-Ended Questions

The majority of participants suggested that Tangy facilitate other recreational games, such as card and board games, or exercise games. Three participants enjoyed Tangy's voice, and indicated that it was very "clear" and "human-like". Two participants expressed their enjoyment of Tangy's arm gestures. One resident, in particular, was especially delighted by Tangy's celebration dance, stating that the expressiveness of the robot's body language made it clear that "Tangy was excited". Four participants mentioned that the game flow speed and Tangy's card detection speed when interacting with each player could be made faster. One participant explained that: "Personally, for me, I would like the game to be faster. But I think it was a good speed for the others." The majority of participants specified that the robot calling out numbers

TABLE III. PARTICIPANT ENGAGEMENT RESULTS

Interaction Stages		Participants							Mean
		1	2	3	4	5	6	7	
Call Bingo Numbers	Total Interaction Time (minutes)	165.84	72.97	100.89	88.44	88.58	92.87	36.50	**92.30**
	Visual Focus of Attention Towards Tangy	51%	53%	29%	14%	28%	57%	45%	**40%**
	Visual Focus of Attention Towards Bingo Card	36%	42%	47%	82%	67%	36%	46%	**51%**
	Percentage of Total Interaction Time	87%	95%	76%	96%	95%	93%	91%	**90%**
Provide Assistance	Total Interaction Time (minutes)	10.79	2.49	0	7.20	8.63	13.38	0	**6.07**
	Visual Focus of Attention Towards Tangy	76%	84%	-	64%	52%	71%	-	**69%**
	Visual Focus of Attention Towards Bingo Card	10%	7%	-	21%	31%	22%	-	**18%**
	Percentage of Total Interaction Time	86%	91%	-	85%	83%	93%	-	**88%**
Weighted Mean of Both Stages	Total Interaction Time (minutes)	176.63	75.46	100.89	95.64	97.21	106.25	36.50	**98.39**
	Visual Focus of Attention Towards Tangy	53%	54%	29%	18%	30%	59%	45%	**41%**
	Visual Focus of Attention Towards Bingo Card	34%	41%	47%	77%	64%	34%	46%	**49%**
	Percentage of Total Interaction Time	87%	95%	76%	95%	94%	93%	91%	**90%**

verbally as well as displaying the numbers on its screen were important during the game.

VII. Discussions and Conclusion

The responses to the post-interaction questionnaire showed that the participants all enjoyed playing Bingo with Tangy and would play Bingo with the robot if it were to host games again in the future. We postulate that the participants' desire for future interactions with Tangy is partly due to them feeling comfortable interacting with the robot, which is a requirement for acceptance of healthcare robots [22]. Namely, in our study, all the participants were comfortable interacting with Tangy and were not intimidated by the robot. We hypothesize that they felt comfortable with Tangy due to its natural human-like social behaviors such as speech, eye gaze and body language (e.g. celebration dance, pointing gestures). The majority of participants identified with Tangy looking at them when they were playing Bingo and one participant said that she "really enjoyed when Tangy looked at her during the game". A study presented in [19] with older adults at a LTC facility and the iCat robot during household tasks also found that a more sociable iCat robot, resulted in the participants feeling comfortable with the robot. Furthermore, healthcare robots such as Tangy should have an appearance that illustrates its capabilities and should be perceived to be useful by older adult users [22]. Overall, the majority of participants liked Tangy's appearance and thought Tangy could help them with the game and would ask for help from the robot in the future. Namely, Tangy's ability to illustrate its capabilities was clear, including a mouth for speech, a tablet for visual display of information, and two arms to display body language/gestures.

Feedback on the interactions with Tangy also provided insights into possible future design improvements. For the Bingo interactions, we had limited Tangy's speed to 0.5 m/s in order to provide it with safe and non-intimidating movements in the environment. However, some residents believed the robot to be slow when moving around the room. In order to address this, our future work will consider matching the speed of a human facilitator. All participants enjoyed the socially interactive elements of the robot (music, jokes, and facts). It is interesting to note that they mainly preferred Tangy's humor through it telling jokes and laughing. This preference could be reflected in Tangy's social utterances by increasing the number and types of jokes the robot provides without interfering with the overall flow of the Bingo game. Participants also enjoyed the robot's background music, and provided genres of music Tangy could play for them. Tangy's music can be tailored in the future to player preferences for increased engagement. Lastly, the assistive behavior types and interactive attributes of Tangy can also be extended to other contexts, including the autonomous facilitation of additional recreational activities as suggested by the participants.

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References

[1] G. Lafortune and G. Balestat, "Trends in severe disability among elderly people: assessing the evidence in 12 OECD countries and the future implications," *OECD Publishing*, 2007.

[2] E. Farina et al., "Evaluating two group programmes of cognitive training in mild-to-moderate AD: Is there any difference between a 'global' stimulation and a 'cognitive-specific' one?" *Aging and Mental Health*, Vol. 10, No. 3, pp. 211-218, 2006.

[3] B. Sobel, "Bingo vs. physical intervention in stimulating short-term cognition in Alzheimer's disease patients," *American J. Of Alzheimer's Dis. & Other Dementias*, Vol. 16, No. 2, pp. 115-120, 2001.

[4] S. Sharkey, "People Caring for People: Impacting the Quality of Life and Care of Residents of Long-Term Care Homes," A Report of the Independent Review of Staffing and Caring Standards for Long-term Care Homes in Ontario, available at: http://www.health.gov.on.ca [Accessed May 2016], 2008.

[5] W.G. Louie, J. Li, T. Vaquero, and G. Nejat., "A focus group study on the design considerations and impressions of a socially assistive robot for long-term care." In IEEE International Symposium on Robot and Human Interactive Communication, pp. 237-242, 2014.

[6] M. Kanoh et al., "Examination of practicability of communication robot-assisted activity program for elderly people", *Journal of Robotics and Mechatronics*, Vol. 23, No. 1, pp. 3-12, 2011.

[7] T. Hamada et al., "Robot therapy as for recreation for elderly people with dementia-Game recreation using a pet-type robot", in IEEE International Symposium on Robot and Human Interactive Communication, pp. 174-179, 2008.

[8] R. Khosla, and M.-T. Chu, "Embodying care in Matilda: an affective communication robot for the elderly in Australia," in ACM SIGHIT International Health Informatics Symposium, pp. 295-304, 2012.

[9] R. Duda, and P. Hart, "Use of the Hough Transformation to Detect Lines and Curves in Pictures," *Communications of the ACM*, Vol. 15, No. 1, pp. 11-15, 1972.

[10] G. Grisetti, C. Stachniss, and W. Burgard, "Improved Techniques for Grid Mapping with Rao-Blackwellized Particle Filters," *IEEE Transactions on Robotics*, Vol. 23, pp. 34-46, 2007.

[11] S. Thrun, W. Burgard, and D. Fox, "Mobile Robot Localization," *Probabilistic Robotics*, pp. 157–184, 2005.

[12] ROS, "Navfn", Available: http://wiki.ros.org/navfn [Accessed March 2016], 2014.

[13] ROS, "Base_local_planner", Available: http://wiki.ros.org/base_local_planner [Accessed April 2016], 2014.

[14] Omron, "OKAO Vision", Available: http://www.omron.com/r_d/coretech/vision/okao.html [Accessed May 2016], 2007.

[15] H. Bay, A. Ess, T. Tuytelaars, and L Van Gool, "Speeded-Up Robust Features (SURF)," *Computer Vision and Image Understanding*, Vol. 110, No. 3, pp. 346-359, 2008.

[16] I. Sucan, M. Moll, and L.E. Kavraki, "The Open Motion Planning Library," *IEEE Robot. Autom. Mag.*, Vol. 19, No. 4, pp. 72–82, 2012.

[17] J. Morris et al., "MDS cognitive performance scale," *Journal of Gerontology*, Vol. 49, No. 4, pp. M174-M182, 1994.

[18] M. Heerink, B. Kröse, V. Evers, and B. Wielinga, "Assessing acceptance of assistive social agent technology by older adults: the almere model," *Int J Soc Robot.*, Vol. 2, No. 4, pp. 361-375, 2010.

[19] M. Heerink, B. Kröse, V. Evers, and B. Wielinga, "The influence of a robot's social abilities on acceptance by elderly users," IEEE International Symposium on Robot and Human Interactive Communication, pp. 521-526, 2006.

[20] A. Field, "Exploratory Factor Analysis," in Discovering statistics using SPSS, Sage Publications Limited, pp.627-685, 2006.

[21] J. E. Helms, K. T. Henze, T. L. Sass, V. A. Mifsud, "Treating Cronbach's alpha reliability coefficients as data in counseling research," *The Counseling Psychologist*, Vol. 34, No. 5, pp. 630-660, 2006.

[22] E. Broadbent, R. Stafford, and B. MacDonald, "Acceptance of healthcare robots for the older population: Review and future directions," *Int J Soc Robot.*, Vol. 1, No. 4, pp. 319-330, 2009.