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Social support agents for older adults: longitudinal affective computing in the home

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Abstract Loneliness and social isolation are significant problems in older adult populations. We describe the design of a multimodal conversational agent-based system designed to provide longitudinal social support to isolated older adults. Results from a requirements analysis study and a remote "Wizard-of-Oz" study are presented that inform the design of the autonomous social support agent. An exploratory pilot study was conducted in which the agent was placed in the homes of 14 older adults for a week. Results indicate high levels of acceptance and satisfaction of the system. Results also indicate that when the agent proactively draws elders into interactions, triggered by a motion sensor, it is more effective at addressing loneliness than when the agent passively relies upon elders to initiate interactions. We discuss future research opportunities for affective computing to address this important societal problem.

Keywords Affective computing · Older adults · ECA · Social interfaces

1 Introduction

Loneliness among older adults represents a significant societal problem, and an important application domain for affective computing. Fully 40 % of older adults experience loneliness [16], and this has been linked with a variety of health problems, including increased risk of cardiovascular disease and death [29]. Loneliness also represents an important application domain for affective computing, since loneliness represents an affective response to social isolation. Automated systems that could identify and intervene on loneliness in older adults could have a significant positive impact on society, especially given the aging of populations in the world: the worldwide population of adults aged 65 and older is projected to triple to 1.5 billion in 2050, according to the World Health Organization.

Social isolation represents a related problem in the elderly, and another opportunity for affectively intelligent systems that provide companionship and social support. One study found that 5-year mortality is three times higher for elders who are socially isolated [25]. Several studies have also shown that the perception of social support can benefit health beyond actual received support [16].

Conversational agents designed to provide social support and wellness counseling—when coupled with the ability to sense and manage user affect and mood-represent a promising technology that has the potential halt the trend of early loss of independence, illness, and death among the elderly. In this paper we report on a series of exploratory design studies we have conducted over the last year on a conversational agent developed to provide social support and wellness counseling to isolated older adults in their homes, for extended periods of time (months or years).

Although many studies have now been conducted on the accuracy of affect detection methods [9], and a few studies have shown short-term efficacy in incorporating user affect into practical applications, such as in tutoring systems [17], the "killer application" for affective computing has yet to be found. We believe that social support systems for older adults

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may represent such an application, in which affect detection and management is not only important, but also could be instrumental in saving lives by intervening on extreme isolation [25] and affective disorders (e.g. depression) that have been linked to increased morality rates.

2 Managing loneliness in older adults

There are at least three approaches a live-in conversational agent could take in managing loneliness for older adults. First, agents could directly provide companionship and the perception of social support, by its mere presence and through social interaction (e.g., "small talk" [2]), but by providing a wide range of social activities that it could conduct with the elder, such as game play. Second, agents can address isolation by helping elders to stay connected with friends and relatives via electronic communication, visit and chat coordination, and proactive prosocial behavior change interventions to establish and maintain friendships. Third, conversational agents can directly intervene on loneliness, depression, and other mood disorders, through talk therapy, ranging from simple active listening skills [22], to full-blown cognitive behavioral therapy [12], to the buffering effects of positive psychology interventions [37] for psychosocial longevity [38]. Physical activity is often prescribed for individuals with depression and other mental health conditions, thus an agent that promotes exercise should also indirectly improve mood [8]. Only 12 % of adults in the US over the age of 75 get the minimum level of physical activity currently recommended by the US Centers for Disease Control and Prevention, and 65 % report no leisure time activity [8], and lack of physical activity has a significant impact on mortality in this age group [8].

3 Related work

We briefly review prior work on embodied conversational agents designed for older adults, agent-based systems that provide social support for older adults, and systems designed to provide automated mood and affect management.

3.1 Embodied conversational agents for older adults

Embodied conversational agents (ECAs) are animated computer characters that act like humans in both appearance and behavior. Designed for face-to-face conversations, ECAs interact with users through verbal and non-verbal behavior cues such as prosody and hand gestures [10]. Bickmore et al. [6,7] investigated exercise promotion in older adults through the use of an ECA that played the role of a virtual exercise coach. In a randomized controlled trial where both groups wore a pedometer for 2 months, one group interacted with the virtual exercise coach that was able to read and respond to the pedometer. The results of this study showed increased physical activity for participants who used the virtual exercise coach, however the effect diminished when the coach was removed suggesting that further research is needed to cause long term behavior change.

The longitudinal use of ECAs has also been explored. Bickmore et al. [5] created a virtual laboratory to study user reactions to ECAs in a longitudinal setting. In this virtual laboratory elderly participants interacted with an ECA acting as an exercise coach from their home once a day for up to 120 days. Results showed that users who interacted with an ECA that used variable dialogue exercised significantly more than those interacting with an ECA with non-variable dialogue, and those who interacted with a virtual coach that presented itself as a person (with a "backstory") used the coach significantly more [4].

3.2 Agents for social support in older adults

There have been a few preliminary studies on the use of agents to provide social support for older adults. Mival et al. [28] used AIBO, a robotic dog, in the UTOPIA project (Usable Technology for Older People: Inclusive and Appropriate) to provide artificial companionship for older adults. Using a Wizard of Oz setup, AIBO spoke to participants during a chess game to provide companionship. Their findings suggested that in order "to form a relationship, the user needs to care about the interaction, to invest emotion in it".

3.3 Mood: longitudinal affective computing

Loneliness is an example of a mood-an affective state that differs from emotion in duration and intensity [24]. Whereas emotions last only a matter of seconds (from initial perception and reaction to decay), moods can last hours or days. Moods are also usually perceived to be less intense than emotions and are generally less-specific [36]. Most researchers categorize mood using Russell and Posner's circumplex model of affect, which classifies affective state (including mood) in terms of valence and arousal [30].

3.4 Agents that manage user mood

The CASPER affect-management agent developed by Klein, was demonstrated to provide relief to users experiencing frustration [22]. The system presented a frustrated user with a series of menus that prompted the user to describe their affective state, provided paraphrased feedback, allowed users to repair the computer's assessment and provided empathetic and sympathetic feedback. This agent was found to be significantly better than a venting-only agent (to which users

could simply describe how they felt in an open-ended manner without feedback), or an agent that ignored their emotions completely, in relieving frustration, as measured by both self-report and the length of time they were willing to continue working with a computer after a frustrating experience. Bickmore and Schulman [3] conducted a similar study in which they demonstrated that empathic accuracy was more important than user expressivity in empathic exchanges with an agent for alleviating frustration. However, both of these systems were designed to address brief affective states (frustration), and were not evaluated with older adults.

Of the many computerized interventions developed to treat depression, only two have been conversational [26]. "Overcoming Depression" features a typed text dialogue interaction with a virtual therapist, but the only evaluation study was inconclusive. "Cope" is a phone-based (IVR) dialogue system evaluated in two clinical trials in the US and UK. Although the trials were quasi-experimental, they both demonstrated that the intervention was effective at improving mood and social adjustment.

4 Design methodology

To better understand how to design an in-home embodied conversational agent for social support we conducted a series of design studies. In these studies we explored how older adults interacted with existing support systems, what topics they would want to talk to an in-home agent about, and how their affective state changed across multiple interactions with a simulated system.

4.1 Understanding existing support systems

The first step we took towards building an in-home embodied conversational agent for social support was to look at its human equivalent: volunteer social support workers [39]. We collaborated with a Boston-based non-profit organization that manages a network of trained social support volunteers who provided weekly visitation for isolated older adults. Members of our research staff became familiar with their existing systems by participating in their training and orientation program. After receiving this training our research staff interviewed four volunteer staff members and accompanied two staff members for in-home visits to one of their clients.

We found the majority of visitation time consisted of the volunteer listening to the older adult, with storytelling by the elder taking up the majority of the interaction. Besides storytelling, discussions focused around small talk (such as the weather), what was on the television, recent events, sports, future plans and the older adult's health. These reports were further confirmed during the two visitations done by our trained research staff.

Table 1 Top conversational topics between agent and participants

Topic	Num. of participants (out of 12)	Average duration (s)
Family	11	150.02
Weather	11	40.23
Storytelling	10	161.71
Future plans	9	53.39
About the agent	8	67.67

4.2 The Wizard of Oz agent

In order to better assess acceptance of a companion agent by isolated older adults, and to characterize the topics they would want to talk to an agent about, we developed a remote "Wizard of Oz" experiment [14,39]. We developed an ECA that could be deployed in the home of an older adult, and remote controlled by an experimenter who listened to the elder speaking. In order to avoid biasing the topics that the elder wanted to discuss, we allowed the elder to speak to the agent, with a webcam and microphone, permitting the experimenter to see and hear the elder's side of the conversation. To control the ECA the experimenter used a control panel that allowed them to give verbal and non-verbal commands to the agent in real time.

Twelve older adults (10 female, aged 56–73, $m = 62$) were recruited for the study via an online job recruiting site. Each had the agent system installed in their home for one week, and could talk to the agent each day as long as they wanted within a scheduled time window. We found that participants had an average of 3.5 conversations with the agent over the course of the week, with each conversation lasting an average of 28.3 min (range 2 min to 2 h). A qualitative analysis of transcripts from these interactions was then conducted to identify the primary topics the older adult discussed with the agent. We found that discussions of family, weather, future planning and storytelling were most commonly discussed with the agent, with more than half the participants talking about these topics (see Table 1). Attitudes toward the agent were also assessed via a debrief questionnaire in which participants reported high levels of satisfaction with the system (6.0 on a 1–7 scale) and a strong desire to continue interacting with the agent at the end of the week-long study.

4.3 Longitudinal changes in affect

To better understand how the affective state of older adults changed across their interactions with the agent, a secondary analysis of the data collected from the Wizard of Oz study was conducted using the video recordings of the elder/agent interactions [31]. For this analysis three research assistants coded two-minute segments at the beginning, middle and end

of fifteen conversations for valence and arousal. We demonstrated high inter-rater reliability in the assessments of the elders' affective state, indicating the feasibility of automatically assessing mood using speech and audio input, inline with previous emotion detection work [19]. We also demonstrated that a significant portion of the variance found in the elders' affective state could not be accounted for by either inter-subject or intra-conversation variance-i.e., that a stable inter-conversation factor of "mood" contributed to observed changes in coded affect.

5 A conversational agent to provide social support to older adult

Based on the results of our design studies, we developed a multimodal fully autonomous embodied conversational agent for isolated older adults, to explore techniques of providing automated social support over extended periods of time. Developed for use within a participant's home via a touchscreen computer, the animated agent (Fig. 1) emulates human conversational behavior through the use of synthesized voice and synchronized non-verbal behavior such as hand gestures, head nods, posture shifts, and facial displays of affect, generated using BEAT [11]. A touch based interface was used instead of a speech based one due to the difficulties most automatic speech recognition systems have with understanding older adults [40], and our positive experience in using touch screen-based dialogue systems with older adults [6,7].

User contributions to the conversation were made via multiple-choice menus of utterances, updated at each turn of conversation. When a user selected an utterance on the screen, the agent would acknowledge their input with a head nod and then speak using synthetic speech and accompanying nonverbal conversational behavior in its response to the user.

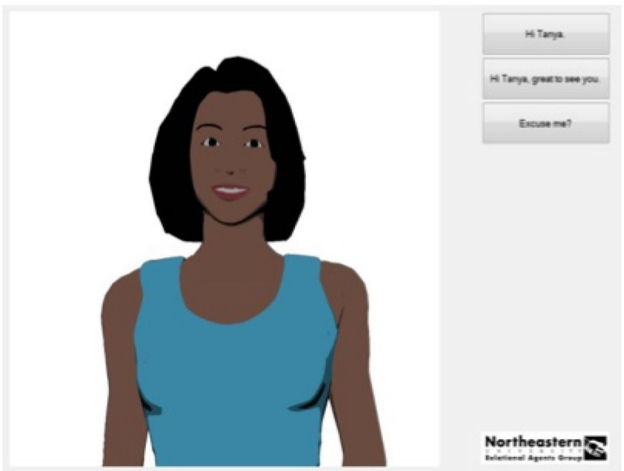

Fig. 1 Screenshot of agent interaction

The dialogue content of the system was designed specifically for isolated older adults based on the approaches outlined in Sect. 2.

Companionship and Social Support: The agent assesses the elder's affective state at the beginning of every conversation via dialogue ("How are you?"), and provides appropriate empathetic feedback. The agent engages elders in brief chat for social support, and talks about a local sports to try and build a sense of companionship. *Loneliness and Depressive Symptom Interventions:* Short anecdotal stories were designed to encourage positive affect. Motivational dialogue designed to promote physical activity (walking) was also included to help combat stress and symptoms of depression.

As an initial exploration into the design of an in-home conversational agent that could provide social support, we developed two versions of the system: Passive and Proactive. In the Passive system, conversations with the agent have to be initiated by the older adult by touching an option on the touchscreen, whereas in the Proactive version, the agent can detect when the older adult walks by the system via a motion sensor and attempts to initiate a conversation by verbally greeting them. We used a Kadtronix USB Plug-n-Play Motion Detector attached to the touch screen monitor to detect motion. To ensure that the Proactive system did not disrupt sleep due to false alarms, it was only activated from 9 a.m. to 9 p.m. every day. In addition, to prevent repetition fatigue, the agent would only attempt to start a conversation with the user at most once a minute. However, the participant was able to start a conversation with the Proactive agent at any time by touching the screen.

6 Study design

To test the acceptance and effectiveness of our system we conducted a between-subjects longitudinal experiment to assess the effects of the Proactive (Sensor) and Passive (Non Sensor) system on the loneliness of isolated older adults. To assess acceptance in the everyday lives of our target population, we put the agent in the homes of participants-all older adults living alone for one week at a time. Measurements were taken at the beginning and end of the week, during each conversation with the agent (from log files), and following each conversation (via a diary we provided to participants). We hypothesized that:

- H1: Isolated older adults will use the Proactive version of the system significantly more than Passive version.

- H2: Isolated older adults will be significantly more satisfied with the Proactive version of the system compared to a Passive version.
- H3: Isolated older adults will be significantly less lonely after interacting with the Proactive version of the system compared to the Passive version after interacting with it for a week.

6.1 Measures

Quantitative measures included:
Loneliness: Loneliness was assessed at the beginning and end of the intervention with the UCLA Loneliness Scale; the most widely used self-report measure of loneliness [32].
Affective State, State Loneliness, Satisfaction with Agent, Relationship Status and Comfort Using Agent: All measurements were assessed using 5 point self-report scale measures (Table 3) in the diary that participants were asked to complete following each conversation with the agent.
Open-Ended Feedback: Feedback was collected following each conversation via the diary, and at the end of the week-long study via a semi-structured interview.

6.2 Method

Participants were recruited via an online advertisement. To be eligible, participant's had to be at least 55 years old, live alone, and not exhibit significant depressive symptoms (must score below 3 (positive for major depression) on the PHQ2 2-item depression scale [23]). Following informed consent and screening, eligible participants went on to schedule a time for the system to be set up and collected from their home.

A research assistant then travelled to participant's homes to install the touch screen computer, have participants fill out intake questionnaires, and provide participants with a stack of diary sheets. Participants were then given a brief tutorial on how to interact with the system and instructed to interact with the system as frequently as they wanted over the course of the week. At the end of the week the research assistant returned to collect the system, administer the debrief questionnaires, and conduct the semi-structured interview.

7 Results

Fourteen participants (3 male, 11 female, aged 56–75, $m = 65$, all regular computer users) were recruited for the study (7 for the sensor condition, 7 for non-sensor condition) via an online job recruiting site, with 12 (1 male, 11 female) being eligible for participation (one excluded due to technical issues with the system, and one excluded due to mental illness, both from the non-sensor condition). System logs were coded and stored after each system returned from the participant's home and were analyzed along with intake/debrief forms and diaries.

Table 2 Average frequency, duration, and change in UCLA loneliness scores between proactive and passive conditions

	Proactive	Passive
Frequency	18 (5.67)	13.8 (9.14)
Duration	135.57 (21.42)	135 (20.58)
Change in UCLA Loneliness Score		
Lower is lonelier	3.57 (6.1)	−.8 (2.77)

7.1 Acceptance and use

Overall, the agent was very well received, with participants conducting 15.9 (SD 8.1) interactions per week on average, lasting an average of 140 (SD 26) seconds each. Post-test Satisfaction was rated 4.4 (SD 2.3) on a scale of 1 (very unsatisfied) to 7 (very satisfied), and Ease of Use was rated 1.9 (SD 1.5) on a scale of 1 (very easy) to 7 (very difficult).

7.2 Quantitative between-subjects results

There were no significant differences between Passive and Proactive groups on frequency ($t(12) = -0.91$, $p = 0.4$) or duration ($t(12) = -0.05$, $p = 0.96$) of interactions participants with the agent (Table 2). Thus H1 was not supported.

However, there was a trend for participants in the Proactive group to have a greater reduction in loneliness over the week compared to participants in the Passive group, $t(12) = -1.67$, $p = 0.13$. We also found a significant correlation between change in Loneliness over the week and the average time spent interacting with the agent, Pearson $r = 0.7$, $p < .05$, in which participants who interacted with the agent longer reported feeling less lonely at the end of the study.

Analysis of diary data indicated a significant correlation between the number of times participants interacted with the agent and how comfortable they were with her, in which the more they interacted with her the more comfortable they became, Pearson $r = 0.40$, $p < .05$. We also found a correlation between participants' reported relationship with the agent and the number of interactions they had with her, Pearson $r = 0.2$, $p < .05$. This is evidence that participants grow more accepting of the agent over time. We additionally found a significant relationship between the reported satisfaction of the interaction and the time of day showing that participants enjoyed talking to the agent more in the morning than they did in the afternoon or evening, one-way ANOVA $F(2,151) = 2.56$, $p < .1$. Finally, correlations trending towards significance between the frequency and duration of conversations with the agent and State Loneliness reported in the diary ($p < .1$ for both) were also found. These relationships

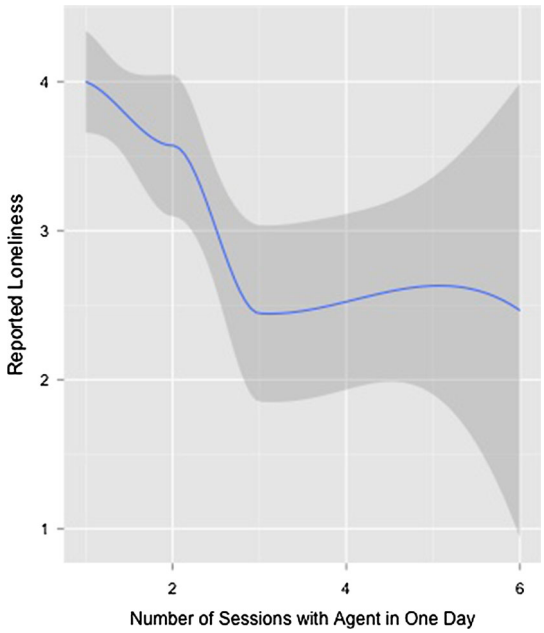

Fig. 2 Reported loneliness vs. the number of sessions participants interacted with the agent (lower loneliness score is better)

Table 3 Comparison between diary measures between sensor and non sensor conditions (reported mean and standard deviation)

Diary measure (*Likert Scales*)	Proactive	Passive
Comfort		
1-Very uncomfortable	4.59 (.8)	4.33 (.85)
5-Very comfortable		
Happiness		
1-Very sad	3.89 (.9)	3.26 (1.17)
5-Very happy		
Loneliness		
1-Very lonely	4.02 (.87)	3.54 (1)
5-Not at all lonely		

showed that lonelier participants talked with the agent more times each day, and the longer they talked with it the agent the less lonely they reported feeling (Fig. 2).

Upon comparing the Proactive and Passive conditions averaged across all interactions per participant using a repeated measures ANOVA, significant differences were found in reported loneliness, happiness and comfort between the two conditions (Table 3). When interacting with the Proactive version of the system, participants reported feeling less lonely $F(1,150) = 7.713$, $p < .01$, happier $F(1,150) = 17.05$, $p < .01$ and more comfortable talking with the agent $F(1,150) = 3.783$, $p < .1$) compared to the Passive version. These results show that proactive engagement by the agent significantly decreased loneliness and improved the affective response towards the system.

7.3 Qualitative results

Qualitative analysis was conducted using the grounded theory method [13] of inductive coding to discover relevant themes in debrief interview transcripts and diary texts. A list of pervasive themes and correlations between participant transcripts was reached by consensus of the research team. The top two themes across participants and with the highest frequency of utterances were Affective State and Social Support. Affective state includes all utterances of emotional valence about a specific interaction with the agent or presence of the agent. Social support includes all utterances by participants about the supportive role of the agent, position of the agent in their social network, and feelings of personal connection to the agent.

7.3.1 Affective state

An additional level of analysis of affective state was accomplished by inductive coding using Ekman's expanded list of emotions (amusement, anger, contempt, contentment, disgust, embarrassment, excitement, fear, guilt, happiness, pride, relief, sadness, satisfaction, sensory pleasure, surprise and shame) [18] and Fredrickson's categories of positive affect (amusement, awe, feeling cared for, inspiration, joy, pride, serenity) [20] (Table 4). Affective responses were induced either by specific dialogue content, such as by amusing stories, or as reactions to agent behavior or the perceived personality of the agent. Participants appreciated when the agent provided content they could relate to and induced positive affect through humor, comforting statements and exercise encouragement. Humor or amusement, which can be employed to cope with life stressors [27], was a recurring theme in transcripts with 4 of 12 participants specifically mentioning a funny story they remembered hearing from the agent during the week. When the agent's topics were perceived as irrelevant or repetitive users were angry with the agent, as one might imagine being angry at a friend who does not listen or only talks about his or her own interests.

7.3.2 Social support

Social support utterances were re-coded to uncover subthemes. Dominant sub-themes were prosocial, friendship, and comforting presence utterances (Table 5). One unexpected sub-theme was judgment of the agent's personality

Social support by the agent was considered personified by 8 of 12 users as 1:1 relationship in which the agent acted as a friend, an exercise buddy, a presence akin to a pet, or a helpful reliever of solitude and inactive time. Among all 12 participants, 9 employed adjectives like "easy-going" "enlightening" "cute and clever", "fun" and "nice" to describe Tanya's personality. Two participants introduced the agent into their

Table 4 Affective state utterance exemplars representing both Sensor (S) and Non-Sensor (NS) participants

Affective State: Exemplar Utterances
"...A couple times when I walked through here she kept saying hello, are you there and I'm like no. Shut up!" (S) [anger, contempt]
"I've had this cough for 3 or 4 days and she you know, she seemed to genuinely respond to that" (S) [feeling cared for]
"She had some real funny stories. I really liked that one about dog sledding because that's something that I always wanted to do haha." (NS) [amusement, joy]
"I struggle with walking. It helped me by hearing her encourage me to walk every day)" (NS) [feeling cared for]
"It was a little weird at first but I didn't mind, it was kind of fun, it was like a game." (S) [amusement]
"She was great. She was upbeat and friendly and seemed sincere." (S) [joy]

Table 5 Social support utterance exemplars representing both Sensor (S) and Non-Sensor (NS) participants

Social Support: Exemplar Utterances
"You know it sort of relieved the solitude a little even thought I knew it was an animated voice and not a real person."(S)
"Yes, in fact, I was on the phone when you rang the bell, talking about Tanya. Miss Tanya." (S)
"It was kind of strange and it was kind of comforting to know that there was someone to say hi to you in the morning" (S)
"Yeah, I considered her a friend. I mean, you become, not attached, but ya know I was looking forward to going home." (S)
"Once I got used to it I looked forward to you know communicating and it was more...you know like a companion to some degree." (S)
"I would avoid her if I met her on the street...she's very boring." (NS)

social network by remarking about the agent's personality or situation to friends or family (e.g. "Tanya has her own room").

7.3.3 Other themes

In addition to thematic coding, deductive coding was implemented to understand satisfaction with the agent. Approximately half of the participants in the Passive condition and 5 out of 7 in the Proactive condition were generally positive about their experience. Most participants in the Proactive condition (6 of 7) would recommend use of the agent to a friend, while only 2 out of 5 Passive condition participants would offer a recommendation.

As found in prior studies with conversational agents that provide longitudinal health counseling [6], most participants found the conversations limited and repetitive by the end of the week ("...the very narrow focus of responding was...it just didn't allow for my personal style" (S)). Many participants volunteered that they wanted the agent to have a much wider range of topics that could be discussed, the ability to have much longer conversations, and wanted her to have more of a sense of humor ("Like have you been pole dancing lately?" (N)).

When asked about their motivation to talk to the agent, 4 of 12 participants cited curiosity about what she was going to say as a primary motivator. While not present in our emotion coding ontology, curiosity is a strength in positive psychology that is being explored to understand its specific benefits [21]. Five participants said they were motivated to talk to the agent out of a feeling of obligation to meet the study objectives. Four participants said they initiated interactions because they were lonely or did not have anything better to do ("...it was just quiet in here and I said you know why don't I go over there and talk to the computer?" (S), "I struggle with sleep so I would turn her on at maybe 2 or 3 o clock in the morning sometimes." (N)).

Since much of the agent's conversation centered on walking promotion, participants cited this as both a motivator to talk to the agent and a reason to avoid her. Specifically, when they had done well on their exercise they wanted to hear positive reinforcement ("...as I got the drift about the exercise then I did...when I would come back from walk or exercising I would go and say yeah did you do it?" (S)) and if they had not done their exercise they intentionally avoided her. In the proactive agent this led to unanticipated behavior in which a participant physically avoided the part of their home the agent was set up in because they had not done their exercise:

> "...if we had a conversation about going for a walk and I was still here then I wouldn't go back and talk to her because it would be the same - are you going to take a walk? I didn't take the walk. So what I would do, in order not to set it off, I would walk over here and around. As opposed to walking in front of it because I know if I did that it would set it off." (S)

Another recurring theme found in the debrief interviews was the way participants distanced themselves from the rest of the older adult population. In these interviews, participants often stated that they enjoyed the system but thought it would work even better for those "other" older adults who were lonely, depressed, or isolated (Table 6) even though the

Table 6 Example utterances from debrief interviews showing the "others" phenomenon in both sensor (S) and non-sensor (NS) participants

Examples of the "others" phenomenon
"I do have a lot of social contacts so if I didn't it might be good for me. This was just showing me how much more I have in reality than a computer character."(NS)
"I do not have problems with getting myself to exercise. So it may be terrific for what it is but it may not be for me... for me it may be for much more elderly or people who really are much more isolated. And then it might be a god-sent." (S)
"I thought that, um, for someone who is living alone, right, and who needed companionship this is a great idea. It really is. Especially for someone who needed to be reminded to take their medication, to eat, or something like that I think it would be good." (S)
"I would highly recommend her to someone who was sick and shut in and really didn't have anybody. " (S)

majority of participants were classified as lonely or mildly depressed themselves.

One possible explanation for this is the "third person effect" [15], a phenomenon in which people often report that persuasive arguments would be more effective on others than they would be on themselves. Due to the effectiveness of our system at treating these conditions however, it is likely that this distancing exhibited by the participants could be a result of the negative views older adults have about aging [1]. This suggests that addressing these negative views may help in increasing the overall effectiveness of the system since it could potentially remove some of the initial user resistance towards using it.

8 Discussion

Addressing isolation and loneliness in older adults represents an important opportunity for affective computing. In this study we were able to demonstrate significant reductions in loneliness through mood management (empathic feedback) based on self-reported affective state through the use of the framework proposed in Sect. 2. Exercise promotion and anecdotal stories were also used to reduce perceived loneliness in participants. Furthermore we found that participants felt a sense of companionship with the agent, and that the agent's presence evolved into companionship by the end of the study for the majority of participants. Through these findings we have demonstrated that a system such as the one described here can provide social support to those in need, acting as a possible alternative for older adults who cannot readily receive human based aid due to its cost and/or availability.

We also explored the use of a proactive conversational agent in which we found that the proactive version of our systems significantly increase our system's effectiveness compared to a user-initiated version. Several studies have shown that lonely people lack social skills, and are often passive and unresponsive in interaction [35]. This connection could explain why the users in our study preferred the proactive variant of the agent since it could compensate for any deficiencies they had in this area.

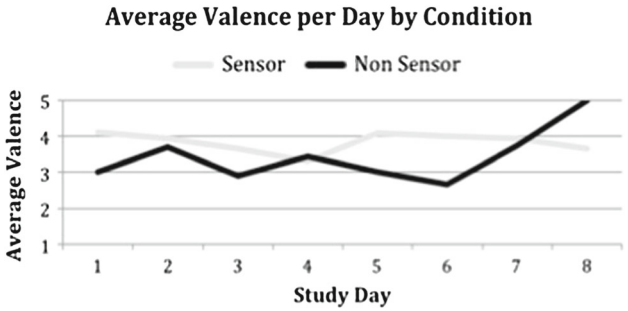

Fig. 3 Change in reported valence between the Proactive and Passive conditions

Our system and pilot study had many limitations. Our most obvious limitation was the number of participants in our study. Although the participants used the system for a relatively long period of time, we realize that the limited sample size reduces the validity of our findings. The participant pool we recruited from also poses as a possible confound to the generalizability of our results since we recruited from an online job recruiting sites, biasing our sample to participants with medium to high levels of computer literacy. Additionally, the fact that we did not have a control group makes it harder to judge the exact efficacy of the study since the act of going to the participants homes to set up and retrieve the system could have possibly affected one of our primary outcome measures, loneliness. Finally, we did not utilize information about changes in the users affective state across multiple sessions to determine the user's mood. As seen in Fig. 3, there was significant daily variation in the users affective state, indicating that the assessment of their mood could have been used to give more appropriate responses to the users affective state at the start of each interaction, along with being another area we could have intervened on.

9 Future work

We are currently developing an affective storytelling module for our system. Based on positive psychology interventions [33], the agent will attempt to evoke positive stories from

elders while assessing their affect in real time using sensors including video-based facial display identification and physiological signals. In this work we hope to not only see if the agent can successfully deliver a positive psychology intervention without human assistance, but if it can detect when these interventions would be most effective based on users' affective state.

We are also working on improving the way the agent facilitates social connectivity. We are currently evaluating a variant of our system in which the agent facilitates video Skype calls between an older adult and individuals in their social network to help strengthen and maintain their relationships. By doing this we hope to further evolve the older adult's relationship with the agent, moving it from presence to friend to gateway to the outside world.

These developments will all be incorporated into a larger agent-base system designed to provide social support to older adults in their homes for extended periods of time. This "AlwaysOn" system will be equipped with a range of sensors to increase responsiveness to elders' presence and nonverbal behavior, as well as a much wider range of dialogue-based activities, including social chat, talk about friends and family, and playing card and board games with the agent [34]. Once completed, we will conduct a month long field study with the system in which we will deploy both embodied conversational agent and robot variants of agent into the home of isolated older adults. We anticipate that these affectively intelligent, social companion agents will play an important role in maintaining the health, wellness, and independence of older adults in the future.

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