Final results of the NINFA project: impact of new technologies in the daily life of elderly people

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Abstract

Background The paper presents the work carried out within NINFA (iNtelligent Integrated Network For Aged people), a project for the wellbeing of the elderly people at home.

Aims The impact of new technologies on elderly people is evaluated with respect to the three main topics faced by NINFA.

Methods NINFA was structured into three main topics: 1) Active user engagement from the very beginning of the planning stage: the use of specially designed questionnaires to evaluate the acceptability of new technology in general and robot caregiver specifically; 2) Assessment of the wellbeing through non-invasive techniques: natural language processing for language change monitoring in elderly subjects; 3) Automated assessment of motor and cognitive functions at home: systems to deliver tests and exergames through user interfaces compliant with elderly subjects.

Results The analysis shows that there is no a priori closure to support the technology, but it must not be invasive and must allow social interactions. The study of speech transcripts shows that a large variation in the number of words used to describe the same situation could be a sign on the onset of cognitive impairments. The specifically designed systems highlight, after the training period, significant improvements in the performances of the participants and a satisfaction with regards to the systems usability.

Conclusions The outcomes of NINFA project highlight some important aspects of the relationship between elderly people and new technologies concerning: engagement and acceptability, assessment of the wellbeing and of the modifications of motor, cognitive and language functions.

Keywords User engagement . Wellbeing assessment . Linguistic and cognitive analysis . Movement analysis . Exergames . "At-home" monitoring . Postural stability

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Introduction

Populations around the world are rapidly aging, the fact that people are living longer together with the decline in fertility has led to a considerable ageing of the world population. According to an estimation by the OECD by the middle of the 21st century more than 20% of the world's population will age 65 and over [1]. This trend will affect and cover not only industrialized nations but also developing nations with costs growing exponentially.

Societies, to adapt to this demographic trend, should aim to encourage investment in healthy aging. The challenge is to create and strengthen conditions for an "active aging", prolonging autonomous living of older people and maintaining their independence at home.

ICT could be part of the solution to this problem, improving social inclusion and offering support to the elderly with the difficulties and challenges associated with aging [2].

In recent years, some attempts have been made to explore the potential of ICT-based solutions in increasing the active involvement of older people in their health care, monitoring their actions to support an independent life, increase their autonomy and help them only in case of need.

The elderly often suffers from problems related to mobility, sight, hearing and others: these difficulties can lead to a slowdown in cognitive performance and memory functions. The design of specific ICT-based assistive technologies can be of great help in prolonging the time in which older people remain active and safe in their preferred environment by providing care in their homes.

Unfortunately, the technological applications developed for seniors are often rejected by end users due to factors specific to this age group. Studies conducted on the elderly in the use of technological tools have shown how the reluctance to adopt them is due not only to the lack of skills but also to the lack of perception of the advantages and benefits in using these tools. These problems are directly related to their design, which is often highly technology-oriented rather than user-oriented.

To guarantee the acceptance of these new technological solutions, it is necessary to take into consideration the age-related changes in perceptual, motor and cognitive abilities. The designer must always takes into account the importance of the compensation processes that older people develop to adapt to changes and the crucial role played by motivation, affection and experience in every social interaction.

This paper presents the work done in the context of NINFA (iNtelligent Integrated Network For Aged people), a sub-project founded within the CNR Project on Aging 2012-2020: ‘Ageing: technological and molecular innovations for improving the health of the elderly people’.

Methods

To cope with the challenges highlighted above, NINFA was structured into three main topics:

1 *Active user engagement from the very beginning of the planning stage*

During the last few years, due to the ageing of the population, many scientists have developed ICT tools to offer elderly people an independent life at home as long as possible. Most of these researchers focused their efforts on problem-solving without adequate care to the agreeability and/or the acceptability of these ICT solutions for their users. But an active user engagement from the very beginning of the planning stage is necessary to develop agreeable and satisfactory tools. To achieve this goal, we designed 2 questionnaires: the first one is an investigation on the acceptable technologies by the elders, the second one is a more specific survey on the acceptability of caregiver robots.

2 *Assessment of the wellbeing through non-invasive techniques*

One of the specific goals of NINFA was to monitor linguistic behavior and spoken language productions of elderly subjects over the time to identify possible language modifications. Linguistic analysis is increasingly used to try to detect Alzheimer's disease or other dementias, due to the fact that, as various studies pointed out [3,4,5], language could be a great marker to assess neurological status of patients. In this scenario, Natural Language Processing (NPL) could help to detect potential unused information contained in spontaneous language samples generated by traditional behavioral and cognitive functioning assessment tests. Starting from this perspective, this study aims to highlight how NLP techniques could be a very powerful and not invasive ally to monitor, in general, the wellness status of elders, not only of the sick but of the healthy too, and a valuable tool for sustainable health care policies.

3 *Training and monitoring of motor and cognitive functions at home*

The goal of this topic is to automate the training and the monitoring of motor and cognitive functions of elderly subjects by specifically designed tests and exergames delivered at home. The adopted approach takes into consideration that neurodegenerative diseases are correlated with motor and/or cognitive dysfunctions [6], whose prevalence increases with age, with slight signs occurring in the early stages of the pathology and, sometimes, prior to clinical diagnosis. While the training of motor and cognitive functions can delay the onset of the disease [7], their monitoring can reveal in healthy elders a worsening trend of the performance, so triggering an early warning on a possible disease onset [8]. In specific pathologies, several studies point out the correlation between specific kinematic parameters of the patient movements and the disease severity assessed by standard clinical scales (e.g. for Parkinson’s

Disease [9]). Moreover, the correlation can be highlighted by concurrent cognitive tasks, as during the execution of combined motor and cognitive tasks [10]. Along this line of studies, we developed a system based on user-friendly and natural (gesture based) Human Computer Interface (HCI) to deliver tests and exergames at home. The HCI implements, at the same time, the system interaction and the motion acquisition, allowing the evaluation of specific kinematic parameters that characterize the movements and the logical choices made by the user during the exergame performance. In particular, the exergames address upper and lower limbs motor functions during the execution of concurrent motor and cognitive tasks. The kinematic parameters considered are those characterizing the performance of subjects during standard clinical assessment tests. The details of the upper limb exergames, the methodology adopted and the results obtained are described in previous papers [11,12]; here, we present the work focused on the lower limbs. Specifically, for the lower limb function, we designed evaluation test and exergames that include some steady posture items of the Berg balance scale [13]. Furthermore, we analyzed the subject performance by means of parameters related to the Center of Mass (CoM). The movement of CoM (or "body sway") and postural stability are correlated in both healthy and neuropathological subjects [14,15]. Several studies have explored this correlation by approaches based on optical depth sensing devices [16,17,18,19]. Monitoring the postural stability is quite important because it is closely related with the risk of fall in elderly people, a burden with an important impact on the quality of life. To this end, we conducted an experimental campaign in which a group of elderly people performed, at home, both the evaluation test, aimed at monitoring posture stability problems, and the exergames designed to improve it. Finally, following the items addressed in the first main topic, we evaluated the usability of the system as perceived by elderly users by a commonly used psychometric scale [20], this to validate the feasibility in using the exergames delivering system at home.

Active user engagement from the very beginning of the planning stage

Both questionnaires were conducted on Italian people aged over 65. Participation was voluntary and anonymity was guaranteed. Each participant signed a disclaimer sheet for privacy. Data was collected through personal interviews conducted by graduates in psychology. Respondents, in both cases, completed a first session on demographics: age, gender, profession and education.

The first study polled 100 elderly aged 65 to 81 (M=70 years; SD=4,6 years) of which 64% male and 36% female (Fig. 1). Most of the respondents has a college or university education (70%) and the part declaring to have only a first-grade education amounts to a mere 2%.

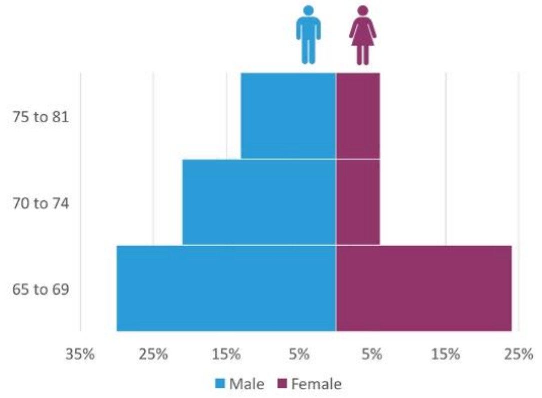

Fig. 1 Sample distribution age by gender

The issues addressed concerned four main topics:

1. questions about domestic technologies: knowledge and use of ordinary technologies (such as refrigerator, smartphone, etc.)
2. use of computer and internet
3. domotics and its use in everyday life
4. finally, were presented 3 cards representing:
   - four sample of man machine interaction;
   - four different type of robots;
   - four possible responses to emergency situations.

   and interviewees were asked to put the four figures of each card in order of approval/acceptance.

The second experiment involved 202 participants. The duration of each experiment session was approximately 1 hour. The response sample was composed of elderly Italian adults living independently (N = 202), aged 65 to 87 (M = 74 years; SD = 2,8 years). 59% of the sample was composed by female and 41% by male (Fig. 2). Participants varied in their educational background, with 39% having college or university education and with 61% having less than a formal college education (35% having only a first-grade education).

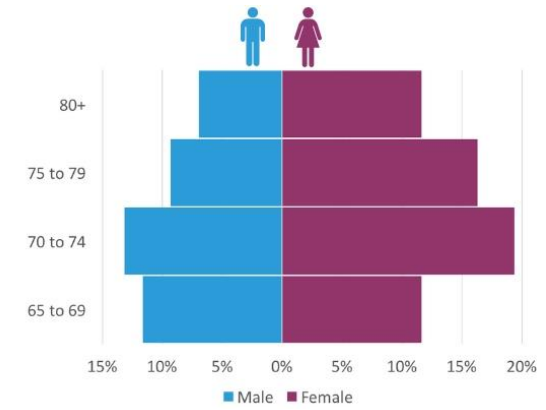

Fig. 2 Sample distribution age by gender

The goal of this research is to gain some insight into the physical features that make a caregiver robot fit and usable in order to understand the peculiarities such device should have to be really used by the elderly at home, focalizing attention especially on physical aspects, using a qualitative approach that tries to explore and better understand empathetic features that, in some way, facilitate the acceptance and desirability of the robots by the elderly. The robots evaluated within this experiment were 25 and have been chosen among various artefacts developed in the world research scene. To reach this purpose, we have created twenty-five cards, one for each selected robot. Each card contains two or more colored images. These images show, in an implicit way, the physical and functional characteristics of the robots and their dimensions. Each participant was asked to judge the robot based on their feelings while observing each card.

The protocol will be implemented in two steps:

1. Participants were asked to put cards in order of preferences. To facilitate the carrying out of this task, the conductor presented the cards in pairs. No verbal information on the role or function of the robot was given to the participants. Conductors were instructed, if questioned about the robot, not to give direct answers, but to stimulate reflection letting the participants to construct his own thought about the presented robot.

2. Then, only on first and last classified card, they were asked to assign a vote on a list of defined qualities. The scope was to derive the attitude towards some given characteristics. We tried to use the attribution theory principles, considering that a way in which elderly can make sense of robots is by projecting existing social schemas onto them. To do this, each participant was asked, for both cards, to give a value to eighteen quality pairs, using the Semantic Differential with a 5-point scale as the rating scale.

Assessment of the wellbeing through non-invasive techniques

The sampling (Fig. 3) involved 58 Italian citizens aged 65 or over (average age 80).

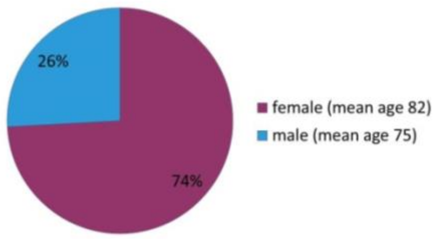

Fig. 3 Sample by gender

One third of the sample comprised self-sufficient elderly living in their own home, the other two thirds were users of a day care center and of an assisted-living center. Part of the participants (~20%) were affected by cognitive disorders (Alzheimer, Parkinson, dementia, etc.). All of them, or their legal guardians, signed an informed consent in order to give their written agreement to participating in the trial.

The test focused on oral production and/or reading. The interview was conducted in two different sessions, with an interval of six months. In each session, the interviewed was required to perform one or more of the following tasks:

1. Autobiographical tale
2. Fairy tale
3. Description of situational picture (Cookie Theft)
4. Reading of a list of words

In the second session, each person was asked to repeat at least one of the assignments accomplished in the first one. All this experiment resulted in a total of 9 hours, 18 minutes and 38 seconds of recording, afterwards transcribed and annotated referring to the range of notations described in “Il Parlar Matto” [21].

Assessment of motor and cognitive functions at home

A vision-based system has been developed for the training and the monitoring of motor and cognitive functions through the implementation of customized evaluation test and exergames. The system hardware for the lower limbs (Fig. 4a) is based on long-range RGB-Depth device (Microsoft Kinect v.2©). The system configuration, as for the upper limb [11], consists of a monitor, positioned in front of the user, on which the visual feedback of the HCI is provided. The RGB-Depth device is connected via USB port to a mini-PC (Intel NUCi7©) that runs the custom software component of the system under the Microsoft Windows 10 environment. The HCI is provided by the hand tracking output of the Kinect Software Development Kit (SDK) and the Graphical User Interface (GUI) on the monitor for the visual feedback (Fig. 1b). The custom software component manages the HCI and the data analysis, archiving the results obtained during the evaluation test and exergame sessions.

(a) (b)

Fig. 4 a) The exergame delivering system, b) Example of the Graphical User Interface

One evaluation test and two exergames have been implemented, which can be chosen by hand movements from a menu displayed on the system GUI (Fig. 4b). The evaluation test is a custom postural stability test, while the other two are motor–cognitive rehabilitation exergames similar to a sequence of dance steps.

1. *Standing up test* - This test is indeed a stability test which combines some of the standing balance items of the Berg scale [13] (see Fig. 5). During the test, a set of kinematic parameters, evaluated from the CoM trajectories, are used to characterize the postural stability [16]. The test is split into different phases, which last few second each: in the first, the subject stands up with the arms along the body; during the second one, the subjects rises the arms forward; in the third one the subject closes the eyes maintaining the previous posture; in the final one, he/she recovers to the first phase posture. We collected CoM parameters in the third phase, which is more challenging and useful to highlight alterations in postural instability.

2. *Follow the dance path* - In this exergame, the subject starts the performance standing up on the red tile of a set of four tiles in different colors (Fig. 6a). Then, he/she is prompted by the GUI displayed on the monitor (Fig. 6b) to move one step forward the other tiles by a pointer, one step after the other, following a predefined path. The path was 25 steps long and it was changed randomly during the exergame sessions.

3. *Choose the suggested path* - This exergame is similar to the previous one, apart from the fact that the choice of the next step along the path is suggested by the color of the tile and not by the pointer on the GUI, increasing the cognitive difficulty of the task.

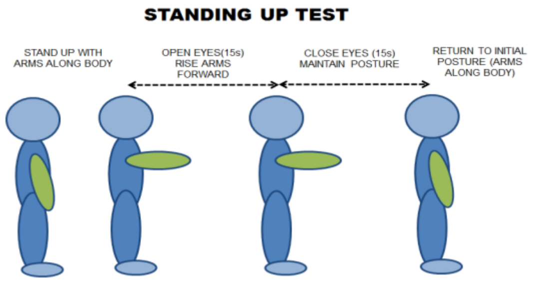

Fig. 5 Standing up test

(a) (b)

Fig. 6: a) The user performing the “Follow the dance path”. b): The GUI for the visual feedback to guide the user

An experiment was conducted to assess possible improvements in postural stability by our approach. Sixteen subject (9 females, 7 males, age between 65 and 78, with no history of neurological, motor and cognitive disorders) were selected. Participation was voluntary and each participant signed a disclaimer sheet for privacy. The group performed the exergames at home, for one month, five days per week. The effectiveness of the exergames in improving postural stability was assessed by the standing up test at two different times: the first time, one week after the start of the experiment; the second time after the end of it. A statistical analysis of the average differences of CoM parameters between these two evaluation points was conducted to analyze the statistical significance of the (possible) improvement in postural stability of the participants. A non-parametric test (Wilcoxon test with $p<0.05$) for paired samples was adopted. The CoM components along the Antero-Posterior (AP) and Medio-Lateral (ML) axis in the transversal body plane were evaluated and their related parameters used to characterize CoM sway and the posture stability [16]. The cognitive aspects were evaluated during the exergame performance by a score related to the number of errors respect to the suggested steps of the path.

Finally, we assessed potential usability issues of the system by the standardized interview of the Post-Study System Usability Questionnaire (PSSUQ) [20] conducted on the participants. PSSUQ is a 19-items ordinal score questionnaire, which addresses user satisfaction with regards to the systems usability, specifically: ease of use, ease of learning, simplicity, effectiveness, information, and user interface. For each item of PSSUQ, users were asked to give a score according to a Likert-scale between 1 (total agreement) and 7 (total disagreement). Lower average scores indicate a greater overall satisfaction of the user.

Results

Active user engagement from the very beginning of the planning stage

The study on the acceptability and use of technologies shows that, theoretically speaking, the elderly population considers technological tools a resource in terms of independence and security.

Just under half of the sample (41%) does not know what the word "domotics" means. Despite this, almost everyone believes that domestic automation is useful or even necessary as a safety aid at home. 98% percent of the respondents said it would be great to live in a domotic house, and think that this could be a solution to their problems (95%).

Despite this, in the face of real situations, these certainties seem to vanish. When asked on which emerging technologies they thought could be useful (Fig. 7), the elderly showed a clear preference for the smart t-shirt, while the video recording of the rooms in the house was not welcome.

But on the contrary, when they had to choose, simulating a real situation of danger (Fig. 8), among the technologies they preferred, the smart t-shirt became the last choice, while the video recording of the house rose to second place, very close to the first choice, a phone call to a person.

In general, from the last part of the survey, despite the enthusiasm shown for home automation, a trend towards less technological interactions emerges (Fig. 8 and Fig. 9).

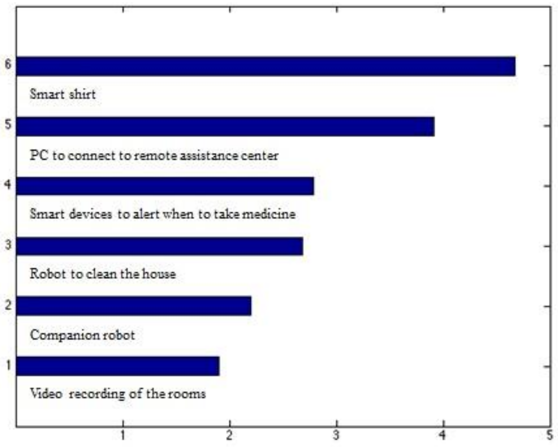

Fig. 7 Among the following technologies of the future still in experimentation which do you think are useful?

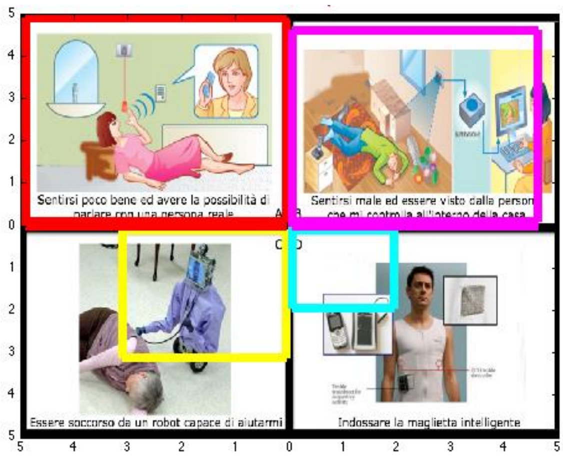

Fig. 8 Dangerous situations card

Fig. 9 Human machine interaction card

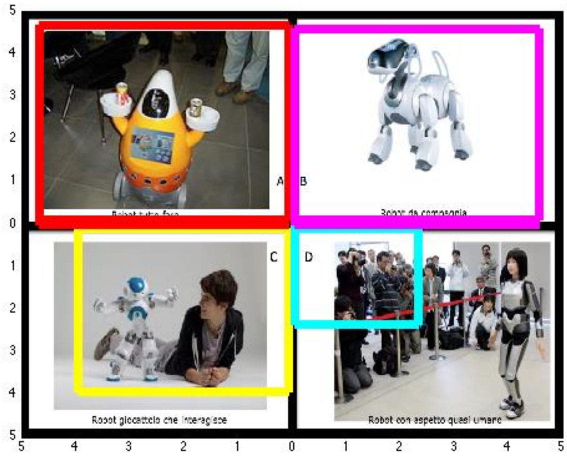

Fig. 10 Robots preferences card

Regarding the aspect a robot caregiver should have, the two interviews lead to similar conclusions.

Even if in other researches, adults interviewed about their imagined home robot, responded in a way that suggested they consider robots as performance-directed machines, rather than social or non-productive devices [22], our study showed a strong preference for robots similar to small animals or babies (Fig. 10), in accordance with previous studies that highlighted a strong preference of older people for small robots in a home setting [23]. In our research, 40% of the sample chose robots with such features as a first robot.

By considering the median, more than 50% of the sample liked GiraffPlus and put it within the top 8 positions, confirming the assumption that making home robots more socially intelligent can contribute to acceptance [24]. After GiraffPlus, we find small robots with characteristics similar to the ones highlighted above (Fig. 11).

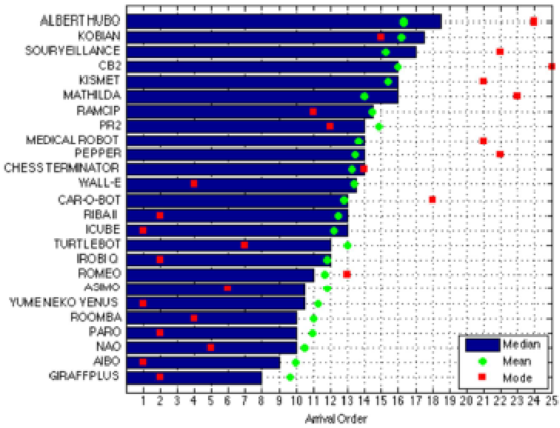

Fig. 11 Distribution of Mean, Median and Mode ordered

The bigger and specializes robots did not receive good appreciation. Maybe this is due to the fact that small dimensions and a low complexity of their function contribute to create a feeling of comfort and confidence. Indeed, the most critical negative factors are large sizes, excess of human similarity, the feeling of low level of controllability or an overly mechanical aspect. The most popular robots seem to be the ones that in some way, maintain their robot identity, clearly recognizable. Robot likeness, to a certain extent, provides a reassuring aspect.

Moreover, the good performance of a robot like GiraffPlus remind us the fact that human–robot relations are social relations and of course they cannot be denied. A robot caregiver must have social capabilities. It must help elderly people, but should also facilitate communication with other human beings.

The pictures, which emerge from both surveys, show that interpersonal relationship is essential, even when it comes to man-machine iteration.

Assessment of the wellbeing through non-invasive techniques

All recordings have been transcribed and texts were organized in six textual archives based on the session numbers and the sample group. POS tagging and lemmatization were performed on whole repository. Moreover, text materials were enriched by means of Named entities and semantically relevant terms recognition tools. Text enrichment allows us to associate different forms to a single object/person to which they refer and to compose terminologies preserving the information of the nested ones, thus facilitating the association of concepts, events and people in corresponding trials.

Only 51, of the 58 involved subjects, took part in both sessions.

	Nº of participants	Total rec. time
First session	56	4h 1m 59s
Second session	53	5h 16m 59s

Table 1 Number of respondents and total recording time by session

The favorite task (83.5% of the sample chose this type of assignment) was the narration of an autobiographical story.

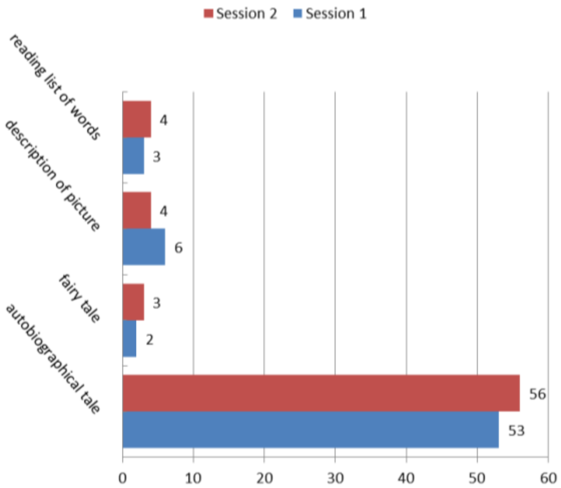

Fig. 12 Distribution by task for the 2 sessions

As shown in table 1, the duration of the entire last session has a longer length than the previous one. This perhaps might be expected in view of the fact that during the second visit the elderly feel more comfortable. However, this phenomenon has a different relevance in the two samples of healthy and pathological subjects. Healthy people are abler to reproduce consistent tales in presence of the same stimuli, as confirmed by the comparison of the length of the two texts.

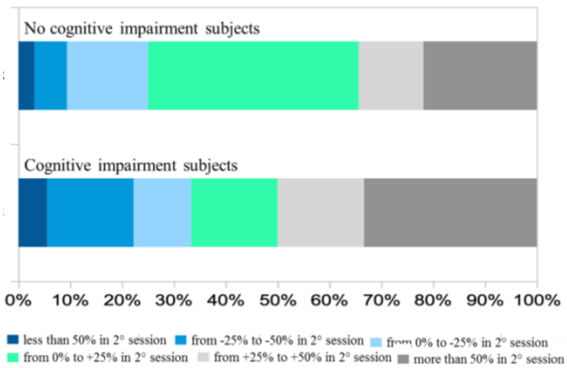

Fig. 13 Difference in the number of words between the two sessions

Figure 12 relates the percentage of respondents with the change, in number of words, of their respective tests in the two sessions.

It is interesting to notice how cognitive impairment subjects have a greater variation of number of words, both positive and negative.

As shown in Figure 13, 57% of the people involved say over 25% more words (50%) or more than 25% less words (22%) in the second session, while the majority of healthy (56%) subjects say more or less the same number of words (±25%) in the two trails.

Fig. 14 Sample of statistics on a Cognitive Impairment Subject (CIS) and a No Cognitive Impairment Subject (NCIS)

The above considerations, coupled with the reading of the transcripts, let us state that, regardless of the disease, one of the great differences between healthy and pathological subjects is that the latter are not able to reproduce the same story over time (Fig. 14).

This could be a good starting point and certainly the analysis could continue trying to use more than two recording sessions.

Assessment of the motor and cognitive functions at home

After the one-month training period, an improvement larger than at least 50% was found on all the CoM parameters of the participants. The significance of the improvement was statistically significant, according to the Wilcoxon test ($p<0.05$). This indicates an improvement of the postural stability of the participants. Also the cognitive scores were improved more than the 30%, on the average, indicating the usefulness of the training system.

Concerning the usability of the system, the PSSUQ analysis shows that the participants rated the usability of the system with an overall average score of 2.3 (±0.4) as shown in Fig. 15. For each question of PSSUQ, numbered from 1 to 19, the average scores are reported. All the values are quite low, considering that the scale ranges from 1 (total agreement) and 7 (total disagreement), even if some features of the system have to be improved (in particular, system messages and information to the users). However, the results indicate that participants expressed good satisfaction on their experience and appreciated the possibility offered by the system to monitor their own health condition at home.

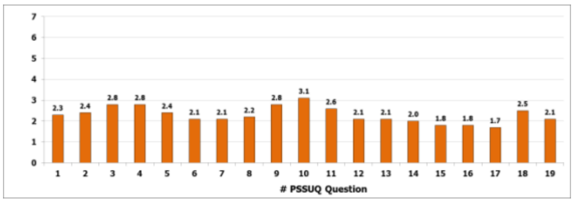

Fig. 15 Results of the PSSUQ questionnaire on system usability

Conclusions

The interviews suggest some important tips for designing technologies that can be used for the elderly. First of all, it emerges how these technologies should facilitate communication with other human beings. Secondly, these artifacts should be almost like games, small and non-invasive. In this sense, NPL as a tool for the early detection of the onset of cognitive impairment could have great potential. It is in fact a not very invasive instrument and one could think about the realization of longer monitoring over time (more than just two registrations). The results on the automated assessment of motor and cognitive functions indicate a statistically significant improvement of the postural stability of the participants, indicating a decreased risk of falls. Further work is necessary to extend to a larger number of subjects the experiment, making the findings more reliable. Other aspects worth to be explored are the possibilities offered by a longitudinal monitoring of posture stability and the analysis of stability in the different phases of the Standing up test, this to evaluate possible clinical relevant outcomes. The good results on user satisfaction respect to the systems usability are a further support in the reliable use of the system at home.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest and are solely responsible for the content and writing of this article.

Informed consent Informed consent was obtained for each participant.

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