# Virtual agents as daily assistants for elderly or cognitively impaired people

## Studies on acceptance and interaction feasibility

Ramin Yaghoubzadeh, Marcel Kramer, Karola Pitsch, and Stefan Kopp

CITEC, Bielefeld University,
P.O. Box 10 01 31, 33501 Bielefeld, Germany
ryaghoubzadeh@uni-bielefeld.de, marcel.kramer@uni-bielefeld.de,
karola.pitsch@uni-bielefeld.de, skopp@techfak.uni-bielefeld.de

**Abstract.** People with cognitive impairments have problems organizing their daily life autonomously. A virtual agent as daily calendar assistant could provide valuable support, but this requires that these special user groups accept such a system and can interact with it successfully. In this paper we present studies to elucidate these questions for elderly users as well as cognitively impaired users. Results from interviews and focus groups show that acceptance can be increased by way of a participatory design method. Actual interaction studies with a prototype demonstrate the feasibility of spoken-language interaction and reveal strategies to mitigate understanding problems.

**Keywords:** Assistive technology, Virtual assistants, Participatory design, Spoken dialogue robustness

## 1 Introduction

The number of people in need of support has been growing considerably in the last decade, and will continue to do so in the future. This applies to the sub-population of older adults, but also to cognitively impaired [1] people with congenital or acquired brain defects, whose life expectancy is nowadays like those of everybody else. People from both groups can exhibit cognitive limitations, either due to age-related mental decay, dementia, or disability. Such limitations can range from serious forgetfulness to a complete lack of the sense of time, and they can make it hard for them to autonomously organize and maintain a daily life with regular activities like meals, medication or social events, as well as extraordinary events like doctor's appointments. However, enabling such people to stay autonomous in their home environment and to have a self-determined way of living for as long as possible has been marked as one of the most important societal goals of the future.

[1] In this paper, we adopt the terminology from the ACM SIGACCESS guidelines. http://www.sigaccess.org/community/writing_guidelines

In: Proceedings of the 13th International Conference on Intelligent Virtual Agents (IVA 2013), pp. 79–91, Edinburgh, UK.
POSTPRINT
The final publication is available at Springer via http://doi.org/10.1007/978-3-642-40415-3_7

Many people are able to live autonomously and with relative physical and mental well-being when given support in organizing and following a structured daily schedule. However, employing professional care services raises growing economic problems and routine tasks such as monitoring and reminding of daily activities consume a lot of valuable work hours of the caregiving personnel – time that is often not available in ambulatory care or that is better spent in uninterrupted in-depth interactions. Technology could offer some of the needed support but often suffers from a lack of ease of use and, consequently, an acceptance barrier with these special user groups.

In this paper, we present the VASA project, a cooperation with one of Europe's largest health and social care providers for both elderly people and people with various disabilities. This project aims to explore how elderly people as well as people with cognitive disabilities can be enabled to autonomously maintain and follow a daily schedule with the help of a computer-driven assistant in the form of a virtual agent. We address this problem from the perspective of the users, i.e. we ask whether and under what conditions a virtual assistant can provide suitable assistantance to such people. We break this down into two research questions: (1) are virtual agents accepted as assistants by these user groups, and which system design would be particularly preferred?; (2) how can the interaction between the agent and such users be made feasible, i.e. sufficiently robust and effective?

In the next section we review related work before we present the results from two studies carried out to elucidate these questions. Section 3 reports results from interviews and focus groups conducted as part of a participatory design approach. Section 4 presents findings from an actual interaction study with a Wizard-of-Oz prototype of a virtual agent-based daily assistant, in which we wanted to know whether robust interaction is possible and, specifically, whether interaction problems can be spotted and repaired by these user groups. Both questions are explored for elderly people and for people with congenital or acquired cognitive disabilities. Section 5 discusses the results and concludes the paper.

## 2 Related work

A substantial body of work exists on special requirements for human–computer interfaces for older people or people with impairments. Jian et al. [6] provide a concise overview of fundamental remedial design practices to counter the effects of perceptive, articulatory, motor, and cognitive decline as well as reduced concentration. Likewise, the GUIDE project [4] has identified sensory, motor, as well as cognitive faculties that are subject to progressive decline, and for which specific countermeasures and guidelines can be used in interactive system design. They advocate the use of suitable user models and provide a catalogue of criteria to classify users according to their physical and mental capacities [4] by means of questions regarding their abilities for daily tasks. Williamson et al. [16] employed participatory design in focus groups to obtain a qualitative analysis of the preferences of older people regarding multimodal reminders. They identified potential reminder tasks and concluded that the participants generally prefer reminder interactions to initiate in a unimodal way and be continued in a multimodal fashion if more information was required.

A number of projects have explored whether embodied virtual agents and speech input or output can be of benefit. The GUIDE project [4], also using focus groups, found out that spoken language was by far the most preferred interaction modality for elderly users unfamiliar with technology, and that avatars should disappear in problem-free interaction but should automatically reappear when a task problem was detected. Beskow et al. [2] applied a user-centered design approach to develop a reminder system for two users with cognitive problems following surgery. They presented a prototype for multimodal schedule management using handwriting recognition and spoken dialogue with a virtual character. Regarding speech input, mild to medium-severity articulatory impairments, such as slightly disfluent or slurred speech, have received particular research focus in recent years [19], with solutions for reduced recognition error rates ranging from the application of acoustic models of elderly speakers, to multimodal fusion of speech input and typed input of initial letters for disambiguation [3]. Even for more heavily impaired patients, solutions exist that can provide fairly reliable environment control via single-word recognition [5].

With regard to virtual agents as potential social companions, Vardoulakis et al. [14] found high acceptance ratings in a Wizard-of-Oz evaluation of a relational agent dialogue system envisioned as a social companion for older people, who were free to choose topics for the conversations. Sakai et al. [11] evaluated a Flash-based virtual agent providing back-channel feedback to monologues produced by elderly patients suffering from dementia, whom they reported as being "willing to be engaged in conversation" with the system.

Compared to the user group of senior citizens, people with congenital or acquired cognitive impairments have received relatively less attention, possibly due to this user group not having exerted great demographic pressure so far. Nonetheless, there are certain parallels with elderly people in terms of cognitive symptoms such as reduced working memory and decreased capacity for concentration, suggesting similar system designs using dialogue or conversational agents. Moreover, this group of people often shows a greater likelihood for behavioral anomalies. These are, for the most part, under control by medication. Yet, it is argued that autonomous systems in actual unsupervised use by those users need to implement dedicated security measures and coping strategies [18].

In sum, related work has shown that spoken dialogue with a virtual agent may be a suitable interaction paradigm for the elderly, but there has been very little work on cognitively impaired users with congenital or acquired cognitive impairments so far. It seems reasonable to assume that virtual conversational agents can provide a suitable way of interacting with technology for those people too, who often are illiterate and can only use simple graphical symbols or icons to interact with their technical environment. In the present work, we wanted to explore (1) if elderly users as well as cognitively impaired people would accept a virtual agent as an assistant helping with scheduling daily activities, and how both groups compare in this respect. In addition, it is not yet well understood (2) how dialogue and multimodal conversational behavior must be structured and presented on the part of the agent, in order to maximize robustness and effectivity of the interaction between these user groups and a virtual agent. Since misunderstandings by the system are inevitable, especially with these user groups and when it comes to unrestricted spoken input in natural environments, a key sub-question is how such users react to misunderstandings of the assistant and whether specific interaction strategies of the agent can help them to spot and repair them in a way suited to their cognitive limitations. The following two sections present studies aimed to shed light on these two questions.

## 3 Study 1: Participatory Design and Focus Groups

Achieving an optimal level of social acceptance for technology is a key guideline of our project, hence both research and development focus on the actual needs of possible users as well as their opinions, suggestions and ideas. In lack of sufficient empirical findings and design guidelines, we employed a user-centered and participatory design approach to investigate the actual needs of the targeted user groups, their ideas and reservations about a daily assistant, and their specific suggestions for an acceptable system design. To this end, we conducted interviews as ethnographic fieldwork as well as focus groups with prospective users living in the facilities of our institutional care-giving partner [9].

### 3.1 Initial interviews

In exploratory interviews with elderly people, ten participants (7 female, 3 male, aged 76 to 85) took part in structured interviews, gathering their opinions about and use of modern technologies, their needs of assistance in everyday life and their daily routines. Furthermore we wanted to examine how the integration of a virtual assistant into participants' daily structures might change possible everday tasks and routines. Participants mainly named physical problems to be relevant causes of a need for assistance. Arguably, gradually decreasing cognitive abilities are barely realized – or outright denied – by older people when speaking about themselves. Several participants were hesitant to delegate any task to any other party, possibly due to biographical issues. Lacking graspable imagery considering technological possibilities, participants could rarely utter concrete wishes.

### 3.2 Focus Groups

Based on the results from the interviews, we devised a step-wise procedure [8] consisting of (1) ascertaining potential users' personal needs, attitudes and technical affinity by discussing a fictional case in focus groups, (2) giving them a live presentation of a system prototype and discussing their first impressions, (3) letting them interact with the agent in a Wizard-of-Oz study, solving a simple task with spoken language, followed by an interview about usability, functionality and design, and (4) having a final focus group discussing impressions and experiences in order to guide the future design of the system. Note that multi-participant focus groups were not possible with the cognitively impaired people, due to peculiarities in terms of social behavior. We thus reverted to focus groups with the care-giving personnel and personal interviews with the actual users.

In an initial focus group of six older adults (4 female, 2 male, aged 73 to 85), we found different degrees of familiarity with technology, ranging from having no cellphone to using a computer and video telephony. Regarding support requirements for a fictional senior person, participants named reminders for food and fluid intake, doctor's appointments and birthdays. In this initial focus group, only two people envisioned a virtual agent to be a helpful assistant for themselves. In the final focus group, step 4 of our method taking place after actually interacting with a Wizard-of-Oz version of the system (see Study 2), this had increased to four people. Four participants stated that they would prefer the physical appearance of a young adult of the opposite gender for the agent, two participants liked the avatar's current more child-like design.

A detailed analysis of ethnographical data on the cognitively impaired users is still underway. However, in terms of commonalities and differences, illustration and large lettering were named as desirable for the calendar as well as different modes of entering appointments and intervals for reminders. While elderly participants suggested a monthly overview, the carers of people with cognitive impairments said a daily view and just-in-time reminders would be useful. Both groups preferred the system to only take initiative when issuing a pre-set reminder, initiated by a pleasant audio signal, proceeding to uttering their name as a second call to attention, and postponing the reminder if no reaction was present, and only activating a camera if an interaction had actually started.

## 4 Study 2: Feasibility of Successful Interaction

Based on the results of the interviews and focus groups, we have developed a first prototype version of the daily assistant. Following internal pilot studies with the conversational agent, Study 2 served to explore whether successful interaction with a conversational agent is feasible for our special user groups. In that, besides trying to achieve successful dialogues in real interactions, we were interested in what happens when interaction problems in the form of misunderstandings on the part of the system – inevitable in speech-based conversational agents – arise. We first describe the system prototype and its Wizard-of-Oz version, used in this study, before the procedure and the results are presented.

### 4.1 Prototype system and experimental setup

In the targeted final system, interactions between the virtual assistant and the human user shall be conducted via a computer or TV screen (optionally a touch screen) and standard speakers, and a directional microphone for automatic speech recognition on the input side. One function of the daily assistant will be to assist in organizing and following a day schedule, which is presented graphically next to the agent. Fig. 1 (left) shows the current version of the system, also used in Study 2.

The virtual agent acts as an assistant in managing appointments on the calendar. The current prototype uses an agent (Fig. 1, left) driven by the ACE architecture [7] for conversational agents, and currently being ported to the ASAP realizer system optimized for incremental dialogue [15]. NLU is realized by spotting keywords and simple grammatical structures (such as direct declaration of new appointments, questions about the schedule) in free-form speech data as acquired from n-gram dictation-style recognizers, delivered by a Windows Speech Recognition or a Nuance Dragon NaturallySpeaking backend. The NLU module is capable of providing incremental results from the parser to the dialogue manager, which is an independent implementation following the basic tenets of the Info-State approach [13]. The current version of the system is capable of going over the weekly schedule with the user in an interruptible fashion and inserting or removing appointments as the user instructs. Schedule data in discussion are provided by the system in a multimodal fashion, using iconic visualization and highlighting on the calendar board, speech synthesis, gaze, head movements, as well as pointing and deictic gestures by the agent. For laboratory setups, an eye tracker component tracks the subject's visual focus to ascertain their capacity to follow the dialogue, in particular whether and where they look at the schedule, and when they turn back to adress the agent.

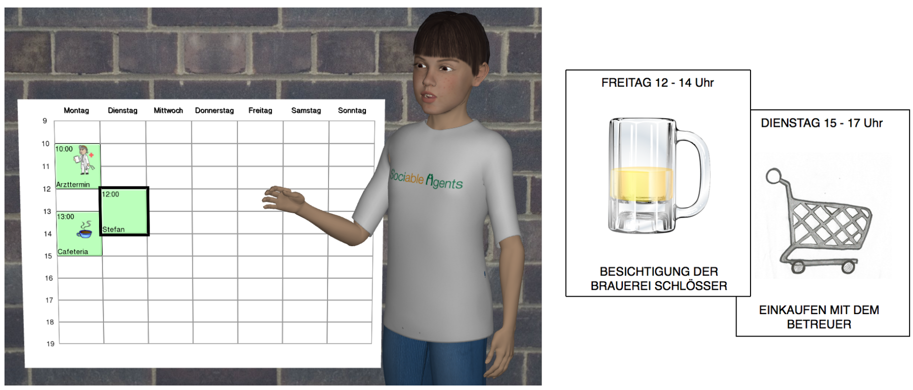


**Fig. 1. Left:** Daily assistant "Billie" presenting the user's appointments; **Right:** appointment cue cards used in the study.

In the present study, we did not use the autonomous prototype system but a Wizard-of-Oz version in order to cancel out errors from accidental misinterpretation and circumvent the need to train speech recognizers for each participant beforehand. The Wizard listened to the user's spoken input and picked system responses from a graphical interface, which were synthesized in realtime by the character engine. The Wizard's GUI featured about 100 predetermined responses, ranging from generic feedback (e.g., "Yes", "Ok") to appointment-specific utterances like repetitions ("So, you have a dentist appointment tomorrow at 10") or requests ("And at what time will it take place?"). To cope with users' alterations of the order or contents of appointments, responses could also be flexibly configured manually by the wizard by typing abbreviated descriptions of, e.g., days, times, or activities, that were automatically expanded and sent to the character engine by the GUI.

The goal of Study 2 was twofold. First we wanted to see whether these user groups can interact with a conversational agent in a smooth and trouble-free way. Second, we also wanted to see what happens in cases when misunderstandings of the system occur. To this end, the following study was conducted with the two user groups, elderly users and cognitively impaired users.

### 4.2 Participants

Cognitively impaired participants were recruited from the clientele of an institution where people of all ages with various cognitive impairments could attend computer and photography courses; they thus had prior experience with interacting with computers via standard input devices. All participants (n=11, 7 male, 4 female, aged 24 to 57) had light to medium mental retardation (approximately F70–F71 on the APA DSM scale [1]), no unmedicated behavioral anomalies, and normal to slightly impaired speech capabilities. They were partly illiterate, but capable of reading at least isolated words, times, or days of the week.

The elderly participants (n=6, 4 female, 2 male, aged 76 to 85) were recruited from the focus groups in the retirement home. They were capable of independent living in their home environment and did not have cognitive impairments at a clinically relevant level.

### 4.3 Method

Participants were seated in front of the agent as shown in Fig. 3 (top). The system was explained as displaying an avatar able to engage in schedule-related dialog in normal spoken language. Participants were instructed to verbally request the system to insert appointments into their own calendar on their behalf. All appointments were given in form of cue cards (Fig. 1, right), designed to contain events from the typical week of the user group as well as a selection of recreational events. Participants were provided with seven cue cards on which the day, time, and the description of the event were given along with an iconic representation of the topic (recall that some of the cognitively impaired people were illiterate). All cards were explained individually beforehand. Participants were free to peruse the cards at any time during the interaction.

Upon giving the instructions, the staff left the room[2]. The wizard made the agent introduce itself and then verbally describe two items already entered in the fictional schedule, highlighting them on the virtual calendar board. The participants were then to start entering their own seven appointments.

During the actual interaction, when instructed by the user to enter an appointment, the agent would proceed with a predefined scheme of introducing errors at certain times: for cards 1, 4 and 5, no error would be introduced; for cards 2 and 7 the time would be misunderstood; for card 3, the topic would be altered to a similar-souding incorrect one; for card 6, both time and day would be altered. All items and errors were presented both verbally by the agent and graphically in the calendar in a small confirmation dialogue started by the agent after each insertion of a new appointment. For this we realized two different strategies: In the *global* condition, the agent summarized items in one coherent utterance ("So you will go shopping, Wednesday at 9?") and waited for feedback; in the *local* conditon slots were presented one-by-one ('So it is on Wednesday?', 'At 9 o'clock?', 'And you will go shopping.'), awaiting feedback after each step. The visual calendar either displayed the whole appointment at once or revealed it slot-by-slot (day, time, content), respectively. In both conditions, the final seventh appointment was summarized by displaying it on the visual calendar only ('So I will enter it like this?'), to determine whether subjects could detect errors that were apparent in visual form only. Whenever subjects spotted and corrected an error, the agent revised the corresponding slots and reiterated the clarification question until subjects signaled the appointment as being correct. The agent then proceeded to ask for more appointments. Whenever the participants did not take the initiative in idle conversation for some time, the agent asked them whether there was anything else to do. If participants repeatedly failed to react when seven topics had not been negotiated yet, or did not desire to add any more appointments, the wizard would proceed to valediction and terminate the interaction.

After the end of the interaction, participants were interviewed according to a structured interview plan. Its first part comprised nine questions about system usability and acceptability, each with a request to give a rating on a graded scale (1 = best, 6 = worst). Questions were: (1) How did you like to plan your week with Billie? (2) Did Billie always do what you wanted? (3) Did Billie provide sufficient help? (4) Could you understand Billie's language well? (5) Did Billie express himself in an easy way? (6) Did Billie understand you correctly? (7) How did you like the image-based calendar? (8) Do you think Billie could be of help to you? (9) Do you think Billie could be a good appointment assistant?

Since we expected impaired participants not to be able to handle abstract numbers consistently, we provided a chart which showed the grades along with appropriate emotional facial icons and asked participants to point at the most fitting one. The second part of the interview comprised open questions about design wishes and desirable additional support functions of the virtual assistant.

[2] One team member stayed in the room with the cognitively impaired people in case a participant would be overwhelmed or panic.

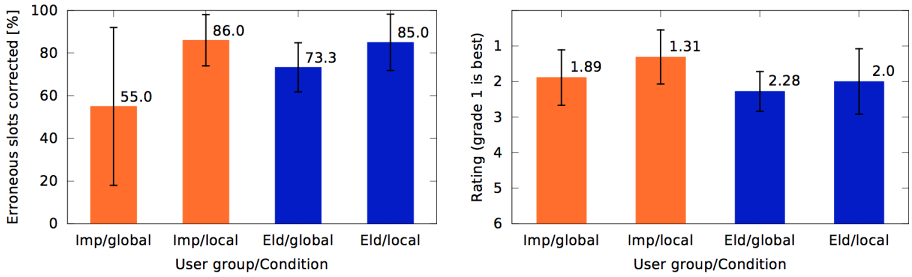


**Fig. 2. Left:** Mean error repair rates in *global* and *local* conditions of cognitively impaired users (abbreviated Imp), and elderly users (Eld). **Right:** Averaged ratings of the system (questions see text) by both user groups, in both conditions.

### 4.4 Quantitative results: Cognitively impaired users

Ten of the cognitively impaired participants (n=11) succeded in entering their appointments, although one of them skipped the final two cards and stated there were no more appointments. One additional card was omitted due to a handling problem. One of the eleven participants did not enter any appointments even after repeated inquiry by the agent, and was disregarded for error repair data analysis since the interaction went from greeting to valediction directly. Recordings and log files from the interactions were subjected to an analysis of how often the users were able to spot and repair a misunderstanding by the agent. Fig. 2, left, shows the mean rates of successful error repairs for both user groups. In the group of cognitively impaired users, 75% of the introduced errors were spotted by the participants overall. More errors were noticed and repaired in the local condition (86%) than in the global condition (55%). Note that with five subjects per condition statistical power is too little for tests of significance, but the difference is considerable in absolute terms. In addition, the variance is much smaller in the local condition than in the global, i.e. inter-individual differences were less pronounced in the more successful condition. Errors in the visual-calendar-only items (not summarized verbally by the agent) were spotted in 66% of cases. The answers to the usability questions, on average, follow the same trend of slightly better ratings in the *local* conditon (*global*: $\mu = 1.89, \sigma = 0.78$; *local*: $\mu = 1.31, \sigma = 0.76$; see Fig. 2, right).

### 4.5 Quantitative results: Elderly users

All elderly participants (n=6) succeeded in interacting with the system and fulfilling the task; in one case the volume level had to be increased after the agent's introduction. The error repairs rates were 73.3% (*global*) and 85.7% (*local*), respectively. Errors in the visual-calendar-only items (without accompanying verbal summary of the schedule data) were spotted in all cases (100%). Compared to the cognitively impaired user group, the conditions did not noticeably influence usability ratings of the system (*global*: $\mu = 2.28, \sigma = 0.56$;

*local*: $\mu = 2.0, \sigma = 0.92$). Further, the interaction styles were more varied than in the other user group, ranging from brief to verbose styles; one participant in particular selected a very verbose style and role-played a back story to the appointments, compatible with accounts of a propensity amongst elderly people for a “social” a-priori interaction style with virtual agents (cf. [17]).

### 4.6 Qualitative analysis: Issues of interactional conduct

The advantage for the *local* repair elicitation strategy, where day, time and topic are presented one-by-one, was more prominent for the group of people with cognitive impairments – possibly they derive more benefit from this stepwise, simple-structured process. To further shed light on those dialogue structures that fostered or prevented error detection and correction in both conditions, we performed analyses of the subjects' interactional conduct and especially the repair attempts encountered. Video recordings of the interaction were analyzed for the collaborative processes between the parties, their verbal and nonverbal actions and the resulting sequential structures [9]. Initial investigation of the video data reveals the importance of the system's ability to invite the user to explicitly compare the tentative calendar entry with the original information. By analyzing the orientation or locus of attention (screen/cue card) of the users one can identify those moments at which they explicitly compared the entry in question with their original information.

For example, in the fragment shown in Fig. 3), the user (here, a cognitively impaired person) interacts with the system in the *global* condition. The user has successfully entered one appointment and now proceeds to the second one, containing the first introduced error. The user reads the appointment off the cue card (Fig. 3, line 01), the gaze alternating between the cue card and the screen. After the utterance, the user looks up to the agent (line 01), waiting for a reponse. The agent repeats the appointment naming the correct day and activity, but incorrect time information (line 02). The user seems to notice the error and looks down to the cue card, apparently checking the information. The user then gazes back to the screen (Fig. 3, top right) and utters an excuse (line 03), and, glancing at the cue card, initiates a self-repair (line 03) before redirecting their gaze to the agent. In subsequent turns, not shown here, an exchange of excuses takes places and the agent repeats the corrected information, which the user explicitely ratifies as being correct while double-checking the cue card.

This short fragment reveals that data entry, error detection and information comparison corresponded directly to gaze shifts between the screen and the card at sequentially relevant moments. The question arises how and at which precise moments users come to realize a problem, how the system can recognize this from the user's gaze behavior or to which extent it can provide orienting devices which invite the user to check for data correctness.


```
01   U:        dann von siebzehn uhr bis neunzehn uhr am dienstag (-) der kochkurs.|
               then from     5pm      to     7pm      on  tuesday     the cooking class
     U-gaze:   @cuecard-----------@screen-----------------@cuecard-----@screen---------
                                                                                 |#Img.1
02   A:        (1.6) also haben sie am dienstag um fünfzehn uhr kochkurs.|
                     so    you have  on tuesday  at      3pm     cooking class.
     U-gaze:   ----------------------------------------------------------|@cuecard------
                                                                          |#Img.2
03   U:        (1.1) äh=nein schuldigung. |(-) siebzehn bis neunzehn uhr.
                     um  no     sorry            5pm     to    7pm
     U-gaze:   -------@screen------------------@cuecard------@screen------------------
                                           |#Img.3
```

**Fig. 3.** Transcript and anonymized snapshots from a repair attempt in Study 2. Transcription follows the GAT conventions [12]: pause length in parentheses, short pauses indicated by (-). Times of the three frames indicated by #Img.x.

## 5 Discussion and Conclusions

In this paper we have presented our first results of a project that explores if and how virtual agents can be employed to assist people with cognitive (and possibly other) limitations in managing their daily schedule and calendar. Our studies involve elderly users as well as, to the best of our knowledge for the first time, cognitively impaired users to address questions of (1) acceptability and (2) feasibility of symmetrical spoken-dialogue interaction. As for the first question, elderly people were found to be more reluctant to use such a system than the (younger) cognitively impaired people. In the early steps of the participatory process, elderly participants tended to recognize the usefulness of the assistive system mostly for third persons, but not for themselves. Notably, interviews, focus groups and encounters with a system prototype that actively engaged the prospective users in the system design, helped to lower this acceptability barrier – that is, the participatory design process itself helped to enhance the acceptance of the technology. Furthermore, such means of participatory design also resulted in specific design suggestions like the preferred form of reminders or a preference for spoken language interaction with the agent. As for the second question, our results show that both groups are also willing and, in principle, able to engage in a spoken-language conversational interaction with the agent. Besides confirming the well-known social effects of a virtual humanoid agent, e.g. eliciting story-telling from some elderly people, we could also show that both user groups are in fact able to handle the common interaction problems speech-based systems bring along, but that this needs to be – and can be – supported by the dialogue strategies employed by the system. Our results suggest that the optimal system behavior comprises explicit confirmation dialogues with information presentation in small chunks or installments. The importance of simple information presentation for elderly people and people with disabilities is widely reported in literature (e.g. [6], [4]). However, in contrast to other studies where users prefered low-verbosity system responses [10], the repetitive and verbose small-chunks condition did not lead to negative consequences for the evaluation of the system or the agent by the users, though future work needs to address the question whether this strategy might turn out unnecessary and bothersome in long-term interaction. Another crucial next step, currently underway, is to see if the autonomous virtual agent can also prove to be a suitable assistant in settings like the one explored here.

**Acknowledgements** – This research is supported by the Deutsche Forschungsgemeinschaft (DFG) in the Center of Excellence 'Cognitive Interaction Technology' (CITEC). Additionally, Karola Pitsch acknowledges the financial support from the Volkswagen Foundation (Dilthey Fellowship). We thank the project members from v. Bodelschwinghsche Stiftungen Bethel and all the participants in our studies.

## References

1. American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders DSM-IV-TR, 4th ed. American Psychiatric Publ., Arlington, VA. (2000)
2. Beskow, J., Edlund, J., Granström, B., Gustafson, J., Skantze, G., Tobiasson, H.: The MonAMI Reminder : a spoken dialogue system for face-to-face interaction. In: Proceedings of the 10th Annual Conference of the International Speech Communication Association, INTERSPEECH 2009. pp. 300–303. (2009)
3. Fager, S.K., Beukelman, D.R., Jakobs, T., Hosom, J.-P.: Evaluation of a Speech Recognition Prototype for Speakers with Moderate and Severe Dysarthria: A Preliminary Report. Augmentative and Alternative Comm., 26(4):267–277. (2010)
4. GUIDE Consortium: User Interaction & Application Requirements - Deliverable D2.1. (2011)
5. Hawley, M.S., Enderby, P., Green, P., Cunningham, S., Brownsell, S., Carmichael, J., Parker, M., Hatzis, A., ONeill, P., Palmer, R.: A speech-controlled environmental control system for people with severe dysarthria. Medical Engineering & Physics, 29(5):586-–593. (2007)
6. Jian, C., Sasse, N., von Steinbüchel-Rheinwall, N., Schafmeister, F., Shi, H., Rachuy, C., Schmidt, H.: Towards effective, efficient and elderly-friendly multimodal interaction. In: Proceedings of the 4th International Conference on Pervasive Technologies Related to Assistive Environments (PETRA 2011), article 45, 1–8. ACM, New York, NY. (2011)
7. Kopp, S., Wachsmuth, I.: Synthesizing multimodal utterances for conversational agents. Computer Animation and Virtual Worlds 15(1): 39–52. (2004)
8. Kramer, M., Pitsch, K.: "Gibt es noch irgendwas, das Sie in der Woche machen wollen?" - Terminplanung mit dem virtuellen Agenten Billie. A peer-reviewed abstract. Presented at the 51st meeting of Arbeitskreis Angewandte Gesprächsforschung, Dortmund. (2012)

9. Kramer, M., Yaghoubzadeh, R., Kopp, S., Pitsch, K. : A Conversational Virtual Human as Autonomous Assistant for Elderly and Cognitively Impaired Users? Social Acceptability and Design Considerations. In: Proceedings of the INFORMATIK 2013 Workshop “Who is afraid of autonomous machines? Transgressions between body, mind, and technology” in Koblenz, Germany. In press. (2013)
10. Okato, Y., Kato, K., Yamamoto, M., Itahashi, S.: System-user interaction and response strategy in spoken dialogue system. In: 5th Int. Conf. on Spoken Language Processing / 7th Australian Int. Speech Science and Tech. Conf, Sydney. (1998)
11. Sakai, Y., Nonaka, Y., Yasuda, K., Nakano, Y.I.: Listener agent for elderly people with dementia. In: Proceedings of the 7th annual ACM/IEEE Int. Conf. on Human-Robot Interaction (HRI ’12). ACM, New York, NY, USA, 199-200. (2012)
12. Selting, M. et al.: Gesprächsanalytisches Transkriptionssystem 2 (GAT 2). In: Gesprächsforschung - Online-Zeitschrift zur verbalen Interaktion 10:353–402. (2009)
13. Traum, D., Larsson, S.: The Information State Approach to Dialogue Management. In: Smith and Kuppevelt: Current and New Directions in Discourse & Dialogue. Kluwer Academic Publishers. pp. 325–353. (2003)
14. Vardoulakis, L.P., Ring, L., Barry, B., Sidner, C.L., Bickmore, T.W.: Designing Relational Agents as Long Term Social Companions for Older Adults. In: Proceedings of the 12th International Conference on Intelligent Virtual Agents. LNCS 7502. pp. 289–302. (2012)
15. van Welbergen, H., Reidsma, D., Kopp, S.: An Incremental Multimodal Realizer for Behavior Co-Articulation and Coordination. In: Proceedings of the 12th Int. Conference on Intelligent Virtual Agents. LNCS 7502. pp. 175–188. (2012)
16. Williamson, J. R., McGee-Lennon, M., Brewster, S.: Designing multimodal reminders for the home: pairing content with presentation. In: Proceedings of the 14th ACM international conference on Multimodal interaction (ICMI ’12). ACM, New York, NY, USA, pp. 445–448. (2012)
17. Wolters, M., Kallirroi Georgila, K., Moore, J.D., MacPherson, S.E.: Being Old Doesn’t Mean Acting Old: How Older Users Interact with Spoken Dialog Systems. In: ACM Trans. Access. Comput. 2, 1, Article 2 (2009)
18. Yaghoubzadeh, R., Kopp, S.: Toward a virtual assistant for vulnerable users: designing careful interaction. In: Proceedings of the 1st Workshop on Speech and Multimodal Interaction in Assistive Environments (SMIAE ’12). Association for Computational Linguistics, Stroudsburg, PA, USA, pp. 13–17. (2012)
19. Young, V., Mihailidis, A.: Difficulties in Automatic Speech Recognition of Dysarthric Speakers and Implications for Speech-Based Applications Used by the Elderly: A Literature Review. In: Assistive Technology, 22(2):99–112. (2010)