The ENRICHME Project: Validation of the Human-Machine Interface

Roxana Agrigoroaie
Autonomous Systems and Robotics Lab
U2IS, ENSTA-ParisTech
Palaiseau, France
roxana.agrigoroaie@ensta-paristech.fr

François Ferland
Interdisciplinary Institute for
Technological Innovation (3IT)
Université de Sherbrooke
Sherbrooke, Québec, Canada
francois.ferland@usherbrooke.ca

Adriana Tapus
Autonomous Systems and Robotics Lab
U2IS, ENSTA-ParisTech
Palaiseau, France
adriana.tapus@ensta-paristech.fr

***Abstract*—Multiple research projects focus on the development of robotic systems that can improve the quality of life of the elderly. This paper presents some of the results from the validation phase of the European H2020 ENRICHME project, which developed a mobile robot assistant with multimodal perception capabilities and an integrated touch-based interface. The system was tested by eleven end-users for a duration of 7 to 10 weeks, in their own houses. We report the results of how the participants used the graphical user interface developed for the system to determine which custom-designed applications were the most popular. Our results show that the end-users used the cognitive games and the environmental data applications the most.**

***Index Terms*—MCI, social robotics, cognitive games**

I. Introduction

The rapid aging process of the worldwide population [1] has led to the necessity of finding viable solutions for the personalized care designed for the elderly. One solution, which shows promising results, is represented by socially assistive robots [2]. Researchers design and develop autonomous robots that are capable of natural interaction with humans, that can adapt their behavior based on the personality of the individuals they interact with [5] [15]. Such robots can provide monitoring [21], help with everyday tasks [11], can alert the family in case of emergencies [21], or they can stimulate different cognitive functions [25], [4], [7].

Some first attempts focused on long-term care for the elderly with social robots. The authors in [4], developed a socially assistive therapeutic robot that provided customized cognitive stimulation for people suffering from cognitive impairment in a music game scenario. The experiment was run for 8 months. More recently, the FP7 Mobiserv project [13] developed an integrated and intelligent home environment for the provision of health, nutrition and well-being services to older adults in order to support the independent living of older people. In the EU FP7 Hobbit project [11], the mutual care concept where the human and the robot take care of each other, was designed specifically for fall prevention and detection. It supports multimodal interaction for different impairment levels. The main purpose of the H2020 Mario project [6] is to help people with dementia to stay socially active by using different human-robot interaction tools: verbal, visual, touch. The H2020 RAMCIP project [14] focused on how a robot can monitor the behaviour of an elderly individual with MCI in order to provide assistance in case of need.

The current work is part of the Horizon2020 ENRICHME European project, whose purpose is to develop a socially assistive robot for the elderly with mild cognitive impairment (MCI) in order to help them remain active and independent for longer and to enhance their overall quality of life.

The paper is structured as follows: section II describes the purpose of the ENRICHME project, the robotic system and the applications developed. Section III describes the participants that took part in the experiments and presents the results. Section IV discusses our results, and finally section V concludes our paper.

II. ENRICHME Project

ENabling Robot and assisted living environment for Independent Care and Health Monitoring of the Elderly (ENRICHME) was a H2020 European research project. Its main purpose was to develop a personal robot for the elderly with MCI. The project had partners from Italy, the United Kingdom, France, the Netherlands, Poland, Spain, and Greece. The system was tested in two settings: in two Ambient Assisted Living (AAL) laboratories (Fondazione Don Carlo Gnocchi, in Italy, and Stichting Smart Homes in the Netherlands) and in three elderly care housing facilities (Lace Housing Ltd - LACE, in the United Kingdom, Osrodek Pomocy Spolecznej - PUMS, in Poland, and Aktios Licenced Eldery Care Units - AKTIOS, in Greece).

The testing participants of the project were recruited based on the following inclusion criteria: aged over 65 years old, diagnosed of MCI provided by a neuropsychologist or identified with mild cognitive impairment (MCI) or mild dementia on the MMSE score [9], and to be independent in executing basic activities for daily living, assessed through the Barthel ADL index [10].

For the purpose of testing the developed system, multiple use cases have been developed. One such use case, related to

This work was funded and done in the context of the EU H2020 ENRICHME Project, Grant Agreement No: 643691

games and entertainment provided by the robot to the user, is described as such:

> Frank likes to be active but due to his MCI he finds it difficult to initiate any activity. Sometimes, the robots' activity sensors and the sensors around the house detect that Frank is agitated and anxious. In order to reduce this anxiety state, the robot comes next to Frank, and suggests him to initiate a cognitive activity. The system knows from past experiences that Frank does not like to be approached from the back, so it approaches him slowly and from the front. Frank likes to play Trivia game and ask the robot to play with him. The robot adapts the difficulty level as a function to his previous performance and the current emotional state. After some games Frank can relax thanks to the robot that assisted him to engage in this activity.

The use case has been proposed based on the feedback given by the elderly and their families and caregivers in the project members countries to a pre-study questionnaire [24].
Some of the most important needs identified are:

- for the robot to call somebody in case of an emergency
- to remind the elderly about the medication that needs to be taken
- to increase the safety in the home by monitoring the environment and suggesting improvements
- to increase the safety of the elderly by monitoring physiological health parameters like heart rate, body temperature, respiration rate
- to help the elderly preserve their memory function by playing memory games with them
- to help them find lost objects
- to remind them about certain appointments
- to encourage and guide in performing physical exercises
- to remind about meal times and drinks and to provide advice about a healthy diet
- to encourage the elderly to enhance their contacts with friends

A. Robotic System

The robotic system used for the project is the TIAGo robot developed by PAL Robotics[1], in Spain. Figure 1 shows the robot interacting with one of the participants.

The robot features a mobile base, a lifting torso, a touch screen mounted on the torso, and a head. The eyes of the robot are equipped with an RGB-D camera, which provide both color (RGB) and depth (D) images. There are two speakers located between the head and the torso. A USB-powered thermal camera (Optris PI 450) is mounted on the head of the robot. The system also features an RFID reader module (ThingMagic Mercury6e) mounted below the touchscreen to detect objects with pre-attached RFID tags, as well as an environmental sensor (UiEM01) which provides temperature, humidity, light and air quality measurements. Smart Home

[1]http://tiago.pal-robotics.com/

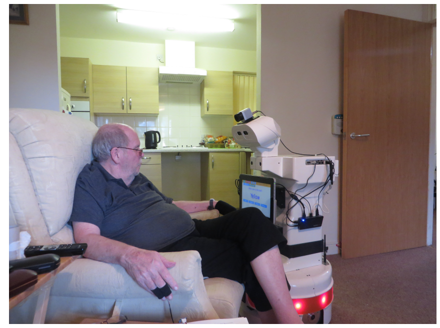


Fig. 1: The ENRICHME robot, based on a PAL Robotics TIAGo, interacting with one of the participants

Fig. 2: GUI main menu

Sensors (Fibaro Motion Sensor FGMS-001) for ambient temperature and humidity or electricity usage (Fibaro Wall Plug FGWP-102) were mounted in each room in the house. Data from these sensors were recorded on a server installed in the house. This server also served as a tunnel for a cloud-based application through which caregivers could interact with the robot and visualise the collected data.

For every-day interactions with the elderly user, a web-based graphical user interface (GUI) was developed for the touchscreen mounted on the torso of the robot. The GUI features nine custom developed applications: Cognitive games, Health tips, Physical activities, Find object, Environmental data (i.e., robot sensors; house sensors), Agenda, Call somebody, Weather forecast and News reading. These applications (also shown in Figure 2) were designed based on the use cases of the ENRICHME project and were customized based on the feedback received from the early test participants of the project. Each application is briefly presented in the following section.

B. Graphical User Interface

Cognitive games: as the end-users are elderly with MCI, we designed and developed nine cognitive games for helping them maintain and even improve their cognitive abilities. The games were designed to train memory, attention, and mental calculations, among others. The nine cognitive games are:

- *Digit and Letter Cancellation*: in a given time all occurrences of a randomly chosen digit/letter have to be found in a list of digits/letters.

- *Integer and Decimal Matrix Task*: the user needs to find in as many matrices as they can the pair of digits (integers or decimals) whose sum equals 10.
- *Memory Game*: the user first needs to memorize a set of images and then to decide if any of them are part of a new set of images.
- *Hangman*: this game is the implementation of the classical hangman game, where the user needs to guess a word by using letters of the alphabet.
- *Speed Game*: in this game two pairs of letter+number are shown on the screen. The user has to select as quickly as possible the pair that represents vowel+even number.
- *Puzzle*: the user has to reconstruct an image by dragging and snapping together puzzle pieces.
- *Stroop Game*: the user has to press on the button that corresponds to the color of the text that is displayed on the screen.

Health tips: In this activity, the user can listen to a series of healthy eating tips presented by the robot. The user can select to go to the next/previous tip or to listen to the same tip again. Currently the system provides nine tips related to a healthy diet: eating more fruits and vegetables, eating more fish, staying hydrated. The healthy tips are based on the British Nutrition Foundation recommendations[2].

Physical activities: For maintaining their physical abilities, the GUI features a physical activities application. The user is presented with a series of upper body exercises (i.e., head, shoulders, arms). Both auditory and visual feedback is provided by the robot for each exercise. The application uses the pose of the user as perceived by the RGB-D camera using the PrimeSense OpenNI body tracker. Based on the position of 22 joints, the angles between the joints of the upper body are computed before providing the feedback for each exercise. The physical exercises were decided together with the physical therapists from the care facilities.

Find object: The user can use the ENRICHME robot to localize different objects around the house. A visual interface was designed for the RFID-based object localization module of the robot. The user selects the object that he/she wishes to find. The robot will display the rooms/regions in descending order of the probability of finding the object in that room/region.

Environmental data: In this application, the user can select between visualizing the data from two types of sensors: an environmental monitoring sensor mounted on the robot and the Smart Home Sensors mounted around the house.

Agenda: The purpose of this application is for the user of the ENRICHME system to be able to visualize the appointments and reminders set up by the caregivers.

Call somebody: This application enables the user to perform video calls. The application was custom designed using WebRTC technology. The user has also the option of texting the contacts that are saved in the phone book of the application.

Weather application: In this application the user can see the weather forecast for its location. There are two visualization options: hourly forecast and daily forecast. The application uses the API of openweathermap.org.

[2]https://www.nutrition.org.uk/healthyliving/healtydiet.html

TABLE I: Testing duration for each participant

Participant	Site	Start date	End date	Total duration
P1	AKTIOS	11/10/2017	20/12/2017	10 weeks
P2	AKTIOS	21/12/2017	28/02/2018	10 weeks
P3	AKTIOS	11/10/2017	20/12/2017	10 weeks
P4	AKTIOS	21/12/2017	28/02/2018	10 weeks
P5	PUMS	02/11/2017	04/01/2018	9 weeks
P6	PUMS	08/01/2018	13/03/2018	10 weeks
P7	PUMS	14/10/2017	24/12/2017	10 weeks
P8	PUMS	02/01/2018	09/03/2018	9 weeks
P9	LACE	06/12/2017	08/02/2018	9 weeks
P10	LACE	08/11/2017	27/12/2017	7 weeks
P11	LACE	29/12/2017	16/02/2018	7 weeks

News reading: The application uses the RSS 2.0 feed of different newspapers to gather the latest news and display them to the end user. The newspaper and the news category can be selected by the user. The news are presented both written and read out loud by the robot.

The ENRICHME system was deployed in the house of the elderly users. In a typical usage scenario, when the user wants to play some cognitive games, they approach the robot. If the robot is located in a different room, the user select the Follow mode (i.e., a mode in which the robot follows the user) on the touchscreen interface and goes to a comfortable place to play the games (e.g., the livingroom sofa). From time to time the caregivers can also be present, but most of the time the user is alone when interacting with the ENRICHME robot.

III. Results

The developed ENRICHME system was tested in the elderly case housing facilities (i.e., LACE, PUMS, and AKTIOS). On each site two robotic systems were deployed.

A total of 11 participants (4 males and 7 females) tested the ENRICHME robot. The testing duration for each robot ranged between 7 and 10 weeks (see Table I). The ages of the participants range between 70 years old and 90 years old. Figure 3 shows three participants interacting with the ENRICHME system in each of the sites.

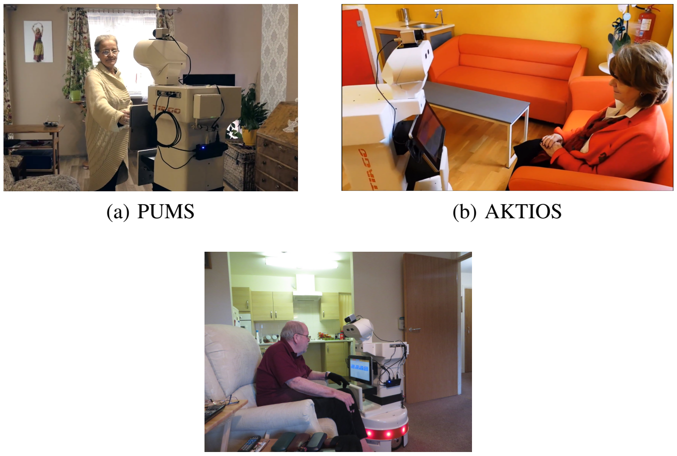
In this paper, we focus on the following questions:

- Q1: Which is the most used GUI application?
- Q2: Which is the most played cognitive game?

Furthermore, we also investigated the performance over time for one of the participants.

In order to answer these questions we have recorded how participants used the ENRICHME system GUI in a MongoDB database. The information was recorded using the following keys: user, application name, events (i.e., open or close the application), date, and time. For each cognitive game, we also recorded the game performance, enabling us to track the performance of the users over the time of the experiments.

Q1: Which is the most used GUI application?



(a) PUMS

(b) AKTIOS

(c) LACE

Fig. 3: Participants interacting with the ENRICHME robot

TABLE II: Usage of each application by the participants

GUI App	P1	P2	P3	P4	P5	P6
Cognitive games	4	4	5	6	93	1843
Health tips	2	4	4	0	13	10
Physical activities	12	22	6	3	6	37
Find object	8	4	12	0	29	4
Environmental data	18	20	22	4	73	125
Agenda	25	33	25	10	24	16
Call somebody	0	26	6	2	9	10
Weather	5	6	4	0	20	41
News	0	7	16	2	7	19

GUI App	P7	P8	P9	P10	P11	Total
Cognitive games	338	418	10	0	2	2723
Health tips	15	14	0	0	2	64
Physical activities	10	35	0	0	2	133
Find object	30	14	0	16	8	125
Environmental data	72	102	16	17	22	491
Agenda	10	21	0	8	5	177
Call somebody	12	20	0	8	1	94
Weather	47	20	0	4	6	153
News	17	19	5	4	7	103

To answer this question, we first have to determine how many times each application was used by each user. Based on the results shown in Table II the most used GUI application is represented by the Cognitive Games (2723 times), followed by the Environmental data application (491 times). The least used two applications are represented by the Healthy Tips (64 times) and the Call somebody application (94 times).

Q2: Which is the most played cognitive game?

Table III shows how many times each game was played by each participant. The most played game is represented by the Hangman game, mostly played by participants P6 (1257 times), P7 (208 times) and P8 (137 times). The second most played game is represented by the Digit Cancellation game, played 272 times by participant P6, and 236 times by participant P8. The two least played games are Integer Matrix game (played 23 times by all 11 participants) and the Speed game (played 24 times by the 11 participants).

TABLE III: Number of times each game was played by the participants

Cognitive game	P1	P2	P3	P4	P5	P6
Digit Cancellation	0	0	0	3	18	272
Letter Cancellation	0	1	0	0	10	196
Integer Matrix Task	0	0	0	0	1	13
Decimal Matrix Task	0	4	2	0	0	24
Memory game	0	0	0	0	12	25
Hangman	2	2	2	1	36	1257
Speed game	0	0	0	0	0	24
Puzzle	1	1	1	2	25	12
Stroop Game	1	0	0	0	1	17

Cognitive game	P7	P8	P9	P10	P11	Total
Digit Cancellation	102	236	4	0	1	636
Letter Cancellation	51	23	0	0	0	281
Integer Matrix Task	5	0	4	0	0	23
Decimal Matrix Task	5	0	0	0	0	35
Memory game	0	3	0	0	0	40
Hangman	208	137	0	0	1	1646
Speed Game	0	0	0	0	0	24
Puzzle	14	14	0	0	0	70
Stroop Game	3	5	2	0	0	29

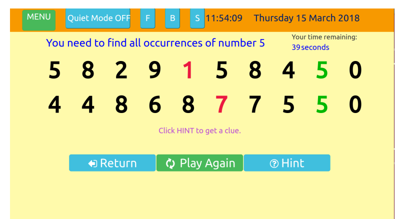


Fig. 4: Example of Digit Cancellation

Performance analysis

Next, we were interested in finding out the evolution over time of the performance during one cognitive game for one of the participants. For this purpose we selected participant P6 as this participant played more than any of the other participants. For this analysis, we selected the Digit Cancellation game. The rationale behind this decision was that this is the second most played game, and it is not language specific. For Hangman, which is the most played game, there are 150 words from five categories (i.e., Animals, Cities, Vegetables, Fruits, and Objects inside the house). A performance analysis would have to be language specific, taking into consideration the difficulty of the word, the familiarity of the participant with that word, something that is outside the scope of this paper.

In Digit Cancellation the user has 50 seconds to find all occurrences of a randomly chosen digit in a list of random 20 digits (an example is shown in Figure 4). The minimum number of occurrences of the chosen digit is 3 and the maximum is 9. The performance parameters of interest are the number of mistakes made and the time needed to find all occurrences. The number of occurrences in each game is random, therefore, we had to select all games that had the same number of occurrences. Participant P6 played the Digit Cancellation game 272 times. There were 132 games with 3 occurrences, 77 games with 4 occurrences, 35 games with 5 occurrences, 17 games with 6 occurrences, 7 games with 7 occurrences, and 3 games with 9 occurrences.

For this analysis we selected the 35 games with 5 occurrences, the 17 games with 6 occurrences and the 7 games with 7 occurrences. We did not consider the games with 3 and 4 occurrences, as the time needed to finish these games was short (M=5.36, M=5.92, respectively) compared to the 5, 6 and 7 occurrences (M=8.22, M=7, M=8.85, respectively).

As no mistakes were made, only the time needed to find all occurrences is shown in Figure 5. The performance is better over time (mostly below 10 seconds), except for games numbers 25 to 28 in case of the games with 5 occurrences, game number 11 for the games with 6 occurrences, and game number 5 for the games with 7 occurrences, when there are peaks in game time. These games were all played in the same day between 13h52 and 13h55. We believe these longer game duration times could be explained by external factors (e.g., fatigue, not feeling well, being distracted by someone else, ...) that cannot be detected by the robot and therefore are not available for further analysis. We applied Spearman's rank correlation to find out the significance of the improvement in game performance. We obtained the following results: for the games with 5 occurrences (p=0.05, r=-0.32), for the games with 6 occurrences (p=0.07, r=-0.43), and for the games with 7 occurrences (p=0.08, r=-0.68). Based on these results, we can conclude that a statistically significant decreasing trend (r=-0.32) in game times could be observed for games with 5 occurrences. Games with more occurrences, while also displaying a decreasing trend, only approach statistical significance, prompting for further experimentation and analysis before confirming an improvement.

In the next section, we provide a discussion of these results together with some of the lessons that we learned and the limitations of the study.

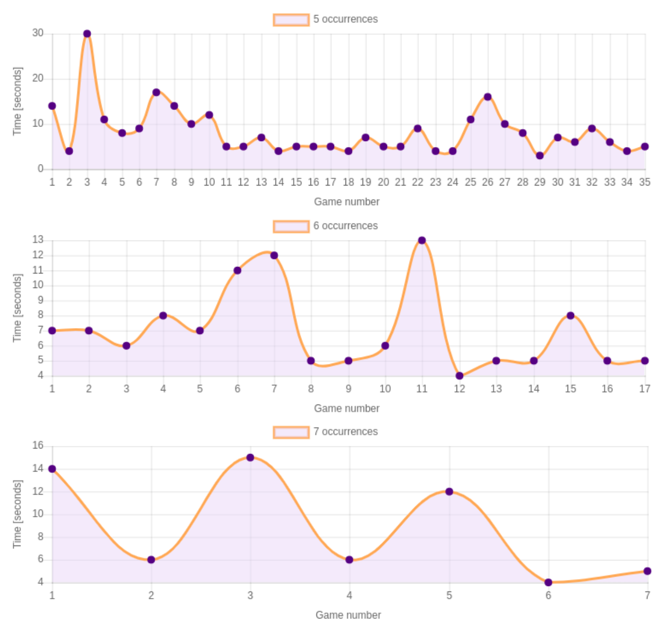


Fig. 5: Performance evolution over time of participant P6 for Digit Cancellation

IV. Discussion

The previously presented results show that all 11 participants interacted with the ENRICHME system. However, there are large differences in the way the participants used the applications provided by the system. Some of them used each application extensively (for example, participants P6 and P8), while others did not use them very much (e.g., participant P9). These differences can be attributed on one part to the preferences of the participants (they might have enjoyed some applications more than others), and on the other part, there was some data that was lost due to technical problems.

The system was tested for a duration of up to 10 weeks. Thus while playing the cognitive games, the participants experience different emotions or moods. As these have an influence on performance, at random times, the self-reported mood of the participants should be recorded.

Another aspect that should be mentioned is that participants might have encountered different difficulties in using the applications. Even if the care givers were trained in how to use each application, sometimes the presence of the technical members is required in order to better explain how a certain application should be used. We believe that it is recommended for the technical partners to be present when the system is presented to the end user. This will ensure that the user knows exactly what to expect from the system.

V. Conclusion

In this paper we have presented some of the results from the validation phase of the H2020 ENRICHME Project. The system was deployed in the houses of 11 participants, who tested the system for a duration of up to 10 weeks. The participants have used all the applications that are part of the system. Some of the most used ones are the cognitive games, and visualizing the data from the environmental sensors (sensors that are placed on the robot and in the house).

Some of our future work include the analysis of the other data recorded by the system (e.g., physiological data) and finding how the physiological state of the user influences the way in which the ENRICHME system is used.

References

[1] Wan He, Daniel Goodkind, Paul Kowal, (2016), "An Aging World: 2015", In: *International Population Reports, United States Census Bureau*

[2] Feil-Seifer, D., and Mataric, M.J., (2005), "Defining Socially Assistive Robotics", *In Proceedings of IEEE 9th International Conference on Rehabilitation Robotics*

[3] Tapus, A., Mataric, M.J., Scassellati, B., (2007), ”The Grand Challenges in Socially Assistive Robotics”, *IEEE Robotics and Automation Magazine (RAM), Special Issue on Grand Challenges in Robotics*

[4] Tapus, A., Tapus, C., Mataric, M.J., (2009), ”Music Therapist Robot for Individuals with Cognitive Impairments”, *In Proceedings of the ACM/IEEE Human-Robot Interaction Conference (HRI)*

[5] Aly, A., Tapus, A., (2014), ”Towards Enhancing Human-Robot Relationship: Customized Robot’s Behavior to Human’s Profile”, *In Proceedings of the AAAI Fall Symposium on AI for Human-Robot Interaction, Washington DC*

[6] Kouroupetroglou, C., Casey, D., Raciti, M., Barrett, E., D’Onofrio, G., Ricciardi, F., Giuliani, F., Greco, A., Sancarlo, D., Mannion, A., Whelan, S., Pegman, G., Koumpis, A., Recupero, D.R., Kouroupetroglou, A., San- torelli, A. (2017), ”Interacting with dementia: The mario approach”. In: *Studies in Health Technology and Informatics*

[7] Tapus, A., Tapus, C., Mataric, M.J., (2009), ”The Use of Socially Assistive Robots in the Design of Intelligent Cognitive Therapies for People with Dementia”, *Proceedings of the International Conference on Rehabilitation Robotics (ICORR)*

[8] Ferland, F., Leconte, F., Tapus, A., Michaud, F., (2014), ”An Architecture with Integrated Episodic Memory for Adaptive Robot Behavior”, *In Proceedings of hte AAAI Fall Symposium on AI for Human-Robot Interaction, Washington DC*

[9] Folstein, M., Folstein, S.E., McHugh, P.R., (1975), ”Mini-Mental State - a Practical Method for Grading the Cognitive State of Patients for the Clinician”, *Journal of Psychiatric Research, 12(3), 189-198*

[10] Mahoney, F.I., Barthel, D.W., (1965), ”Functional Evaluation: The Barthel Index”, *Maryland State Medical Journal, 14:61-5*

[11] Fischinger, D., Einramhof, P., Wohlkinger, W., Papoutsakis, K., Mayer, P., Panek, P., Koertner, T., Hofmann, S., Argyros, A., Vincze, M., Weiss, A., Gisinger, C., (2013), ”Hobbit - The Mutual Care Robot”, *ASROB-2013 in conjunction with IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Japan*

[12] Lorenz, T., Weiss, A., Hirche, S., (2015), ”Synchrony and Reciprocity: Key Mechanisms for Social Companion Robots in Therapy and Care”, *International Journal of Social Robotics*

[13] Nani, M., Caleb-Solly, P., Dogramadgi, S., Fear, C., Heuvel, H., (2010), ”Mobiserv: An integrated intelligent home environment for the provision of health, nutrition and mobility services to the elderly”. In: *4th Companion Robotics Workshop in Brussels*, Brussels, 30th September

[14] Kostavelis, I., Giakoumis, D., Malasiotis, S., Tzovaras, D. (2016), ”RAMCIP: Towards a Robotic Assistant to Support Elderly with Mild Cognitive Impairments at home”, In: *Pervasive Computing Paradigms for Mental Health*, 186-195

[15] Woods, S., et.al, (2007), ”Are robots like people?: Relationships between participant and robot personality traits in human–robot interaction studies”, In: *Interaction Studies*

[16] Shibata, T., (2012), ”Therapeutic Seal Robot as Biofeedback Medical Device: Qualitative and Quantitative Evaluations of Robot Therapy in Dementia Care”, *IEEE Proceedings*

[17] Shibata, T., Mitsui, T., Wada, K., Touda, A., Kumasaka, T., Tagami, K., Tanie, K., (2001), ”Mental Commit Robot and its Application to Therapy in Children”, *Proceedings IEEE/ASME International Conference on Advanced Intelligent Mechatronics, vol2, pp 1053-1058*

[18] Wada, K., Shibata, T., Saito, T., Tanie, K., (2003), ”Psychological, Physiological and Social Effects to Elderly People by Robot Assisted Activity at a Health Service Facility for the Aged”, *Proceedings of IEEE/ASME International Conference on Advanced Intelligent Mechatronics*

[19] Yamazaki, K., Ueda, R., Nozawa, S., Kojima, M., Okada, K., Matsumoto, K., Ishikawa, M., Shimoyama, I., Inaba, M., (2012), ”Home-Assistant Robot for an Aging Society”, *IEEE Journals and Magazines*

[20] Bohren, J., Rusu, R.B., Jones, E.G., Marder-Eppstein, E., Pantofaru, C., Wise, M., Mösenlechner, L., Meeussen, W., Holzer, S., (2011), ”Towards Autonomous Robotic Butlers: Lessons Learned with the PR2”, *Proceeding IEEE International Conference on Robotic Automation*

[21] Coradeschi, S., Cesta, A., Cortellessa, G., Coraci, L., Galindo, C., Gonzalez, J., Karlsson, L., Forsberg, A., Frennert, S., Furfari, F., Loutfi, A., Orlandini, A., Palumbo, F., Pecora, F., von Rump, S., Stimec, A., Ullberg, J., Ötslund, B., (2014), ”GiraffPlus: A System for Monitoring Activities and Physiological Parameters and Promoting Social Interactoin for Elderly”, *Human-Computer Systems Interaction: Backgrounds and Applications 3 Advances in Intelligent Systems and Computing Volume 300:261-271*

[22] Graf, B., Reiser, U., Haegele, M., Mauz, K., Klein, P., (2009), ”Robotic Home Assistant care-o-bot 3-product Vision and Innovation Platform”, *IEEE workshop on advanced robotics and its social impacts*

[23] Leconte, F., Ferland, F., and Michaud, F. (2015) ”Design and Integration of a Spatio-Temporal Memory with Emotional Influences to Categorize and Recall the Experiences of An Autonomous Mobile Robot”, *Autonomous Robots*

[24] Cylkowska-Nowak, M., Tobis, S., Salatino, C., Tapus, A., and Suwalska, A. (2015) ”The Robot in Elderly Care.”, In: *Psychology and psychiatry, sociology, health care and education - SGEM 2015, pp:1007-1014.*

[25] Tanaka, M, Ishii, A and et al, (2012), ”Effect of a human-type communication robot on cognitive function in elderly women living alone”, In: *Medical Science Monitor*, vol. 18