Technology and Health Care 21 (2013) 217–231
DOI 10.3233/THC-130718
IOS Press

Robot services for elderly with cognitive impairment: Testing usability of graphical user interfaces

C. Granata[a,*], M. Pino[b,c], G. Legouverneur[b,c], J.-S. Vidal[b,c], P. Bidaud[a] and A.-S. Rigaud[b,c]
[a]*ISIR – Institut des Systèmes Intelligents et de Robotique, UPMC-CNRS UMR, Paris, France*
[b]*AP-HP, Broca Hospital, Geriatrics Department 2, Faculty of Medicine, Paris, France*
[c]*Université Paris Descartes, Paris, France*

Received 13 October 2012
Accepted 17 December 2012

Abstract.
BACKGROUND: Socially assistive robotics for elderly care is a growing field. However, although robotics has the potential to support elderly in daily tasks by offering specific services, the development of usable interfaces is still a challenge. Since several factors such as age or disease-related changes in perceptual or cognitive abilities and familiarity with computer technologies influence technology use they must be considered when designing interfaces for these users.
OBJECTIVE: This paper presents findings from usability testing of two different services provided by a social assistive robot intended for elderly with cognitive impairment: a grocery shopping list and an agenda application. The main goal of this study is to identify the usability problems of the robot interface for target end-users as well as to isolate the human factors that affect the use of the technology by elderly.
METHODS: Socio-demographic characteristics and computer experience were examined as factors that could have an influence on task performance. A group of 11 elderly persons with Mild Cognitive Impairment and a group of 11 cognitively healthy elderly individuals took part in this study. Performance measures (task completion time and number of errors) were collected.
RESULTS: Cognitive profile, age and computer experience were found to impact task performance. Participants with cognitive impairment achieved the tasks committing more errors than cognitively healthy elderly. Instead younger participants and those with previous computer experience were faster at completing the tasks confirming previous findings in the literature.
CONCLUSIONS: The overall results suggested that interfaces and contents of the services assessed were usable by older adults with cognitive impairment. However, some usability problems were identified and should be addressed to better meet the needs and capacities of target end-users.

Keywords: GUI, usability testing, elderly users, cognitive impairment, graphical user interface, assistive robots

1. Introduction

Population aging has implications on many aspects of society such as the economy, politics, family, epidemiology and healthcare [1,2]. Older adults are at major risk of experiencing age or disease related cognitive impairment such as Mild Cognitive Impairment (MCI), or Alzheimer's disease (AD) [3,4].

*Corresponding author: Consuelo Granata, ISIR 4, UPMC-CNRS UMR, place Jussieu, 75005 Paris, France. Tel.: +39 339 37 64 664; E-mail: consuelo.granata@isir.upmc.fr.

In elderly individuals, cognitive impairment most commonly concerns memory, but it can affect other aspects of cognition such as attention, language, perceptual skills, orientation and problem solving. While mild cognitive deficits can interfere with the performance of instrumental activities of daily life (e.g., driving, managing finances or medication), severe deficits often lead to complete disability. Thus, older adults suffering from cognitive impairment may require varying degrees of assistance to perform daily tasks.

Assistive Technology (AT) refers to technological products, services or systems used to improve functional capacity and social behavior of individuals with disabilities, including age-related cognitive or physical deficits [5]. AT for elderly with cognitive impairment serves different purposes [6]: assistance on daily tasks, communication and social interaction, management of behavioral symptoms, health monitoring, stimulation and entertainment, among others. Robotics has contributed to the development of AT for older adults with the design of embodied agents which provide various services to assist end-users on their everyday functioning (e.g. assistance for mobility, cognitive aids, health monitoring, communication, safety, etc.). Within this field, several social assistive robots are being developed [7,8]. However, designing Graphical User Interfaces (GUI) for Human-Robot Interaction (HRI) suited to non-expert computer users and elderly people with cognitive impairment is still a challenge [9–11].

The influence of software usability (e.g., interface complexity, functionality) and individual factors (e.g. age, computer experience, cognitive abilities) on technology acceptance by older adults has been largely documented [12,13]. Among the factors that have proven to be problematic for older adults when interacting with software applications or browsing the Web are: the demands on working memory to storage and process contextual information, the use of navigation menus [14], the discrimination of relevant information on a visual display such as hyperlinks [15] and the use of windows and scrolling bars [16]. Indeed, improving the accessibility of Web content and GUIs for elderly users has become a critical issue over the last years [11,17]. In contrast, little work has been conducted on Web accessibility, interface and software design for elders with cognitive impairment (MCI, AD) [18–23].

In the field of assistive robotics some studies have assessed acceptability and interaction modalities with elderly with cognitive impairment [24–26]. But only few of them have addressed usability issues of GUIs for robots or similar systems [27,22]. This is a shortcoming since, when robots use a touch-screen as input device, applications are normally accessed through the GUI. Then, once the application is running, the user has to navigate through the system using next and previous buttons, pull-down menus or other navigation controls. If target users face difficulties to understand and navigate through the system there will be a reduction, or a total lack, of effectiveness and productivity of the robots services. Nowadays, guaranteeing GUI usability is a fundamental factor since the interaction with digital information is dominated by GUI based systems. Still, basic actions required to operate these systems, such as icons comprehension and use of navigation controls, are likely to be error-prone for elderly with cognitive impairment [20,23,28,29]. Consequently, GUI specifications are an important issue that must be addressed when designing interactive systems for this population.

In this study we conducted usability testing of two services accessible through the GUI of an assistive robot with two user groups: elderly persons with MCI and elderly healthy controls. Findings are analyzed with regard to user performances, individual factors and GUI design.

1.1. Assessing usability and technology acceptance with elderly users

A number of factors, e.g., usability, perceived usefulness and ease of use, trust, costs, technology experience and attitudes towards technology [7,30–32] influence technology acceptance by older adults.

Fig. 1. The Kompaï robot (from Robosoft).

Therefore, successful design of interfaces requires the consideration of users preferences, skills and needs. In this context, a user-centered design approach, that places the user at the center of the process, may prove very helpful [33].

At the early stages of this process, a variety of methods are used to define users profile with regard to socio-demographic, cognitive and perceptual characteristics, lifestyle, technology experience, goals, needs, and preferences towards the product. In the case of elderly users one must carefully assess the presence of perceptual deficits related to visual acuity, contrast sensitivity, speech and sound discrimination, and of cognitive impairments such as memory decline, comprehension problems, attention deficits (e.g. multitasking capacity), slower processing speed, and decreased executive functioning (initiating, scheduling and monitoring actions for goal-directed behavior) [16,30,34]. Based on this information a prototype of the product can be developed for analysis through iterative assessments. At this stage of the design cycle, usability evaluation with the target population is the best way to detect ergonomic problems, and thus to improve the design. Usability refers to a set of quality attributes to assess the ease of use of technological products including [35,36]:

1. Learnability: How easy it is to learn the system functionalities.
2. Efficiency: Number of tasks users can perform in an amount of time or speed of performance.

Fig. 2. Main menu screen of robot GUI. From upper left to lower right: E-mail, Video Calls, Cognitive Stimulation, Shopping List, Weather Forecast, Agenda, Web Games, Medication Reminder, and Robot Control. Smaller icons on the lower left side represent the on/of control for voice command.

3. Retention over time: How easy it is to remember how to use the system after a period of nonuse.
4. Error rate: Number of commission or omission errors users make while performing a task.
5. Satisfaction: How pleasing it is the interaction with the system to accomplish a goal.

Different usability techniques exist for evaluating GUIs and in general interactive systems (e.g. usability testing, cognitive walk-troughs, heuristic evaluation) [37]. Still, the most useful technique for collecting empirical data of representative end-users while they use a system is usability testing. This method allows discovering interface problems that may hinder the user experience and provides information to solve them. In particular, formative usability testing allows the collection of quantitative and qualitative data about user performance [38]. Furthermore, through this method, it is possible to analyze the impact of different variables on task performance (e.g. when comparing two or more groups of users with different cognitive profiles). These tests are usually conducted in a laboratory setting under controlled conditions.

2. The development of the robot's GUI

The robot used in this study is Kompaï (Fig. 1), a social assistive mobile platform developed by Robosoft [39] intended to provide cognitive and social support to older adults with cognitive impairment.

Robot input devices include a set of microphones (for voice-based control) and a touch-screen (for GUI-based control). For high-level control and user interfaces, the Kompaï uses a tablet PC with a 12.1" Premium WXGA (1280 $\times$ 800) display and running Windows 7. Among the services that the robot provides there are (Fig. 2): 1) Shopping List management, 2) Agenda, 3) Medication Reminder, 4) Robot Control, 5) E-mail, 6) Video Calls, 7) Web Games, 8) Weather Forecast, 9) Cognitive Stimulation. These services were selected from results of two previous needs assessment studies carried out with elderly with cognitive impairment and their caregivers [40,41]. The software architecture was programmed in MRDS (Microsoft Robotics Dev Studio) platform in CSharp language. In this development phase, only

Table 1
Demographic data of the MCI and Healthy Control (HC) groups

	Group	
	MCI	HC
N	11	11
Gender	$M = 5$; $F = 6$	$M = 0$; $F = 11$
Age mean (SD)	76.63 (7.92)	76.36 (7.85)
Range	73–86	66–88
E *	$< 7 = 5$; $\geqslant 7 = 6$	$< 7 = 6$; $\geqslant 7 = 5$
CE**	none = 6; regulary = 5	none = 4; regulary = 7

*EL = Educational Level; **CE = Computer Experience.

the shopping list and agenda services were completely operational. For the management of these two functions we used Google API developed for .NET applications.

3. Research questions

In this study we conducted usability testing of the first GUI prototype focusing on the agenda and shopping list applications. Our purpose was to answer to the following questions:

1. Are there any significant differences between elderly with MCI and elderly with normal cognition with regard to task performance?
2. Are there any individual factors such as age, gender, computer experience and education level that influence task performance?
3. Which graphical elements of the interface should be addressed in order to improve the usability of the system for the target end-users?

4. Methodology

4.1. Participants

A total of 22 older adults, aged between 60–86 years (M = 76.5, SD = 7.7) took part in this study. They were distributed in two groups: elderly with a diagnostic of MCI [42] (N = 11) and elderly healthy controls (HC) (N = 11). Participants in the MCI group were recruited through the Broca Memory Clinic, HC were recruited through local senior associations. All participants volunteered for the study. The criteria for inclusion of participants in the study were: both genders; being over 60 years old; living in Paris or Ile de France; having a diagnosis of MCI according to the criteria of Petersen et al. [42] (MCI group). The exclusion criteria out-ruled those with psychiatric conditions, behavioral problems, or sensory deficits that would influence the ability to comprehend or perform the tests. French ethical committees CCTIRS (Comité consultatif sur le traitement de l'information en matière de recherche dans le domaine de la santé) and CNIL (Commission nationale de l'informatique et des libertés) endorsed this project. Socio-demographic characteristics of the sample are presented in Table 1.

4.2. Material

Subjects performed the experimental tasks on the tablet PC of the Kompaï robot. A stylus pen was used to input commands to the computer screen. Two cameras were employed to capture screen activity and user's behavior. The Observer R XT software was used to analyze the data.

Table 2
List of dependent variables for agenda and shopping list tasks

Dependent variable	Description
Agenda	
DateT, DateE	T* and E* when selecting date
AddT, AddE	T and E when adding the appointment to the calendar
DetailsT, DetailsE	T and E when adding the appointment details (time, place, purpose and type of appointment)
ConfirmT, ConfirmE	T and E when confirming the appointment details
Shopping list	
Cat1T, Cat1E	T and E when choosing the category corresponding to the first product
Prod1T, Prod1E	T and E when selecting the quantity of the first product and when adding it to the shopping list
Cat2T, Cat2E	T and E when choosing the category corresponding to the second product
Prod2T, Prod2E	T and E when selecting the quantity of the second product and when adding it to the shopping list
Combined measures	
AgendaT, AgendaE	Total T and E for the whole agenda task
Shop1T, Shop1E	Total T and E when adding the first product to the shopping list
Shop2T, Shop2E	Total T and E when adding the second product to the shopping list
ShopT, ShopE	T and E for the whole shopping list task

*T = Execution Time (s); **E = Number of errors.

4.3. Procedure

First, a researcher described the purpose of the study. Individuals who expressed interest in participation signed a written informed consent form. A structured questionnaire was used to collect socio-demographic data. Then, a test moderator explained the general characteristics of the robot, the evaluation procedure and conducted the tests. Participants were asked to complete a series of tasks detailed in Section 5.4. Performance measures (execution time and number of errors) were collected for each task. Tests were conducted individually and all sessions were video recorded. Data analysis was performed using The Observer R XT software.

4.4. Usability tasks

4.4.1. Agenda

Participants were asked to enter on the agenda a medical appointment at Broca Hospital on December the 12th, 2011 at 10 o'clock (Fig. 3a). The task consisted on four steps that required different actions:

- Selecting the required date: first, the month by clicking on month back and forward navigation arrows and then the day by clicking on the day in the month view (Fig. 3b)
- Adding an event by using the plus sign button placed on the left lower side of the screen (Fig. 3c)
- Entering in a pop-up window event details: the hour (using an up-down menu), kind of event (clicking on specific icons), purpose of the event and its location (using a virtual keyboard) (Fig. 3d)
- Confirming the event by clicking on the add button (Fig. 3d)

For each step we collected two performance measures: Execution Time (T), which refers to the task completion time, and number of Errors (E) referring to failed actions while completing the task. Table 2 presents the list of dependent variables for each subtask and global performance measures.

4.4.2. Shopping list

Participants were asked to compile a shopping list (Fig. 4a) by choosing two products of different categories (fruits and meats). For each product subjects were required to:

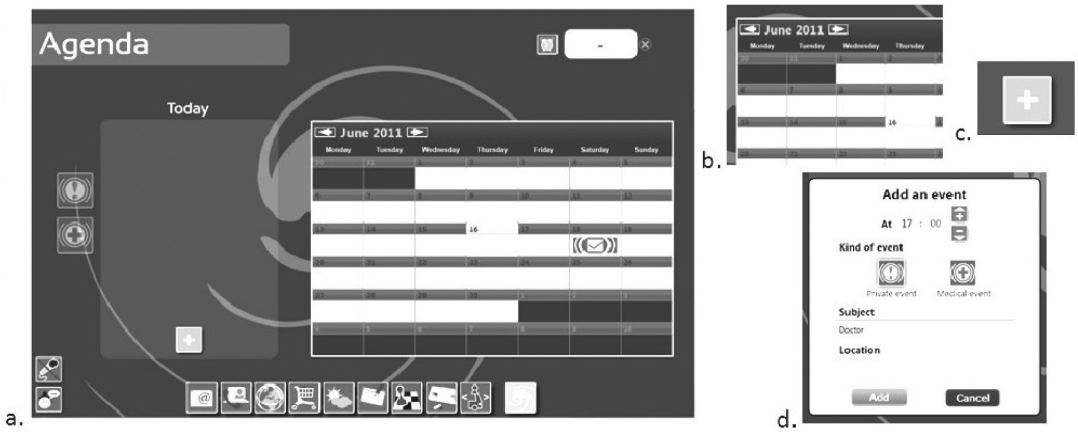

Fig. 3. a. Agenda page; b. Calendar to select the appointment date; c. Plus sign button to open windows of appointment details; d. Windows to enter details and to confirm the appointment.

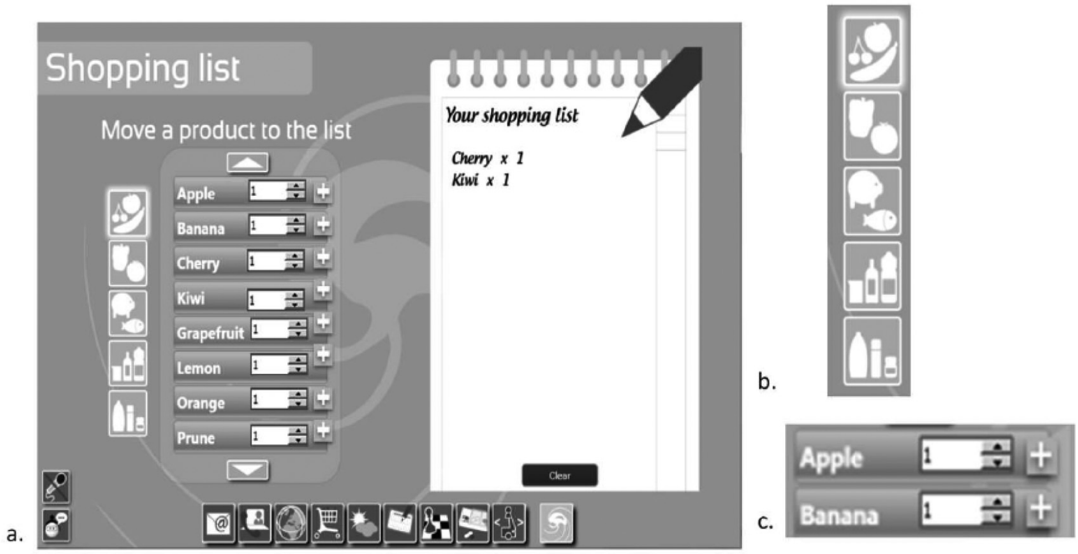

Fig. 4. a. Shopping list page; b. Product category menu; c. Numeric up/down control to select the product quantity; d. Plus sign button to add the selected product to the shopping list.

– Select product category by clicking on the corresponding icon (repeated measure for the second product) (Fig. 4b)
– Select the product by using the navigation up/down arrows (repeated measure for the second product)
– Select product quantity by using the numeric up/down control and adding it to the shopping list using the plus sign button (Fig. 4c)

For each step we collected two performance measures: Execution Time (T) and Errors (E). See Table 2 for the list of dependent variables corresponding to this task.

Table 3
Average number of errors and completion time for all shopping subtasks by group, age and computer experience

	CAT1	PROD1	SHOP1	CAT2	PROD2	SHOP2	SHOP
Errors							
MCI	0.72	0.9	1.63	0.2	0.18	0.45	5.72
HC	0.09	0.27	0.36	0.09	0.18	0.27	3.45
Youngers	0.36	0.45	0.81	0.18	0.18	0.36	3.27
Olders	0.44	0.55	1	0.22	0.22	0.44	6
Novels	0.3	1	1.3	0.2	0.2	0.4	5.8
Experienced	0.5	0.25	0.75	0.16	0.16	0.33	0.33
All	0.4	0.59	1	0.18	0.18	0.36	4.59
Execution time (s)							
MCI	23.58	22.2	45.78	11.85	10.78	22.63	221.79
HC	15.53	18.86	34.4	10.01	6.76	16.77	193.47
Youngers	13.25	12	25.25	11.22	5.44	16.66	133.69
Olders	27.52	28.91	56.44	10.89	14.11	25	292.17
Novels	16.09	31.24	47.34	14.01	11.08	25.09	255.27
Experienced	22.44	11.6	34.04	8.36	6.84	15.21	167.93
All	20.53	20.53	40.09	10.93	8.77	19.07	207.63

Table 4
Average number of errors and completion time for all agenda subtasks and for the entire experiment by group, age and computer experience

	Date	Add	Details	Confirm	Tot agenda	Total
Errors						
MCI	0.36	0.54	1.36	0.36	2.63	8.35
HC	0.39	0.54	1.18	0.36	2.45	5.9
Youngers	0.18	0.45	0.63	0	1.27	4.54
Olders	0.55	0.55	2.11	0.66	3.88	9.88
Novels	0.6	0.6	1.7	0.7	3.6	9.4
Experienced	0.16	0.5	0.91	0.08	1.66	1.99
All	0.36	0.54	1.27	0.36	2.54	7.13
Execution time (s)						
MCI	22.7	27.51	87.34	15.61	153.37	375.16
HC	24.67	19.36	89.23	9.02	142.29	355.76
Youngers	15.29	16.53	55.77	4.16	91.77	225.46
Olders	33.05	31.12	130.57	14.96	210.72	502.89
Novels	31.11	30.43	100.04	21.22	182.82	438.09
Experienced	17.49	17.79	78.48	4.9	118.67	286.6
All	23.68	23.53	88.28	12.32	147.83	355.46

5. Results

This section presents main findings of this study with respect to two criteria, the characteristics of the sample and the role of group and individual factors on task performance (Execution Time and Errors). These analyses were conducted using the Wilcoxon signed-rank and the Kruskal-Wallis chi-squared tests. All the results are reported in Tables 3 and 4.

5.1. Users characteristics

Age was considered as a binary variable when the test required the use of categorical variables (< 78 years old $= 0$; $\geqslant 78$ years old $= 1$). In these cases median was chosen as cut-of value. Participants were

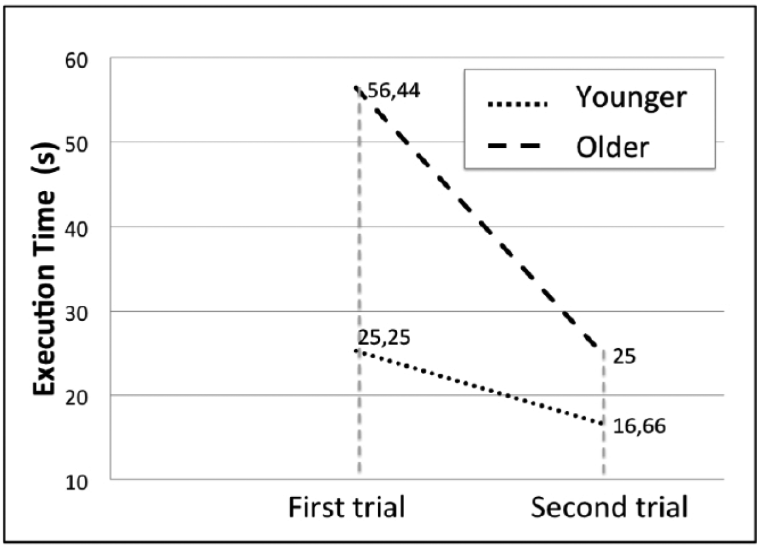

Fig. 5. Improvement of performances repeating the shopping task.

then distributed in two groups: oldest-old adults (N = 11, M = 82.4, *SD* =2.9) and young-old adults (N = 11, M = 70.5, *SD* = 6.2).

Concerning education level (EL), 50% of the sample had less than 7 years of education, and 50% plus than 7 years of education ($< 7 = 0$; $\geqslant 7 = 1$). The participants in the MCI and in the HC groups did not differ in age ($p = 0.97$), years of formal education ($p = 0.99$), or computer experience ($p = 0.67$). On the contrary there was a significant difference between groups concerning gender, the HC being composed only of women ($p = 0.01$).

Subjects were asked to indicate whether they were regular computer users (they made use of the computer almost every day, e.g. for work, entertainment, communication) or not (none or little experience = 0; regular experience = 1). 12 participants (45.4%) had either none or little previous experience with computers and 10 participants (55.6%) had a regular experience. There was a significant negative relationship between age and computer experience, the group of oldest-old adults having less experience ($r = -0.60$, $p < 0.005$). Demographics for each group are listed in Table 1.

5.2. *Group effects*

No significant differences were observed between MCI and HC participants with regard to Execution Time as confirmed by the Wilkoxon test ($p = 0.77$). However, results revealed that in general, participants in the MCI group ($M = 375.16$ s) were slower than HC ($M = 355.76$ s) at completing tasks. This trend was not observed for all subtasks, as was the case with *DateT* and *DetailsT* (Table 4). Entering the details of the event on the agenda was the subtask that took participants in both groups more time to complete. Finally, when performing the shopping list task, results showed that speed of performance improved significantly in both groups when adding a product to the list for the second time (MCI: z = 2.38, $p = 0.009$; HC: $z = 2.2$, $p = 0.01$). However, the reduction in time in *Shop2* with respect to *Shop1* did not differ significantly between both groups (χ^2 (1; $N = 22$) = 0.39; $p = 0.53$).

Concerning the Errors variable, testing for statistically significant differences between groups using the Kruskal-Wallis chi-squared test showed that MCI participants committed more errors than participants in the HC group in the shopping list task (χ^2 (1; $N = 22$) = 4.76; $p = 0.03$) and in some of the subtasks associated such as *Cat1* (χ^2 (1; N = 22) = 3.73; p = 0.05) and *Shop1* (χ^2 (1; N = 22) = 4.52; p = 0.03). On the contrary, no statistical significant difference was found between the two groups for the agenda task. In general the highest number of errors was observed for the subtask of entering the details of the event in the agenda for both groups (Table 4).

5.3. Individual factors effects

Results were analyzed statistically with regard to education level, computer experience and age. Gender factor was excluded from this analysis because sample group sizes were very unequal in this variable. When analyzing user performances by considering their education level, no significant differences were observed on task completion time neither on number of errors as confirmed by a Wilcoxon signed-rank test.

The Computer Experience (CE) factor turned out to be very discriminative both on Execution Time and Errors. Participants having a regular computer experience were faster and committed fewer errors than those who had no computer experience at all. For instance, with respect to the Execution Time variable, significant differences between experienced and inexperienced users were found for the total duration of the experience (z = 5.02; p = 0.03), for the shopping (z = 5.32; p = 0.02) and the agenda task (z = 3.40; p = 0.05). The same trend was observed in some of the subtasks: *Prod1* (z = 8.80; p = 0.003), *Cat2* (z = 4.88; p = 0.03) from the shopping list task, and *Date* (z = 5.02; p = 0.02) and *Confirm* (z = 9.2; p = 0.0002) from the agenda. Regarding the Errors variable, a significant effect of CE was observed for the entire evaluation (z = 4.11; p = 0.04), for the agenda task (z = 5.20; p = 0.02) and for the subtasks *Details* (z = 4.57; p = 0.03) and *Confirm* (z = 6.49; p = 0.01).

Other factor that was found to have an influence on task performance was Age. Younger participants were faster than the older ones to complete the entire evaluation (z = 10.56; p = 0.001), the shopping list (z = 5.43; p = 0.02) and the agenda task (z = 9.32; p = 0.002). This trend was also confirmed for some of the subtasks: (*Prod1* (z = 5.13; p = 0.02), *Shop1* (z = 7.07; p = 0.008), in the shopping list, and *Date* (z = 7.42; p = 0.006) and *Confirm* (z = 8.53; p = 0.003) in the agenda task. Younger participants committed also fewer errors during the entire experience (z = 7.92; p = 0.005), in the agenda task (z = 9.65; p = 0.001) and in the *Confirm* subtask of the agenda (z = 9.62; p = 0.002).

Individual factors also played a role in initial learnability. In the present study this criterion was evaluated by the shopping list task that comprised two identical steps: selecting the product category (*Cat1, Cat2*), choosing the product and adding it to the list (*Prod1, Prod2*). Repeating a sequence of identical procedures can be used to evaluate the learnability of an interface. Results revealed that, in average, all participants spent more time completing the first step than the second one, which suggests that the task procedure was quickly acquired. It was therefore interesting to examine to what extent certain factors could affect learnability. Statistical analysis showed a significant improvement in task completion time for the older participants when performing the shopping task in the second trial (z = 66; p = 0.001). Younger participants also improved their task completion time but the difference between the first and the second trial was not significant (z = 46; p = 0.28). Indeed, older participants took more time to complete the first phase of the task (*Cat1* + *Prod1*) than younger subjects. In the second phase (*Cat2* + *Prod2*) while younger subjects showed a slight improvement in task completion time, participants in the older group significantly improved obtaining almost the same results than younger participants (Fig. 5). The difference between the two groups with regard to their performance in the two trials was also significant (χ^2 (1; N = 22) = 5.43; p = 0.02). These findings suggest that two trials were enough to see initial speed differences between age groups disappear.

6. Discussion

The main goal of this study was to evaluate the usability of the GUI of an assistive robot for elderly with cognitive impairment (MCI). We focused on two services accessible through the GUI: the agenda and the shopping list applications. Findings from this assessment allowed us to answer to the research questions formulated above (Sec 4).

1. Some significant differences were observed between elderly with MCI and elderly with normal cognition with regards to the number of committed errors, of task completion time.
2. Some individual factors such as Age and Computer Experience were founded to have a significant influence on both Execution Time and Errors variables. Older and inexperienced users took significantly more time to complete the tasks and committed more errors.
3. Some graphical elements of the interface may be deemed unsuitable for using by target end-users. Improving them can certainly facilitate the use of the interface.

With regard to these findings, in the following sections we discuss the influence of cognitive profile and of other individual factors on GUI usability. Besides, we examine some GUI design features that need to be improved in order to make the interface more intuitive for target end-users.

6.1. *Effects of cognitive profile on GUI usability*

With respect to the shopping list and agenda applications results revealed that participants in both groups (MCI and HC) were able to complete the tasks without major assistance. However, statistical analysis showed that both groups differed significantly with regard to the number of errors made during the entire experience, although no difference was observed in task completion times. The analysis of the results from this study must take into consideration that participants in both groups were novice users of the robot GUI and there were no significant differences between the two groups regarding Computer Experience. In fact, there was almost the same number of experienced and inexperienced users in MCI and HC groups. As a consequence, usability problems observed during the test seem to be related to particular GUI elements that are particularly challenging for users with cognitive impairment due to decline of some mental functions as attention and perceptual skills. In fact, MCI participants performed worse than HC subjects in Errors variable as well as in Execution Time, even if differences observed did not reach statistical significance levels for this second variable. To a certain extent, these findings are not surprising since deficits in memory or other cognitive functions (language, visuospatial ability or executive function) are so subtle in individuals with MCI that these can only be detected by neuropsychological assessment. Still, MCI is characterized by slower speed of performance in instrumental tasks [43]. The demands on working memory can be reduced by providing environmental support [14] to facilitate recognition instead of relying on free recall [44]. Including a larger sample of subjects for each group and adding a Young Adults control group could help to control for this variable in future studies. Conducting a crossed analysis of error types and specific cognitive deficits could also help to illustrate better which commands and controls are more demanding for elderly with MCI. In addition, this will help designers to provide adapted GUI solutions to compensate cognitive deficits.

6.2. *Effects of individual factors on GUI usability*

With regard to the second question, two individual factors, Age and Computer Experience, had a significant effect on user performance, concerning both Execution Time and Errors. Younger participants were quicker to complete tasks than older participants. Also, participants with computer experience were faster than those who had no experience. These results corroborate previous findings from several studies in which the comparison of computer task performance between older and younger adults showed that age and computer experience predicted required execution time (for a review see [12]). To interpret these results one must consider that there was a strong correlation between age and computer experience: older participants had less computer experience than the younger. This result concurs well with a sociological reality about older adults: participants in the group of oldest-old adults were retired before computers were widely used at work. In contrast, younger participants were familiar with computers for several years before retirement and could acquire some computer skills. No correlation was observed between the other individual factors such as Education Level and Gender on user performances. With reference to education, it is possible that the number of years of education does not represent well enough the knowledge and skills that a person has acquired throughout his/her life. To take into account the effects of socio-cultural level on computer task performance it would have been better to create a composite factor including not only the years of education, but also income, professional field and life style. For this study, it was difficult to set up a reliable measure for this variable. Moreover, having a small sample could have also lead to misleading results, if we consider that several authors have found that education is one of the factors that explains computer task performances in older adults [12]. As to Gender effects, it was not possible to carry out an analysis of this variable since groups were very unequal with regard to this factor; for instance, the HC group was exclusively composed of women. Besides, results showed that age-related differences regarding execution time could be substantially reduced after training. This finding is in complete agreement with results from a number of studies that compared cognitive training effects on elderly and young individuals [45,46]. However, it does not prove there was a real learning effect. Indeed, the performance improvement is probably due to the immediate repetition of two subtasks. The subject could have implicitly reproduce and improve the actions previously performed, without a real learning effect. In order to neutralize the effect induced by the immediate repetition the execution of the second phase could be delayed by introducing interference tasks, or by repeating the experiment in another test session. In any case, even well-designed computer applications and interfaces require training [38]. Furthermore, the socio-cultural level did not seem to have any effect on the considered variables. The lack of correlation between the socio-cultural level and the other factors can easily be explained by the type of measures unsatisfying insofar as there is little or no standardized scales designed to reflect the entire lifetime from schooling to the last position held, taking into account the various trainings likely to occur during a lifetime. The effects of socio-cultural level are well known in the psychometrics and neuropsychology field, which continues to develop more appropriate ways to control this factor. In this present study, it was difficult to set up a reliable assessment of this variable.

6.3. GUI design features assessment

One of the aims of this study was to assess the understanding and the ease of use of the graphical elements of the interface by the target end-users. Graphical elements included button icons and navigation controls.

Concerning the shopping list, the task was achieved by all the participants without major assistance, but the performance improvement repeating the procedures (*Shop2*) suggests that the intuitiveness of the interface can be increased. For example, the fact that participants spent less time for selecting a product the second time, probably is due to a lack of intuitiveness in selection mechanism. This can be improved by displaying initially just the icons of all the available categories (see Fig. 4). The whole list of products should appear only after the parent category has been selected. Moreover, results underline the difficulties faced by older and inexperienced participants using the NumericUpDown control (when adding a product in the shopping list). This could be related to their lack of knowledge concerning usual GUI navigation controls [47].

The assessment of the agenda graphical features revealed that older and inexperienced participants had some problems understanding the function of certain navigation controls such as the back and forward arrows to select the date and the add button to save an appointment. However, we also noted a problem of all participants understanding the plus sign button to open the window of the appointment details. This means that this button is misconceived regardless of the user profile. We suggest for the improved design, to make the details window open, directly by selecting the date. Finally, the use of a virtual keyboard could explain the difference between experienced and novice users in execution time when entering the appointment details in the agenda task. The experienced users were faster than the novice participants.

7. Conclusion

This initial usability study of the robot GUI allowed us to identify some usability problems that elderly people encountered while performing some tasks using the system. These problems were found to be primarily related to the cognitive profile, age and computer experience. We believe that the age-related decline affects the use of computers and other devices because it is associated with decline in physical functions, for example, psycho-motor skills and vision, which makes it more difficult to handle the devices or see the content of the displays. Furthermore, some objects widely used in the most common graphical computer interfaces (e.g. drop-down and navigation menus, small buttons and hyperlinks) are very familiar to experienced computer participants but completely unknown to the novice users.

Including a larger number of participants and a control group of young adults could help to identify, in a clearer manner, usability problems related either to age or to cognitive impairment. However, our findings have the potential to contribute to GUI improvement, because they allowed the identification of the key design features for GUIs intended for elderly users. We have suggested some improvements of the features that have proved particularly critical for the users (e.g. ambiguous buttons and hardly visible menus). Subsequent usability tests are planned to validate the new GUI design, including a large number of participants in order to have even more relevant and detailed results.

Acknowledgement

This work has been supported by French National Agency (ANR) through TECSAN program (project QuoVADis – ANR-07-CNSA-Tecsan).

References

[1] Lafortune G, Balestat G. Trends in severe disability among elderly people: Assessing the evidence in 12 OECD countries and the future implications. OECD Publishing, 2007.
[2] UnitedNation. World Population Ageing, 2009.
[3] Gusmano MK, Rodwin VG. The elderly and social isolation. Testimony to the New York City Council Committee on Aging. 2006.

[4] Victor C, Scambler S, Bond J, Bowling A. Being alone in later life: loneliness, social isolation and living alone. Reviews in Clinical Gerontology. 2000; 10(04): 407-417.
[5] Hersh MA, Johnson MA. On modelling assistive technology systems-Part I: Modelling framework. Technology and Disability. 2008; 20(3): 193-215.
[6] Lauriks S, Reinersmann A, Van der Roest H, Meiland F, Davies R, Moelaert F, et al. Review of ICT-based services for identi_ed unmet needs in people with dementia. Ageing research reviews. 2007; 6(3): 223-246.
[7] Feil-Seifer D, Mataric MJ. Defining socially assistive robotics. In: Rehabilitation Robotics, 2005. ICORR 2005. 9th International Conference on. IEEE, 2005, pp. 465-468.
[8] Hirth J, Schmitz N, Berns K. Towards Social Robots: Designing an Emotion-based Architecture. International Journal of Social Robotics, pp. 1-18.
[9] Young JE, Hawkins R, Sharlin E, Igarashi T. Toward acceptable domestic robots: applying insights from social psychology. International Journal of Social Robotics. 2009; 1(1): 95-108.
[10] Broekens J, Heerink M, Rosendal H. Assistive social robots in elderly care: A review. Gerontechnology. 2009; 8(2): 94-103.
[11] Gregor P, Newell AF, Zajicek M. Designing for dynamic diversity: Interfaces for older people. In: Proceedings of the fifth international ACM conference on Assistive technologies. ACM; 2002; 151-156.
[12] Wagner N, Hassanein K, Head M. Computer use by older adults: A multi-disciplinary review. Computers in Human Behavior. 2010; 26(5): 870-882.
[13] Wu Y, Slyke CV. Interface complexity and elderly users: Revisited. Southern Association of Information Systems Conference, Savannah, Georgia, USA. 2005; 289-294.
[14] Hawthorn D. Possible implications of aging for interface designers. Interacting with computers. 2000; 12(5): 507-528.
[15] Chadwick-Dias A, McNulty M, Tullis T. Web usability and age: How design changes can improve performance. ACM SIGCAPH Computers and the Physically Handicapped. 2002; (73-74): 30-37.
[16] Fisk AD, Rogers WA, Charness N, Czaja SJ, Sharit J. Designing for older adults: Principles and creative human factors approaches. vol. 2. CRC, 2009.
[17] Arch A. Web accessibility for older users: A literature review. w3c working draft, 2010.
[18] Astell A, Alm N, Gowans G, Ellis M, Dye R, Vaughan P. Involving older people with dementia and their carers in designing computer based support systems: some methodological considerations. Universal Access in the Information Society. 2009; 8(1): 49-58.
[19] Astell AJ, Ellis MP, Bernardi L, Alm N, Dye R, Gowans G, et al. Using a touch screen computer to support relationships between people with dementia and caregivers. Interacting with Computers. 2010; 22(4): 267-275.
[20] Riley P, Alm N, Newell A. An interactive tool to promote musical creativity in people with dementia. Computers in Human Behavior. 2009; 25(3): 599-608.
[21] Topo P, Mäaki O, Saarikalle K, Clarke N, Begley E, Cahill S, et al. Assessment of a music-based multimedia program for people with dementia. Dementia. 2004; 3(3): 331.
[22] Peterson CB, Mitseva A, Mihovska A, Prasad NR, Prasad R. The phenomenological experience of dementia and user interface development. In: Applied Sciences in Biomedical and Communication Technologies, 2009. ISABEL 2009. 2nd International Symposium on. IEEE; 2009; 1-5.
[23] Savitch N, Zaphiris P. An investigation into the accessibility of web-based information for people with dementia. In: 11th International Conference on Human-Computer Interaction, 2005.
[24] Pollack ME, Brown L, Colbry D, Orosz C, Peintner B, Ramakrishnan S, et al. Pearl: A mobile robotic assistant for the elderly. In: AAAI workshop on automation as eldercare. vol. 2002; 2002.
[25] van Breemen A, Yan X, Meerbeek B. iCat: an animated user-interface robot with personality. In: Proceedings of the fourth international joint conference on Autonomous agents and multiagent systems. ACM; 2005; 143-144.
[26] Schaeffer C, May T. Care-o-bot-a system for assisting elderly or disabled persons in home environments. Assistive technology on the threshold of the new millenium, 1999.
[27] Hellman R. Usable user interfaces for persons with memory impairments. Ambient Assisted Living. 2012; 167-176.
[28] Scialfa C, Spadafora P, Klein M, Lesnik A, Dial L, Heinrich A. Iconic Sign Comprehension in Older Adults: The Role of Cognitive Impairment and Text Enhancement. Canadian Journal on Aging. 2008; 27(3): 253-265.
[29] Leung R, McGrenere J, Graf P. Age-related di_erences in the initial usability of mobile device icons. Behaviour and Information Technology. 2011; 30(5): 629-642.
[30] Pak R, McLaughlin A. Designing Displays for Older Adults. CRC, 2010.
[31] Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly. 1989; 319-340.
[32] McCloskey DW. The importance of ease of use, usefulness, and trust to online consumers: An examination of the Technology Acceptance Model with older customers. Journal of Organizational and End User Computing (JOEUC). 2006; 18(3): 47-65.

[33] Rubin J, Shirk HN. Handbook of Usability Testing: How to Plan, Design, and Conduct Effective Tests. Journal of Technical Writing and Communication. 1996; 26(1): 97-106.

[34] Schaie KW. Cognitive aging. National Academies Press, 2004.

[35] Nielsen J. Usability engineering. Morgan Kaufmann, 1993.

[36] Ferré X, Juristo N, Windl H, Constantine L. Usability basics for software developers. Software, IEEE. 2001; 18(1): 22-29.

[37] Rubin J, Chisnell D. Handbook of Usability Testing: How to plan, design and conduct effective tests. Wiley-India, 2008.

[38] Fisk AD, Rogers WA, Charness N, Czaja SJ, Sharit J. Designing for older adults. CRC Press, 2004.

[39] Robosoft Kompaï, users manual v3.0. Interact with Kompaï;. Accessed: 30/06/2012. http://85.31.145.61/index.php.

[40] Wu YH, Faucounau V, Boulay M, Maestrutti M, Rigaud AS. Robotic agents for supporting community-dwelling elderly people with memory complaints Perceived needs and preferences. Health Informatics Journal. 2011; 17(1): 33-40.

[41] Faucounau V, Wu YH, Boulay M, Maestrutti M, Rigaud AS. Caregivers' requirements for in-home robotic agent for supporting community-living elderly subjects with cognitive impairment. Technology and Health Care. 2009; 17(1): 33-40.

[42] Petersen RC, Smith GE, Waring SC, Ivnik RJ, Tangalos EG, Kokmen E. Mild cognitive impairment: Clinical characterization and outcome. Archives of neurology. 1999; 56(3): 303.

[43] Wadley VG, Okonkwo O, Crowe M, Ross-Meadows LA. Mild cognitive impairment and everyday function: evidence of reduced speed in performing instrumental activities of daily living. Am J Geriatrics Psychiatry. 2008; 16(5): 416-424.

[44] Mead SE, Batsakes P, Fisk AD, Mykityshyn A. Application of cognitive theory to training and design solutions for age-related computer use. International Journal of Behavioral Development. 1999; 23(3): 553-573.

[45] Mykityshyn AL, Fisk AD, Rogers WA. Learning to use a home medical device: Mediating age-related di_erences with training. Human Factors: The Journal of the Human Factors and Ergonomics Society. 2002; 44: 364-354.

[46] Morrell RW, Park DC, Mayhorn CB, Kelley CL. Effects of age and instructions on teaching older adults to use ELDERCOMM, an electronic bulletin board system. Educational Gerontology. 2000; 26(3): 221-235.

[47] Harada ET, Mori K, Taniue N. Cognitive aging and the usability of IT-based equipment: Learning is the key. Japanese Psychological Research. 2010; 52(3): 227-243.