An Animaloid Robot as a Cognitive Stimulator to support Elders with Cognitive Impairments: Preliminary Requirements

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ABSTRACT. *We focus on some preliminary, theoretical and practical, requirements for an agent-based system for cognitive interaction with older people. We stress (a) the acceptability of an artificial agent by elders; (b) a user model, which includes user knowledge, expectations, goals; (c) a representation system, (d) an interaction system, including physical and verbal interaction. We describe in some detail a preliminary study aimed at assessing the acceptability of interaction of cognitively impaired elders with an artificial companion by studying their reactive behaviour during a simple experimental session. First results show that affective aspects of interaction with an artificial companion are not affected by negative feelings towards technology, but that positive attitudes are required in order to achieve awareness of its usefulness for a cognitive interaction. We also give some suggestions about method for the development of a working cognitive interaction system. The agent should build its user model - including relevant knowledge, expectations, and goals - by interactive learning, and operate jointly with a situation awareness engine.*

KEY WORDS: *animaloid, cognitive interaction, elders, gerontechnology.*

1. Introduction

The age-related physiological fall of cognitive abilities becomes a more and more challenging problem in our society; cognitive impairments affecting older people are often combined with the fact that many elders are, under various circumstances, living alone. Technology should not replace natural human interaction, but a possible help in some situations may come from interaction with artificial agents.

One natural solution, which older people have been using for centuries, is to live with an animal: this may improve the quality of life, obviously because it relieves loneliness but also because it gives elders something to do, to attend, to physically interact with, a cognitive challenge, and also enables them to gain a safety feeling because an animal does not focus the person's physical or mental disabilities. Pet-therapy is frequently used for the care of people affected by cognitive disabilities, with good results, e.g. improving social behaviours (Kongable *et al.*, 1990). On the other hand, for safety or hygienic reasons real animals are often not allowed in residential houses, or they are not otherwise liked. Moreover, their intelligence may not be sophisticated enough for cognitive challenges required in helping elder people. Thus the hypothesis of replacing real animals with animal-shaped objects is becoming object of a serious investigation (Nakajima *et al.*, 2001).

Animal-shaped toys have been evolved into animal-shaped robots, or animaloids, and researchers have started investigating how robotic companions can be used with elderly people, not only as "emotional activators", but also for addressing interactive and communication functions, so acting as a support for their cognitive difficulties. For example, the interaction with the AIBO robotic dog on four elders with dementia resulted in improved communication patterns (Yonemitsu *et al.*, 2002). In a different comparative study, nine older women from a nursing home, with moderate to severe dementia, received two interactive sessions of 10 minutes each, with a plush cat and with the robotic cat NeCoRo; the emotional effects of such interactions on the patients were also studied (Libin *et al.*, 2004a). The same authors introduced also the new concepts of "robotic psychology" and "robot therapy", focusing on "interactive stimulation robots" (Libin *et al.*, 2004b). A unified assessment tool, named the Person-Robot Complex Interaction Scale (PRCIS) was also defined. In Japan, at the National Institute of Advanced Industrial Science and Technology (AIST), Takanori Shibata et al. have developed a robotic baby seal, named Paro. They carried out several experiments involving Paro and different groups of subjects, from children to elderly, to persons with cognitive disabilities (Wada *et al.*, 2005). At MIT Media Lab a group of researchers are developing a Teddy Bear-like robot, to investigate on the recognition of affective contents of touch in human-animaloid interaction (Stiehl *et al.*, 2005).

A most advanced result to be pursued, but still less achieved, is to make robotic companions act as true cognitive stimulators, by fully exploiting their interactivity and their (although limited) processing capabilities. In this paper, we focus on some preliminary, theoretical and practical, requirements for such a project.

In our view, an agent-based system for cognitive interaction with older people should be based at least on studies about:

(a) the **acceptability** of an artificial agent by elders;

(b) a **user model**, which includes user knowledge, user expectations, user goals;

(c) a **representation** or ontological system, essentially able to implement at least categorical functions;

(d) an **interaction** system, including physical and verbal interaction.

In order to better define acceptability, it is useful to distinguish three aspects of human interaction with artefacts:

affective, including emotional responses elicited by the artefact like fear, attraction, pleasantness, etc., or something referable to an immediate sense of a possible and meaningful integration into the person's own life space;

cognitive, including not much the knowledge about how to use it (which would be the usual cognitive aspect of attitude), but rather the use of cognitive resources such as memory or attention in tasks concerning a joint operation involving both the person and the artefact;

functional, including the perception of the potential usefulness and the possible control of the artefact in practical situations.

For example, an artefact may be acceptable on the affective grounds if it looks attractive and not frightening, on the cognitive grounds if it supports person's cognitive processes, and on the functional grounds if a person can clearly see what she can do with it.

We already undertook the first step, trying to assess the acceptability of interaction with an artificial companion by studying the reactive behaviour of older people with limited cognitive impairment during a simple experimental session. We are going to describe this study in some detail (for a full treatment, see Odetti *et al.*, 2007), and then to give some suggestions about the other points made above.

The pilot study described in this paper was conducted jointly by the Gerontechnology Group of the ARTS Lab at the Scuola Superiore Sant'Anna, and by the DISEM (Department of Endocrinological Science and Medicine) of the University of Genoa, between September 2006 and January 2007, to preliminarily evaluate how acceptable robot-mediated pet-therapy is for older people with moderate cognitive impairments (MCI or other kinds of dementia diseases in early stage).

The study was intended to gather some basic preliminary user-centered information. It is worth to point out that, although our preliminary survey was based on a group of people with clear cognitive disorders, it is not intended to be restricted to a clinical domain but it is aimed at investigating somewhat broad requirements, that can hold with elderly people in general. We think, however, that initially considering interaction with an artificial agent in patients with some clearly diagnosed cognitive impairment can force us to set such requirements more strictly even for less severe, not openly diagnosed, cognitive diseases "normally" found in senescence.

2. Method

2.1. *Participants*

Participants were 24 patients of the DISEM dementia evaluation service, in early stages of dementia of different types; their MMSE score averaged 27 ± 3 points. Informed consent was signed by each patient. Participants' average age was 76.6 (s=6.23); 12 of them were males and 12 were females. They were affected by the following disorders: 11 probable Alzheimer's disease (AD) (NINCDS-ADRDA criteria), 7 amnestic Mild Cognitive Impairment (aMCI) (Petersen *et al.*, 2001), 1 vascular dementia, 1 fronto-temporal dementia, 1 Parkinson dementia, 1 multi system atrophy and 2 subjective memory deficit.

2.2. *Scenario*

The experimental sessions took place in the room of medical examination, at the end of standard visits; some patients were at their first visit, others were returning patients. The examiner was sitting at the desk, with a laptop computer, and the patient was sitting in front of him/her. During the "standard" visit, the robot was not visible by the patient, who knew that she/he would have been involved in a very simple experiment at the end of examination. Nothing suggested the presence of unusual technology in the scenario. The informed consent briefly talked about a safe experiment, without suggesting that a robotic dog was going to enter the room. This was fundamental, since it was important to measure the reaction to a completely unexpected event like the entrance of an animaloid in the scene.

2.3. *Materials*

The experimental equipment was composed of one Sony AIBO ERS-7 robotic dog, one laptop computer (normally used by the examiner to take notes during the visit), and a simple client-server software, through which the examiner could easily control the execution flow of the experiment.

Simple robot motion tasks and reactive behaviours were implemented using URBI (Universal Real-Time Behaviour Interface, a client-server framework for high-level control of robotic platforms; Baillie, 2005).

The visual client application consisted essentially in a remote control to trigger the transitions between successive steps in the experiment. It was developed using C++ and QT4, and connected to the URBI server running on AIBO through a dedicated library.

2.4. *Experimental setup*

Sessions with patients were articulated into two main phases: first, on a command received from the remote controller managed by the examiner, the AIBO robot walked along a pre-defined path close to the patient and sat down, roughly in front of him/her. Then, it wagged its tail and barked in a "friendly" way. It was obviously fundamental that the dog was perceived as not aggressive.

With AIBO walking in, the examiner observed the patient reaction. If the patient showed fear or repulsion, the examiner tried to reassure her/him. Then, the examiner asked a couple of questions to the patient: "Does it reminds you of something? What does it look like to you?", and "Do you like it?". The answer to the second question was used by the examiner to decide whether the session could go on. In case of a negative answer, AIBO was sent away by the examiner. The same if the patient was showing fear or repulsion, and the examiner did not succeed in encouraging him/her. In case of a positive or a neutral answer, the examiner started the second phase of the session, picking up the AIBO dog from the floor and putting it on the desk, between him and the patient.

With a command from the remote control, the examiner let AIBO activate two different reactive behaviours. Then, he started petting the AIBO's back while talking to the patient. AIBO reacted to this action by wagging its tail and moving its head and mouth, to suggest a feeling of "happiness".

Then, the examiner asked the patient whether he/she wanted to try and do the same. If the answer was positive, the examiner invited the patient to gently pet the dog's back, and observed his/her reaction to AIBO's behaviour.

Then he asked the patient "Would you enjoy having such a robot at home?", going more in depth in case of positive answer: "what could you do with it? Do you think that you could play together? Do you think that it could be useful to you in any way? How?". At this point, during this discussion, the examiner suggested: "this dog could help you in reminding today's date. Do you want to try?". If Yes, the examiner would tell the patient how to let AIBO say the current date: "please, touch [the sensor on] its head for 2 seconds". After this interaction was completed, the session ended with a few more questions, aimed at evaluating the patient's feelings while interacting with the AIBO dog.

The following questions were asked during the sessions: Q1: Are you afraid of it? Q2: Does it remind you of a dog? Q3: Do you like it? Q4: Do you think it could be useful to you? Q5: Do you feel any attraction towards electronics goods? Q6: Would you like to give orders to it?

Furthermore, a general question about which electronic goods were present at the patients' home was asked.

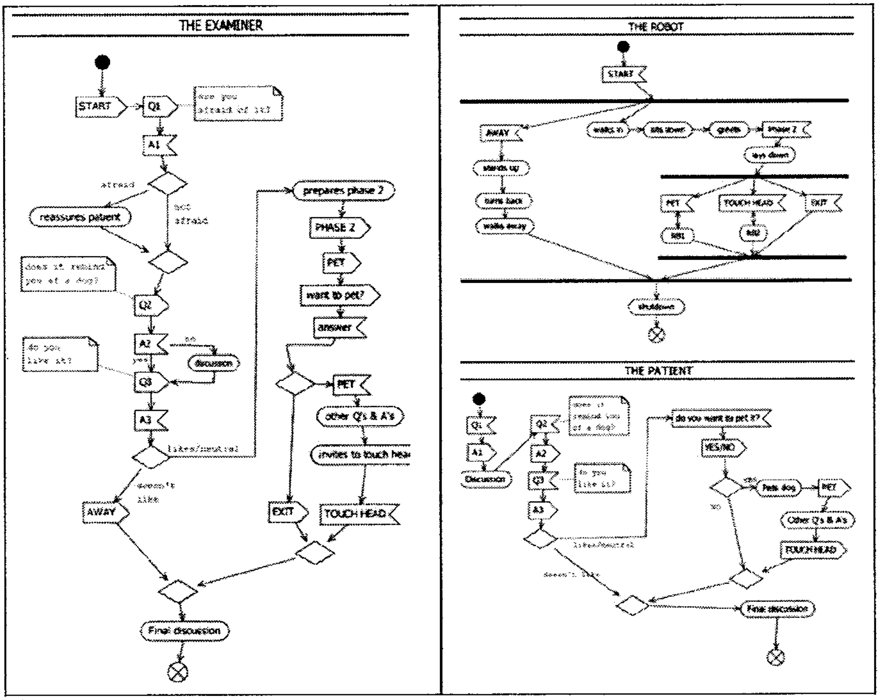

Figure 1. *UML activity diagram*

3. Results

Table 1 summarizes the patients' answers in terms of frequency, average score, and normalized average score in the [0..1] range for questions Q1, Q2, Q3, Q4, Q5, and Q6.

From the analysis of the scores, we can easily see that the AIBO is generally perceived by the pilot group as harmless, friendly, cute. During the study, only 2

	0 (NO)	1	2	3	4	5 (VERY)	Avg. (norm.)
Q1	23	0	0	1	0	0	0.13 (.03)
Q2	1	1	0	2	6	14	4.21 (.84)
Q3	1	1	1	1	1	19	4.38 (.88)
Q4	9	0	2	4	2	7	2.46 (.49)
Q5	9	2	2	4	2	5	2.13 (.43)
Q6	(NO) 12					(YES) 12	0.50

Table 1. *Scores for answers to questions 1-6: frequency, average and normalized average*

patients answered negatively to Q1 or Q3, causing the examiner to send the robot away. On the other hand, it is rather evident that the participants to the study tended not to perceive its potential usefulness, or at least, not as clearly as they recognized it as cute and friendly (avg. score 2.06 for Q4). Only one half thought that they would like to give orders to the dog. Answers to Q4 and Q6 actually show a strong relationship with Q5 scores, as shown by Table 2.

	Q1	Q2	Q3	Q4	Q6
Corr(Qi, A5)	-0.22	0.43	0.32	0.67	0.65

Table 2. *Correlation between answers to Q1,2,3,4,6 and answers to Q5*

Dividing the group into two subgroups SG0 (including patients who answered with a 0 score to Q5) and SG+ (Q5 score ≥ 1) the resulting scores (Table 3) are significantly different. They clearly show that the patients who did not completely reject technology tended to accept the idea that a companion robot like AIBO could also be useful in their daily life.

Question		Avg. score All $\overline{Q5} = .43$	Avg. score SG+ $\overline{Q5} = .68$	Avg. score SG0 $\overline{Q5} = 0$
Affective interaction	Q1	0.03	0.00	0.07
	Q2	0.84	0.92	0.71
	Q3	0.88	0.91	0.82
Functional interaction	Q4	0.49	0.68	0.18
	Q6	0.50	0.73	0.11

Table 3. *Subjects with a 0 score on Q5 have a very low score also on Q4 and Q6, while scores on Q1,2 and 3 remain substantially uniform*

Significant difference in answers to Q4 and Q6 also appears when the group is divided in two subgroups basing on gender (Table 4).

Question		Avg. score		
		All	M	F
Affective interaction	Q1	0.03	0.00	0.05
	Q2	0.84	0.91	0.76
	Q3	0.88	0.85	0.91
Attitude to technology	Q5	0.43	0.38	0.47
Functional interaction	Q4	0.49	0.40	0.60
	Q6	0.50	0.38	0.64

Table 4. *Normalized average scores, by gender*

Finally, as shown in Table 5, no relationship seems to exist between answers to questions from 1 to 6 and MMSE score, while a negative correlation is suggested with education level.

	Corr(Qi, S)	Corr(Qi, MMSE)
Q1	-0.18	-0.06
Q2	-0.05	0.02
Q3	-0.49	0.25
Q4	-0.55	0.35
Q5	-0.51	0.34
Q6	-0.45	-0.02

Table 5. *Correlation values between question scores, years of scholarity and MMSE scores*

4. Discussion

A preliminary analysis of the acceptability of animaloid companion robots by older people with limited cognitive impairment has shown that different attitudes to technology (rejection vs. a generically non negative attitude) do not affect significantly the **affective** components of interaction between an AIBO robot and older people with early/pre-clinical dementia (Tables 3, 4). On the contrary, the ability to imagine that such an artefact can also be useful, and that it is possible to have a **functional** interaction with it, seems to depend strongly on the non negative feeling for technology.

Differences between women and men did not seem very relevant in answers to questions dealing with the affective component of human-robot interaction, while women seem to be slightly more attracted than men by electronic goods and technology. This is a somewhat unexpected result, which is coherent with answers to question Q4 and Q6: attention to functional aspects of interaction, including usefulness and control of the artefact, seems to be stronger in women.

Finally, the negative correlation between question scores and level of education could suggest that less educated people accept the robot and its potential usefulness more easily than people with a higher level of education.

The animaloid-like appearance seems not to be a significant advantage because some of the subjects are not able to recognize it (as we could expect due to the cognitive problems). Few emotional links are also created. This is probably due to the already limited cognitive capacities of the subjects. These are very preliminary results which need to be investigated more in details with the animaloid robot autonomously behaving and during the evolution of the cognitive disability from the very onset.

A fully interacting system for older people, acting in human centered environment as a companion in their daily life, capable of recognising and monitoring their actions, would require complex perceptual, knowledge representation, and communication subsystems. Some practical compromises about sensorimotor aspects then should be put in place. Perceptual constraints can be overcome by mature technologies, e.g. by using scanning systems for object recognition, smart tags, or by making communication rely on voice recognition/production. Our preliminary study about interaction shows that in some conditions this can be acceptable.

Our study did not yet consider **cognitive** aspects of interaction. From this point of view, various challenging problems must be solved in order to make a working model. Here we can only suggest some ways to set up next steps, obviously not deriving from above described results. The most difficult problems from the cognitive perspective are in knowledge representation, notably in how to feed the system with really relevant knowledge. We think that a good way to achieve this result would be through interactive learning, not explicit top-down teaching. The agent should be actively searching for information in order to build and update its user model. User model should include user goals, expectations, and actions (routines firstly, but also non routines); the agent should have its own expectations and problem detection would rely on the comparison between both expectation patterns.

The above considerations are leading toward the new, emerging paradigm of Ubiquitous Robotics, strictly related to the application domain of Ambient Assisted Living, that arises from a shift of the focus from the more "traditional" concept of Ubiquitous/Pervasive Computing (i.e. from information) to matter and physicality. Networked, ubiquitous robotic systems conveying data *and* physical actions in intelligent environments, can provoke a profound and pervasive impact at different scales: global, local, "personal", external and internal and so forth. The role of a relational artifact, like an animaloid companion robot, embedded in an Ubiquitous

Robotics system, would vary greatly, depending on the user's functional and cognitive profile.

When considering the full range of conditions related to ageing, three large groups of potential older users of Ubiquitous Robotics systems can be identified: people with physical or psychological reductions but without definite cognitive deficits; older people affected by minor cognitive deficits; older people with moderate to severe dementia. In the first group, the robot could interact with a digital personal planner, to remind the user of her/his daily schedule. With a user of the second group, the robot could provide the user with cognitive feedback and support during the execution of activities of daily living. Finally, with patients affected by moderate to severe cognitive impairment, the communication functionalities would drastically lose meaningfulness, because such patients would be unable to understand the meaning of the messages themselves.

Cognitive aspects of a model aimed at interacting in real time with impaired people especially include resource-related processes, like working memory and attention. One possible development of research is studying how the above described targeted knowledge representation could work in conjunction with a situation awareness monitoring engine. Situation awareness (Endsley, 2004) is a concept that has been proposed especially in studies about aviation, emergencies or other contexts where environmental knowledge is critical and information flow may be overwhelming. This term refers to the continuous extraction of environmental information, the comprehension of its meaning, its integration with previous knowledge to form a consistent mental representation, and the projection of that representation in anticipating events in the near future. Older people often may find themselves in contexts where attention to situation and error-free decision can be critical. In order to build a working monitoring engine, a shared representation system should be developed; for example, each event could be coded as having attributes like "what", "when", and "where" (Livnat et al., 2005).

Overall, our preliminary work shows that interaction of older people with artificial agents can work in some definite conditions. In particular, it shows that merely encouraging affective aspects of interaction or a mere acquaintance with a robotic companion may not be sufficient. Also an explicit belief of its usefulness, and of its functional operation and ways of control should be promoted. Our long-term aim is to design and develop cognitive ubiquitous robotics, including a full treatment of cognitive aspects, for older people both subject to "normal" cognitive ageing and to "mild" cognitive impairments.

The full team of authors that participated in the preliminary experiment included Luca Odetti, Paolo Dario, Silvestro Micera (EZ-Lab), and Maria Paola Barbieri, Debora Mazzei, Elisa Rizza (DiSEM).

5. References

Baillie J.-C. "URBI: towards a universal robotic low-level programming language", *Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems, (IROS 2005)*, 2005, p. 820-825.

Endsley M.R. "Situation awareness: progress and directions", in S. Banbury & S. Tremblay (Eds.), *A cognitive approach to situation awareness: Theory, measurement and application*, Aldershot, UK, Ashgate Publishing, 2004, p. 317-341.

Kongable L. G., Stolley J. M, Buckwalter K. C. "Pet therapy for Alzheimer's patients: a survey", *J. Long Term Care Adm.*, 18(3), 1990, p. 17-21.

Libin A. V., Cohen-Mansfield J., "Therapeutic robocat for nursing home residents with dementia: preliminary inquiry", *American J. of Alzheimer's Disease and other Dementias*, 19 (2), 2004a, p. 111-116.

Libin A. V., Libin E. V., "Person-robot interactions from the robopsychologists' point of view: The robotic psychology and robotherapy approach", *Proc. of the IEEE*, 92 (11), 2004b, p. 1789-1803.

Livnat Y., Agutter J., Moon S. , Foresti S., "Visual Correlation for Situational Awareness ", *Infovis*, IEEE Computer Society, 2005.

Nakajima K. , Nakamura K., Yonemitsu S. , Oikawa D., Ito A., Fujimoto T., Nambu A., Tamura T. Y., "Animal-shaped toys as therapeutic tools for patients with severe dementia", *Proc. 23rd Int'l Conf. of the IEEE Engineering in Medicine and Biology Society*, 42001, p. 3796- 3798.

Odetti L. , Anerdi G. , Barbieri M.P. , Mazzei D. , Rizza E. , Dario P., Rodriguez G., Micera S. , "Preliminary experiments on the acceptability of animaloid companion robots by older people with early dementia", *EMBC07, 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Lyon, August 23-26, 2007.

Petersen R. C. , Stevens J. C. , Ganguli M. , Tangalos E. G. , Cummings J. L. , DeKosky S. T. , "Practice Parameter: Early detection of dementia: Mild cognitive impairment (an evidence-based review). Report of the quality standards subcommittee of the American Academy of Neurology", *Neurology*, 562001, p. 1133-1142.

Stiehl W. D., Lieberman J., Breazeal C., Basel L. , Lalla L., Wolf M. , "Design of a Therapeutic Robotic Companion for Relational, Affective Touch", *14th IEEE Int'l Workshop on Robots and Human Interactive Communication (RO-MAN 2005)*, Nashville, TN, USA, 2005, p. 408-415.

Wada K., Shibata T., Saito T., Tanie K., "Effects of Three Months Robot Assisted Activity to Depression of Elderly People who stay at a Health Service Facility for the Aged", *Proc. 2005 IEEE Int'l Conf. on Robotics and Automation (ICRA 2005)*, Barcelona, Spain, April 2005, p. 2785-2790.

Yonemitsu S. , Higashi Y., Fujimoto T., Tamura T., "Research for practical use of rehabilitation support equipment for severe dementia", *Gerontechnology*, 2(1), 2002, p. 91.