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Persuasive robotic assistant for health self-management of older adults: Design and evaluation of social behaviors

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Abstract

Daily health self-management, such as the harmonization of food, exercise and medication, is a major problem for a large group of older adults with obesity or diabetics. Computer-based personal assistance can help to behave healthy by persuading and guiding older adults. For effective persuasion, the assistant should express social behaviors (e.g., turn taking, emotional expressions) to be trustworthy and show empathy. From the motivational interviewing method and synthetic assistants' literature, we derived a set of social behaviors, and implemented a subset in a physical character, a virtual character and a text interface. The first behavior type concerns conversing with high-level dialogue (semantics, intentions), which could be implemented in all 3 assistants. The other behavior types could only be implemented in the characters: showing natural cues (e.g., gaze, posture), expressing emotions (e.g., compassionate face), and accommodating social conversations (e.g., turn taking). In an experiment, 24 older adults (45–65) interacted with the text interface and one of the characters, conform a "one-week diabetics scenario". They experienced the virtual and physical character as more empathic and trustworthy than the text-based assistant, and expressed more conversational behavior with the characters. However, it seems that the preference of interacting with the character or the text interface was influenced by the conscientiousness of the participant; more conscientious people liked the text interface better. Older adults responded more negative to the characters that lacked the social behaviors than to the text interface. Some differences between the virtual and physical character probably occurred due to the specific constraints of the physical character.

Keywords: Persuasive computing; Human–robot interaction; Health-care

1. Introduction

In the year 2000, one in ten individuals in the world was 60 years or older and one in fourteen was at least 65. It is expected that these numbers will increase to one in every five persons being 60 or older and nearly one in six people 65 or older in 2050 (United Nations, 2002). On top of that, the prevalence of chronic diseases is rising amongst older people because of urbanization and an unhealthy lifestyle (Wild et al., 2004) (e.g., diabetes, COPD, obesities). A major problem is that only 50% of the chronically ill adheres to their treatment advice (WHO, 2003). For older adults, this problem is particularly hard because of their health illiteracy and deep-rooted daily routines—or lifestyles.

Information and Communication Technology (ICT) might provide the required support to better cope with the personal health constraints, such as doing exercises (Kidd and Breazeal, 2006; Ruttkay et al., 2006; Bickmore et al., 2004; Goetz et al., 2003; Gockley and Mataric, 2006), giving social support (Kidd et al., 2006; Kriglstein and Wallner, 2005), and helping with lifestyle change (Bigelow et al., 2000; Looije et al., 2006). Research on persuasive technology (Fogg, 2002) and affective computing (Picard, 1997) is providing technological (partial) solutions for the development of this type of assistance, e.g., for the

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realization of social behavior, such as social talk and turn taking (Bickmore et al., 2004; Kidd et al., 2006; Goetz et al., 2003; Gockley and Mataric, 2006), and of empathic behavior, such as attentiveness and compliments (Kidd et al., 2006; Bigelow et al., 2000; Looije et al., 2006; Kriglstein and Wallner, 2005). In our view, psychological techniques for behavioral change, such as motivational interviewing, should be accommodated by this type of ICT support (e.g., Rogers, 1951; Looije et al., 2006; Miller and Rollnick, 1991). However, a concise and coherent set of behaviors – worked-out in specific user-interface behaviors – for such an accommodation is lacking. Derived from relevant literature of psychology, persuasive technology and affective computing, this paper presents a first set of behaviors (e.g., compassion) that map support objectives (motivating, educating, and supporting) on specific – *social* – user-interface behaviors for the intended ICT support. In an experiment, we tested how far these social behaviors help to make the interface more empathetic and trustworthy, which are preconditions for long-term use.

It should be noted that older adults experience specific hindrances to actually make use of ICT support, due to relatively limited computer skills (partly due to limited sensory, physical and cognitive abilities), and motivation to use a standard Windows, Icons, Menu and Pointing (WIMP) device (Czaja and Lee, 2007). An important question is how to realize user interfaces with which older adults feel at ease and which are pleasant in use (Czaja and Lee, 2007). Different user-interface types for older adults' health assistance have been developed, such as text or WIMP-based questionnaires and feedback providers (Blanson-Henkemans et al., 2007; Bigelow et al., 2000), and character educators and buddies (Looije et al., 2006; Kidd et al., 2006; Goetz et al., 2003; Gockley and Mataric, 2006; Kriglstein and Wallner, 2005). A speech interface may be more natural to use than a text interface for people who are not experienced with computer technology (Neerincx et al., 2008). A user interface with a character-like appearance (e.g., animal) could further improve the feeling of comfort of older adults with technology (Kidd et al., 2006; Kriglstein and Wallner, 2005). Social behavior increases when a character-like appearance is used (Kidd et al., 2006; Kriglstein and Wallner, 2005) and as a result the resistance towards the interface might decrease. However, empirical research on possible benefits of these types of user interfaces on older adults' appreciation and conversational behavior is lacking.

This paper presents an experiment, comparing a text-based interface with a – virtual and physical – character providing health assistance for older adults. For this comparison, we used the currently most common dialogue: written input and output (keyboard and window) for the text (WIMP) interface, and spoken input and output for the character. Overall, the expectation was that social behaviors improve users' appreciation and enriches their interaction behavior; i.e., more talking, looking, laughing will occur. Furthermore, it is expected that such user-interface behaviors can be best incorporated in characters in comparison with virtual characters and text interfaces. However, we assume that characters which do not show the required social behavior evoke relatively large negative responses of the users. Finally, we expect that the personality of the user influences his/her preference for a specific interface.

2. Research approach

Within the SuperAssist project, in which this experiment was performed, we apply a user-centered design approach, in which support concepts are being developed, tested and implemented incrementally (Neerincx and Lindenberg, 2008; Blanson-Henkemans et al., 2007). Within the SuperAssist project diabetes is taken as a case study for the development of personal assistants for older adults. The support content about diabetes is based on a thorough domain and task analysis with involvement of patients (e.g., interviews), medical experts (e.g., with respect to diet and lifestyle advice for people with obesity), and computer support experts (e.g., current e-health solutions); see Blanson Henkemans et al. (2009). Scenarios are derived from this analysis, getting the use context clear, and enabling assessments of the expected support effects and corresponding behaviors (Blanson-Henkemans et al., 2008; Rosson and Carroll, 2001). In the practice of medical research, the well-being of patients should remain central, and empirical foundation of computer support – such as a persuasive assistant – should burden this user group as little as possible (Coyle et al., 2007). To reduce this burden, general support characteristics can first be tested with healthy persons. The general characteristics of these persons that may affect support preferences, such as age, should be similar to the target group as far as possible. Scenarios help to address the effects of context-of-use in the evaluation. Furthermore, scenarios can help healthy participants empathize with the use of health assistants in complex and tedious patient situations during the evaluation. The evaluation may show positive and negative outcomes on core support characteristics, and recommendations for improvement. When the outcomes are mainly positive, the tests with patients should be started. This paper presents an experiment with healthy adults in the age group with a relatively high risk to acquire diabetes type II (i.e., age between 45 and 65). The experiment shows whether this user group in general appreciates the social behavior of virtual or physical characters, and responses well to the persuasion skills that are relevant for chronic diseases like diabetics. If the assistance works well on these aspects, we will test the support with older adults with diabetics in a subsequent experiment.

3. Social computer skills for persuasion

We aim at computer-based personal assistance that persuades and guides older adults to behave healthily.

Research on persuasive technology (e.g., Fogg, 2002) shows that such technology is perceived as a "social actor" by the user. Consequently, the technology reactions (feedback) should be social and therefore follow principles of empathy. In addition, research on automation and personal assistants shows that the technology should be trustworthy to evoke adequate user behavior (e.g., Neerincx and Streefkerk, 2003; Cassell and Bickmore, 2000).

3.1. Empathy

Rogers (1951) was the first to note that to induce behavioral change in a client a therapist has to be empathetic. A technique for behavioral change that is derived from various psychological theories, from which Rogers' theory is the most prominent, is Motivational Interviewing (Miller and Rollnick, 1991). The key principle of motivational interviewing is that the patient's self-knowledge about the effects of his/her behavior, combined with self-efficacy, i.e., the ability to reach the desired effect by himself/herself, results in more stable and prolonged behavioral change. By implementing characteristics such as empathy, we want to increase the persuasive abilities of the personal assistant to change attitude and behavior of the user. In total *ten skills* can be identified for a Motivational Interviewing therapist, which are as follows:

1) Be complimentary rather than punitive (Give compliments where applicable, and do not punish after a fault).
2) Be attentive (Clearly show to the speaker that you are listening, among other things in your non-verbal behavior).
3) Express compassion through reflective listening (React appropriately on what is said, if someone says: "I'm not feeling well" show compassion).
4) Communicate respect for and acceptance of clients and their feelings (Do not react negatively on feelings and actions of the client).
5) Establish a non-judgmental, collaborative relationship with the client (Do not judge, but support).
6) Be a knowledgeable support person (Do not lie and know what you are talking about).
7) Gently persuade, with understanding that change is up to the client (Explicitly say that change is up to the client).
8) Develop discrepancy between client's goals or values and current behavior (Help clients appreciate the value of change).
9) Adjust to, rather than oppose, client resistance (Accept the client's reluctance as natural).
10) Support self-efficacy and optimism (Focus on client's strengths to support the hope and optimism needed to change).

The HealthBuddy® is an example of persuasive technology that applies Motivational Interviewing in a very limited way (Bigelow et al., 2000; van Dijken et al., 2005). The HealthBuddy® supports people with chronic diseases such as COPD and diabetics with a text-based user interface.

3.2. Trust

Because the assistant handles delicate data and acts autonomously; it is of utmost importance that people trust the personal assistant. The system therefore has to behave in a competent manner. Trust can grow with experience with the system, and is influenced by errors from the system, and interface and user characteristics (Muir, 1994). Trust is also a critical factor in interpersonal relationships (Lee and See, 2004): To achieve trust, the interaction between user and system must follow the same dialogue conventions as are exhibited in human–human interaction (e.g., social talk, politeness, consistency, turn taking) (Cassell and Bickmore, 2000). Particularly for older adults, positive feedback is important to have confidence in a good ending (Czaja and Lee, 2007; Jussim et al., 1995).

4. Implementation of social behavior for a persuasive assistant

Research in the area of affective computing (Picard, 1997) aims at technology to (partially) automate social behavior (i.e., sensing, interpreting and accommodating emotions). Liu and Picard (2005) showed that a personal assistant is appreciated more and therefore used for a longer period of time if its expression (e.g., empathy) is attuned to the user's state. The statements of Reeves and Nass (1996) that people will have higher appreciation of technology if it is socially and physically present has been confirmed in research that compared text and characters (Moreno et al., 2001) and in research that compared physical and virtual characters (i.e., favorable results for the physical character, (Bartneck, 2003; Kidd, 2003; Wainer et al., 2006; Goetz et al., 2003)). Fong et al. (2003) enumerate several behaviors of such a social (synthetic) character, as follows:

1) Communicate with high-level dialogue (address semantics and speakers intentions adequately).
2) Use natural cues (e.g., gaze, gestures, posture, etc.).
3) Express and/or perceive emotions (e.g., show a happy face).
4) Learn/recognize models of other characters (e.g., recognize the difference between an introvert and extravert personality).
5) Exhibit distinctive personality and character (e.g., be introvert or extravert).
6) Learn/develop social competencies (e.g., dialogue conventions such as turn taking and social talk).

The social synthetic behaviors listed above should include the social skills enumerated in Section 3. The first

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three (empathy) skills of motivational interviewing match the first three behaviors listed above. Furthermore, the trust requirement of Section 3.2 is matched by the sixth behavior. The fourth and fifth social behaviors are relevant for more long-term relationships and will not be implemented in our first prototype that focuses – as a start – on short-term effects. Table 1 shows how the empathy and trust objectives (what) are related to the social behaviors (how) of a computer assistant.

To study the effects of these behaviors in a user study, we implemented the behaviors of Table 1 in four different assistants: a virtual and a physical social character and a virtual and a physical non-social character. As a control condition, we added a text interface. All personal assistants exhibited the same level of high-level dialogue (1st behavior). The non-social character does not apply the other three types of behavior (i.e., it does *not* use natural cues, express emotions and show social competencies). Table 2 shows the relative presence of these three behaviors in the different interfaces with the corresponding positive or negative effects on the empathy and trust objectives.

4.1. Text interface

The text interface is a chat program where the experimenter asks questions and the participant answers by means of a keyboard (Fig. 1a). It is implemented in C♯ and it is the client in a TCP/IP protocol. The questions from the program appear in the upper window of the interface while the answers are typed in the lower window. By clicking the send-button the participant sends the message.

Complimentary behavior is implemented using *high-level dialogue* for complimenting the participants when they adhere well to their therapy or when they answer a question correctly. In line with the motivational interviewing skills users receive no punitive remarks when they give an incorrect answer, such as "that was wrong". The interface does not say that the participant is wrong, but simply gives the explanation of the correct answer.

4.2. Characters

We use two types of characters: the virtual (Fig. 1b) and the physical (Fig. 1c) iCat from Philips.

We use the iCat because of the ability of the iCat to express emotions (and thus be a social character). It seems that older adults are also supported socially when their caretaking abilities are addressed (Kidd et al., 2006) and there is no extra burden to communicate with the device (Kriglstein and Wallner, 2005). The iCat both addresses the caretaking and limits the burden by its ability to listen and talk.

Table 1
Relation between empathy and trust objectives with social behaviors of a computer assistant.

	Empathy			Trust
	Complimentary	Attentive	Compassionate	——
High level dialogue	X			
Natural cues		X	X	
Express/perceive emotions			X	
Social dialogue competencies				X

Table 2
Relative presence of social behaviors with the corresponding positive or negative effects on the empathy and trust objectives.

	Empathy	Trust	
	Natural cues	Express/perceive emotion	Social competencies
Social character vs. text	+ Text has no natural cues for attentiveness, the social character has	+ The social character shows emotions, the text interface does not	+ The social character is better able in making social competencies explicit (e.g., turn taking)
Non-social character vs. text	− The non-social character has negative cues for empathy (e.g., glancing past the participant)	− The non-social character shows no emotions, contrary to social conventions	− The non-social character does not behave according to social conventions
Social vs. non-social character	+ + The social character's non-verbal dialogue acts agree with social rules, the non-social au contrary	+ + The social character shows emotions, the non-social one not	+ + The social character acts according to social conventions, the social character not
Physical vs. virtual character	+ The physical character can use natural cues better, for instance, to look at someone	+ The physical character is better able to express emotions and to make them more clear	= The social competencies for the physical and virtual characters are the same

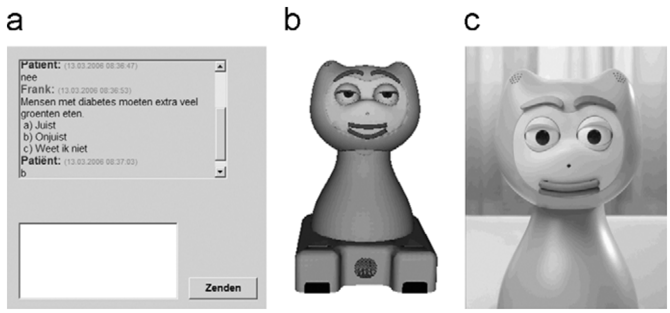

Fig. 1. Text interface (a), virtual iCat (b), and physical iCat (c).

The iCat is a plastic yellow cat with a face and a body that move to follow a person for instance. It expresses emotions by moving its lips, eyebrows, eyes, eyelids, head and body. To make its movements credible the iCat uses principles of animation (van Breemen, 2004), which are focused on making a smooth movement instead of the common machine-like behavior of characters—such as moving at constant velocity and in straight lines. Because credibility is lost when the transition between emotions is abrupt, fluent animations are important. In the iCat, a smooth transition between movements is assured by using a Transition filter (van Breemen, 2004).

The iCat has a speaker, microphones, a webcam, a proximity sensor and touch sensors. With these, it can speak, hear, see and feel. The iCat uses speech for input and output, as it has no keyboard or display. Our iCat uses the Dutch male voice from (Loquendo, 2007).

4.2.1. *Social vs. non-social characters*

The system is made to appear compassionate by implementing *emotional behavior* and *natural cues* such as happy, sad, and understanding. When happy, the character is smiling, while it shakes its head, moves its head downwards and closes its eyes a bit to show it is sad. The understanding emotion was a deep nod with an understanding "mmm" sound that came from the Loquendo text-to-speech engine library.

We implemented three different *natural cues*; looking, understanding, and listening, to make the social character appear attentive. We implemented both that the social character is looking at the participants with a listening expression and that it sometimes nods its head with or without an understanding "mmm" sound. The listening movement means open eyes and green ears to indicate its attention to the speaker.

The social character performs behaviors for all three empathy skills (be complimentary, be attentive, show compassion). In the non-social character only behavior for the complimentary skill is implemented, because this is implemented in the text it speaks. The non-social character does not express emotions, does not follow the participant with its eyes and head, and does not blink or nod. It even looks past the participant to make the non-social condition more extreme.

4.2.2. *Physical vs. virtual characters*

In the experiment the iCat is used as the physical character as well as the virtual character. The implementation of the behaviors is the same for the physical and the virtual character except for gazing towards the participant. In the social condition the physical iCat follows the participant with its head and we hoped this would be interpreted as if it was listening to the participant. In the virtual condition the iCat is positioned on the screen so that it looks to the participant.

We expect that the physical character would be experienced as a better social actor than the virtual character because of its physical presence on the table (Reeves and Nass, 1996). We think, following (Bartneck, 2003; Kidd, 2003; Wainer et al., 2006; Goetz et al., 2003), that a physical character will have a greater social facilitation effect, the tendency for people to perform simple tasks better when in the presence of others (Triplett, 1898), than a virtual character (Bartneck, 2003). Thus our hypotheses are

H1. Social characters are perceived to be more empathetic and trustworthy than a text interface. Furthermore, characters evoke more conversational behavior stimulated by the empathic behavior of the characters than the text interface.

H2. Non-social characters are found to be less empathetic and trustworthy than a text interface. Furthermore, non-social characters evoke the same amount of conversational behavior as a text interface.

H3. Social characters are found be more empathetic and trustworthy than non-social characters. Furthermore, social characters evoke more conversational behavior stimulated by the empathic behavior of the social characters.

H4. Physically present characters are found to be more empathetic than and equally trustworthy as virtual characters. Furthermore, physical characters evoke more conversational behavior stimulated by the empathic behavior of the physical characters.

5. Experiment

5.1. *The roles*

In the experiment every interface fulfilled the roles of buddy (introducing, asking about participant's well-being and showing compassion), educator (informing and asking about general health and diabetes) and motivator (asking lifestyle questions and providing feedback on desired changes). The different roles assist, by providing information and feedback, in increasing the self-help ability and motivation of users, increasing knowledge about their disease and increasing knowledge about the effects of their lifestyle on their disease.

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5.2. Wizard of Oz

The experiment was done in a Wizard of Oz setting. A Wizard of Oz experiment means that participants think they are interacting with an autonomous system, while in fact the system is partly or completely operated by the experimenter. In this experiment, participants were told they were communicating with an intelligent interface which automatically responded on their answers. In fact the experimenter followed a script with prepared texts, making sure the reactions of the interface did not differ between participants, from which the experimenter could choose dependent on the reaction of the participant (e.g., the interface reacted differently to a correct answer than on an incorrect answer). For the text interface this prepared texts appeared in a text box on the screen of the participant, while with the characters the texts were pronounced by the text-to-speech program Loquendo (Dutch male-voice Willem). The scripts also included the emotions and other movements from the iCat, such as following the participant with its head.

5.3. Method

Participants: Twenty-four non-diabetic participants took part in the experiment; twelve females and twelve males, aged 45–65 (M age = 55.04, SD = 5.74). The experiment took around 2 h.

Setting: The experiment was conducted in a room that resembled a living room. There was a table with an LCD screen, a webcam (Logitech Sphere), and a laptop on it. Only when the physical iCat was used, would it be on the table (Fig. 2). The LCD screen was used for the text interface and the virtual iCat while the laptop screen was used for the questionnaires (see below). The laptop and LCD screens were linked to each other, so that participants only needed one mouse and keyboard to use both screens. We used two screens, because research suggests that people are more likely to react positively towards a computer program when questions about the computer program are posed by the same computer on which the program runs (Reeves and Nass, 1996).

Experimental design: All participants interacted with the text interface and one other personal assistant. One group ($N = 12$) interacted with the physical iCat and the other

Fig. 2. Experimental setup.

Table 3
The different experimental conditions.

	Text	Social and non-social virtual	Social and non-social physical
Group 1	X	X	
Group 2	X		X

group ($N = 12$) worked with the virtual iCat (Table 3). The text interface was used as a baseline condition. Participants interacted with both the social and non-social character. The social/non-social variable was thus a within-subjects factor while physical/virtual was a between-subjects factor. The conditions were counter-balanced; every order of conditions was done by a female and a male participant. Hypothesis 1, 2 and 3 were thus tested with 24 participants, within subject and Hypothesis 4 was tested between subject with in each group 12 participants.

Scenarios: Three scenarios were written about diabetics with self-care problems. The scenarios describe a situation typical for a diabetic patient, which were derived from a domain analysis (De Haan et al., 2005; Kuijten, 2006). The scenarios were given in the same order to every participant, but the order of the experimental conditions was varied. The scenarios all started with a short introduction on the situation of the patient. The first scenario focused on a 62-year-old diabetic with problems adhering to the diet, the second scenario was about a 56-year old patient who is reluctant to perform the feet self-checks regularly, and the third scenario involved a patient of 43 who regularly forgets to take his medication. In each scenario, the "physician" (the experimenter) asked the "patient" (the participant) to try out a personal assistant for a week. It was explained to the patients that the assistant would ask them questions about their health and diabetes on Monday, Wednesday, Friday, and Sunday. For each day there was short scenario which explained what the participant did the rest of the day and the next day. In reality a session took about half an hour.

Questions: A block consisted of eight questions: four open questions informing about the health of the patient and four multiple choice questions on diabetes. Before and after the block the personal assistant greeted the user. To test for an effect of the personal assistants on learning rates, three of the four multiple choice questions concerned the same diabetes facts as in other blocks.

The formulation of the questions and of the reactions on the participants' responses was based on motivational interviewing. Examples of health questions are as following: "How are you feeling today?" and "What is your blood glucose level?" The reaction of the personal assistant was attuned to the answer of the participant: if the participant was optimistic about his/her health, the interface said it was happy for the participant. To participants in the social condition, the iCat showed a facial expression in line with its verbal reaction.

Examples of multiple choice questions on diabetes were: ''Is a blood glucose level of 8 healthy? (A) yes, (B) no, (C) I do not know'', ''Should diabetics eat a lot of sugar? (A) yes, (B) no, (C) I do not know.'' In line with motivational interviewing, if the answer was wrong the interface did not say that the participant was wrong, but gave the explanation of the correct answer. If the participant gave the correct answer, the interface said the participant was correct and explained why the answer was correct. When the interface was social it showed a happy or neutral expression depending on whether the answer was correct or not.

There were thus four blocks of questions; in between every block there was a short break in which participants read a short story about what the patient did during the day in this break.

Measures: To test the hypotheses, we used several subjective and behavioral measures. We measured to what extent participants perceived the personal assistants as empathic and trustworthy actors, and to what extent the participants treated the personal assistant as a social actor.

- Personality
  The participants' personality was measured with a short personality questionnaire (15 items). The personality questionnaire was based on the Big-Five questionnaire (Goldberg, 1992). The Big-Five assumes five important personality traits: extroversion, openness to experience, emotional stability, agreeableness and conscientiousness. We used a shorter version of this questionnaire that consisted of fifteen items on a 9-point Likert scale which were divided in five groups of three items. This smaller version of the Big-Five was validated at TNO (Van Vliet, 2001).
- Conversational behavior
  We recorded the face of the participant with a webcam (Logitech Sphere) during the experiment. The video data were scored offline on four variables for behavior towards the personal assistant that indicated heightened involvement with the assistant:
  - Talking: The percentage of the total interaction time that participants were talking or typing with the personal assistant. Also, how many words were used, formal or informal word use and the number of positive and negative utterances were measured.
  - Looking: The percentage of total interaction time that the participant looked at the assistant. This was only measured when the participant was working with one of the characters.
  - Laughing: How many times the participant laughed or smiled during the interaction.
  - Goodbye: How many times the participant said goodbye during the interaction. Saying goodbye is an act of politeness and therefore shows that a participant sees the interface as a social entity.

Table 4
Overview of questionnaires and items used in the experiment.

	Nr. of questions	Answer possibility (nr. of questions)
Users personality	15	9-point Likert scale (15)
Empathetic abilities	14	5-point Likert scale (14)
Social personality	15	9-point Likert scale (15)
Acceptance	16	5-point Likert scale (16)
Trust	4	5-point Likert scale (4)
Overall	9	5-point Likert scale (3)
		Choice (4)
		Yes/no (1)
		Open (1)

- Questionnaires (Table 4)
  - Empathic abilities: We measured empathic abilities of the interfaces with a 14-item questionnaire. Participants had to rate the personal assistants on the ability to express empathy on a 5-point Likert scale. Items included: ''did the assistant look at you?'', ''how friendly did the personal assistant appear to you?'' The items were based on items of the Social Behavior Questionnaire (SBQ) (de Ruyter et al., 2005).
  - Social personality of personal assistants: The same personality questionnaire that was filled out by the participants about themselves was given to the participants to fill out for the personal assistants. The higher the overall score the more social and empathetic the personal assistant was perceived.
  - Trust: To assess how trustworthy participants rate the personal assistants, we used four items, on a 5-point Likert scale, about level of trust, credibility, intelligence and expertise. These items were also based on items of the SBQ (de Ruyter et al., 2005).
  - Acceptance: To measure the acceptance level of the personal assistants a shortened version of the Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire (Venkatesh et al., 2003) was used. The questionnaire uses a 5-point Likert scale. We translated this questionnaire into Dutch and made it shorter (16 items). The UTAUT was originally developed for technology acceptance at work and therefore specific work-related questions were excluded in this experiment. We did include the questions about performance of the assistant, effort that was needed, attitude towards the assistant, anxiety, and behavioral intention. The UTAUT gives information about the trustworthiness of the assistant.
  - Overall: Participants were asked to rate the personal assistants: would they use a personal assistant if they had diabetes (yes/no), how much did they like each personal assistant (5-point Likert scale), which personal assistant did they find the most reliable/believable/professional (choice between the three assistants), which personal assistant's dialogue did they prefer (choice between the three assistants).

We also asked for general remarks about the assistants (open question). In total this questionnaire consisted of nine items.

Procedure: Each participant was explained that the goal of the experiment was to determine which personal assistant they would like to use if they had diabetes. It was emphasized that the personal assistants were specifically designed to ask questions on health and diabetes and react to the answers of those questions, but were not able to do more. Participants were told they would work with three different personal assistants and with each; they would receive four blocks of questions. Prior to interacting with a personal assistant they would receive a scenario about a diabetic with whom they had to identify.

The experimental session started with a questionnaire about personal data and the personality questionnaire. To give all participants some knowledge about diabetes, they were shown an animation of about 3 min about diabetes, made by a student, and a short movie of 12 min, which was a shortened version of an educational video about diabetes. They also received information from the experimenter about the (low level of) treatment adherence in diabetics.

The participants read 3 different scenarios about a diabetic patient. The scenarios were given to every participant in the same order. The scenarios stated that a patient had to test the assistant for a week.

The experimental session was started by the personal assistant who started asking some general questions, so participants could get used to the personal assistant. If the iCat was used, participants were explained they could ask the iCat to repeat the last sentence when they had difficulty understanding it. At the end of each "day" participants read short stories about what the subject of the scenario did during the day. They finished the "week" after the fourth block of questions. The participants were then asked to fill out the three questionnaires about the personal assistant.

After the three scenarios were completed, participants were asked to fill out a last questionnaire about their overall opinion of the three personal assistants.

Data analysis: The means of the items on the Likert scale questionnaires were analyzed with a Mann-Whitney U statistical test. The mean results of the video analysis of the conversational behavior were analyzed with a *T*-test and the means of the Likert scale items of the overall questionnaire were analyzed with a Friedmann Anova. Furthermore, a Spearman rank order test was performed for correlations between the questionnaires. We decided not to test for learning effect of the diabetes questions, because it was found that most participants answered all the questions correctly from the start.

5.4. Results experiment

This section reports first the results that were statistically significant ($p<0{,}05$) for the hypotheses we formulated at the outset. All analyses were done, but to be more concise we will only report the statistical significant results. This will be followed by a correlation analysis to explore possible relationships between variables.

Hypotheses:

- *Social characters* vs. *text*: The expectation was that the social characters would be rated higher on empathy and trust, and evoke more conversational behavior.

  Table 5 summarizes the results for this hypothesis. The social character was rated higher on the Social Personality questionnaire for the items Warm, Creative, Talkative, Original, Spontaneous and Artistic. In addition, it induced more social behavior from the participants than the text interface: Looking, Laughing and Goodbye; they also really felt that the character was looking at them (4.5 on scale 1–5). The percentage time of the dialogue was higher for the text interface, but did not include more content. Participants talked/typed more when they were using the text interface compared with the character. In the overall questionnaire we asked the participants if they would use a personal assistant when they would need one: 87.5% said they would use one. About half of them preferred to use the text interface while the other half preferred a social iCat.
- *Non-social characters* vs. *text*: We expected the text interface to score higher on empathy and trust.

  Table 6 summarizes the results for this hypothesis. The text interface was indeed rated higher on two acceptance questions: the items Pleasant and Home use. At evoking social behavior the text interface scored significantly lower on looking and saying goodbye. The typing time was significantly higher for the text interface; this is negative for the text interface because it did not contain more content. The overall questionnaire showed that the text assistant was perceived as a better personal assistant than the non-social character.
- *Social* vs. *non-social characters*: We had expected that the social character would score higher on empathy and trust, and evoke more conversational behavior.

  Results (Table 7) show that the social character did indeed score higher than the non-social character on items from the Empathy questionnaire (Looking and Friendly), Social Personality (Creative) and Acceptance (Pleasant). The social character did also evoke more conversational behavior than the non-social character (Laughing and Looking). Moreover, the social character overall questionnaire showed that the social assistant was perceived as a better personal assistant. In general, there were more significant differences between the social and non-social characters than both between the virtual and the physical character and between the text and characters: seven items showed significant differences (Table 7).
- *Physical* vs. *virtual characters*: We expected that the physical characters would be rated higher on empathy and evoke more conversational behavior.

Table 5
The means of text and social characters on items that showed a significant difference.

Questionnaire (nr. of questions)	Question (scale)	Mean social characters	Mean text	Test significance
Social personality (15)	Warm (1–9)	6.4	4.9	Mann-Whitney U $p<0.02$
	Creative (1–9)	6.2	4.2	Mann-Whitney U $p<0.01$
	Talkative (1–9)	6.8	5.4	Mann-Whitney U $p<0.05$
	Original (1–9)	6.3	4.8	Mann-Whitney U $p<0.02$
	Spontaneous (1–9)	6.3	5.2	Mann-Whitney U $p<0.05$
	Artistic (1–9)	5.5	3.6	Mann-Whitney U $p<0.01$
Conversational behavior (4)	Looking (%)	53.3	0	T-test $p<0.001$
	Talk/typing (%)	6.8	17.2	T-test $p<0.001$
	Laughing (nr.)	4.0	1	T-test $p<0.01$
	Goodbye (nr.)	0.9	0	T-test $p<0.01$

The higher the value the more positive the tested aspect was assessed (with exception of talk/typing).

Table 6
The means of text and non-social characters on items that showed a significant difference.

Questionnaire (nr. of questions)	Question (scale)	Mean non-social characters	Mean text	Test significance
Acceptance (16)	Pleasant (1–5)	3.2	3.9	Mann-Whitney U $p<0.05$
	Home use (1–5)	3.1	3.9	Mann-Whitney U $p<0.05$
Conversational behavior (4)	Looking (%)	29.8	0	T-test $p<0.001$
	Talk/typing (%)	7.3	17.2	T-test $p<0.001$
	Goodbye (nr.)	0.7	0	T-test $p<0.001$
Overall (3)	Good (1–5)	3.2	3.8	Sign test $p<0.05$

The higher the value the more positive the tested aspect was assessed.

Table 7
The means of social and non-social characters on items that showed a significant difference.

Questionnaire (nr. of questions)	Question (scale)	Social	Non-social	Test significance
Empathy (14)	Looking (1–5)	4.5	2.0	Mann-Whitney U $p<0.01$
	Friendly (1–5)	4.7	3.9	Mann-Whitney U $p<0.05$
Conversational behavior (4)	Laughing (Nr.)	4.2	1.4	T-test $p<0.05$
	Looking (%)	59.9	37.8	T-test $p<0.05$
Social personality (15)	Creative (1–9)	6.13	4.2	Mann-Whitney U $p<0.01$
Acceptance (16)	Pleasant (1–5)	3.9	3.2	Mann-Whitney U $p<0.05$
Overall (3)	Good (1–5)	3.9	3.2	Sign test $p<0.01$

The higher the value the more positive the tested aspect was assessed.

Table 8
The means of physical and virtual characters on items that showed a significant difference.

Questionnaire (nr. of questions)	Question (scale)	Physical	Virtual	Test significance
Social personality (15)	Satisfied (1–9)	6.4	7.5	Mann-Whitney U $p<0.05$
	Kind (1–9)	6.5	7.8	Mann-Whitney U $p<0.01$
	Friendly (1–9)	7.1	7.9	Mann-Whitney U $p<0.05$
Trust (4)	Intelligent (1–5)	3.7	2.9	Mann-Whitney U $p<0.05$

The higher the value the more positive the tested aspect was assessed.

Table 8 summarizes the results for this hypothesis. In contrast, the items Satisfied, Kind and Friendly, showed significant higher values for the virtual character (a between-subjects factor). On intelligence, a question of the trust questionnaire, the physical character scored significantly higher than the virtual characters.

Other results:

To see if the behaviors were correlated, we correlated the different questionnaires for empathy, personality, trust, acceptance, and behaviors. All items on the questionnaires were positively correlated (Table 9). Furthermore, the conversational behaviors were

Table 9
Correlation matrix of the questionnaires.

Questionnaire (nr. of questions)	Empathy	Personality	Trust	Acceptance	Behaviors
Empathy (14)	1	0.63*	0.60*	0.53*	0.30*
Social personality (15)	0.63*	1	0.35*	0.36*	0.38*
Trust (4)	0.60*	0.35*	1	0.60*	0.20
Acceptance (16)	0.53*	0.36*	0.55*	1	−0.02
Behaviors (4)	0.30*	0.38*	0.20	−0.02	1

* $= p < 0.02$.

positively correlated to the empathy and personality questionnaires.

Next to this we found a correlation between the personality of the participant and the personal assistant of their choice. The more conscientious someone rated him/herself in the personality questionnaire the less he/she liked the social iCat. The Spearman rank order correlation, with pair wise deletion, showed that there was a correlation (−0.447) between conscientiousness of the participant and how much the social character was liked.

6. Conclusion and discussion

In this study, our aim was to find behavior for an electronic personal assistant that improves the self-care capabilities of older adults. The psychological method of "motivational interviewing" provides a sound basis to persuade adults to behave healthy. Based on this method and recent research on affective computing, we derived two objectives of a persuasive assistant, to show empathy and establish trust, and found four social behaviors that could be mapped onto these objectives: high-level dialogue, natural cues, use of emotions, and social dialogue competencies. As far as possible, these behaviors were implemented in three assistants – a (classical) text interface, virtual character and a physical character – incorporating, increasingly natural, social behavior.

The results of our experiment partially supported three of the four hypotheses on the positive effects of these behaviors. First, the social characters were found to be more empathetic than the text interface, and the characters evoked more conversational behavior, both as expected. It should be noted that typing with the text interface took substantially more time (more than twice) than talking with the character without increasing the content. In this experimental setting the participants were inclined to make the effort, but it is unclear whether they will still do so with long-term use. Speech, as implemented in the character interfaces, removes some hindrances that older adults might experience when they use classical input devices such as keyboard and mouse. Regarding the second hypothesis, the non-social characters were perceived as less trustworthy than a text interface, and were appreciated less, exactly as we expected. Regarding the third hypothesis, social characters were perceived as more empathetic and trustworthy than non-social characters, and evoked more conversational behavior, also as expected. The non-social physical iCat was seen as annoying by the participants, because it ignored them (e.g., looked past them) and in that way ignored conversational conventions. This indicates that it is of utmost importance that behaviors are social behaviors, because otherwise the behaviors are contra-productive. Regarding the fourth hypothesis, the physical characters were indeed found to be more trustworthy but less empathic than the virtual character, which was not expected (cf. (Lee et al., 2006), who found little differences between virtual and embodied characters). This negative outcome on empathy might be due to specific constraints of the iCat: it makes relatively much noise when it moves, and the head and body movements are perhaps not fluent enough. Another technical constraint was the (occasionally) appearing of errors in the movements and speech, such as skipping choices of the multiple choice questions. Furthermore, it may be that our three character roles did not capture important advantages of a physical character that can act in the real environment. For instance, more positive outcomes might show up with a character that helps to attend to a medicine box with a specific location in house, compared to a virtual character that is not a real actor in this house (c.f. Shinozawa et al., 2005).

It was promising to notice that almost 90% of our participants asserted that they would use a personal assistant if they needed one, and that the iCat and text interface were equally preferred (both 50%). It seemed that conscientious persons particularly prefer a text interface. Furthermore, it was promising that most participants had no trouble learning to interact with the iCat assistants, perhaps indicating that there may be little hindrances to make use of the iCat for older adults. The dialogue should be made more varied in the next version, both for the text and character interfaces: participants who disliked the assistant thought it was repeating too many questions and gave too often similar responses. By using a speaking and hearing, emotional, physical character in this experiment, we choose for the most "natural" human-character communication and compared it with a conventional text chat. Subsequent experiments should study more in detail what the costs and benefits are of the different modality choices.

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Daily health self-management, such as the harmonization of food, exercise and medication, is a major problem for a large group of older adults with obesity or diabetics. Persuasive assistants that are emphatic and trustworthy may help solve this problem if they apply principles from the psychological method of "motivational interviewing". Although our experiment was limited in its methodology by the fact that we used healthy people rather than unhealthy people, it provided at least partial evidence that applying these principles might indeed be a fruitful approach. An experiment using the virtual iCat with people with obesity provided further support for this approach (Blanson-Henkemans et al., 2009). In this experiment, patients with obesity used either a web interface with the proposed – virtual-iCat mediated – motivational support or without. The support resulted in better adherence to the personal goals for diet, exercises and diary-notations, and a significant improvement of the body mass index.

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