

Designing Relational Agents as Long Term Social Companions for Older Adults

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Abstract. Older adults with strong social connections are at a reduced risk for health problems and mortality. We describe two field studies to inform the development of a virtual agent designed to provide long-term, continuous social support to isolated older adults. Findings include the topics that older adults would like to discuss with a companion agent, in addition to overall reactions to interacting with a remote-controlled companion agent installed in their home for a week. Results indicate a generally positive attitude towards companion agents and a rich research agenda for virtual companion agents.

Keywords: relational agents, social interfaces, social dialogue, wizard-of-oz study

1 Introduction

Studies have demonstrated that a lack of social support can have negative effects on the health and well-being of older adults [1], and older adults who face extreme isolation face significantly higher risks of mortality than their connected peers [2]. A recent meta-analysis estimates that 7-17% of older adults face social isolation and 40% experience loneliness [3] (social isolation refers to minimal contact with others, whereas loneliness refers to the subjective, usually negative, reactions to a person's social experiences [4]).

To address these problems, we are developing a virtual agent that can provide social support and wellness coaching to isolated older adults, in their homes, for months or years. This companion agent will be always on, always available, to provide a range of support interactions including: companionship dialogue, game co-play, exercise and wellness promotion, social activity tracking and promotion, facilitating connections with family and friends, and memory improvement tasks, among others.

To inform the design of this agent's dialogue capabilities, we conducted two field studies to determine what older adults would want to talk about with an in-home companion agent.

2 Related Work

2.1 Social Technologies for Older Adults

Many researchers have explored technologies that provide social activity scaffolding for older adults. In a longitudinal field study, Plaisant, et al., investigated shared, symmetric access for family calendars, as a way for remote, inter-generational family units to stay in touch and improve awareness surrounding daily activities [5]. Wearable and stationary devices that promote multimedia sharing with family and friends have also been designed to improve the social-connectedness of isolated adults [6].

Technologies designed specifically to provide companionship for older adults are an area of recent research. Leite, et al., developed a robotic companion designed for game co-play [7]. Wada, et al., have examined non-conversational therapeutic robots, and Klamer, et al., have examined the health benefits of in-home robots [8,9]. Cavazza, et al., explored the challenges surrounding a conversational agent companion that is able to intelligently ask about a user's day [10]. To explore how agents might be more useful than found in [9], this work undertakes a larger sample of participants in advance of full technology in participants' homes

2.2 Wizard of Oz Methodologies

In a Wizard of Oz (WOZ) study, a user interacts with a computer that is not autonomous, but rather one that is remotely-controlled by another human (often unbeknownst to the user) [11]. This technique is frequently used to explore human-computer interactions that are not possible with current technologies, such as full speech generation and understanding. WOZ methods have been used to explore companion agents, but only in single lab-based sessions [12]. Dow, et al., propose a new design for controlling embodied characters, one that blends both machine and human control [13]. We utilize this approach in the present work.

2.3 Relational Agents

Relational agents are autonomous, embodied agents designed to form relationships with their users by building trust, rapport, and therapeutic alliance over time [14]. These agents are typically designed as computer-animated, humanoid agents that simulate face-to-face dialogue with their users. Relational agents have been successfully used in health interventions, including several designed specifically for older adults [15]. When designing agents to promote social connectedness, relational agents provide several affordances. The agents are autonomous, since family, friends, and caregivers may not be available at all times.. The agents are conversational, because older adults with limited computer literacy are familiar and comfortable with this interaction format. Finally, the agents are relational, in that they are designed for companionship and long-term continual use, and thus can adapt to the changing nature of the socio-emotional relationship users have with them.

3 Preliminary Exploration: Eldercare Companion Volunteers

Our initial approach to understanding how elders might interact with companion agents was to meet with human role models: volunteers who provide periodic visitation to isolated older adults. We collaborated with a non-profit organization in Boston that manages a network of trained volunteers who provide support and assistance to elders and adults with disabilities. Members of our research staff first went through the orientation and training that is provided to new volunteers. We then conducted interviews with four volunteers and accompanied two of them on home visits to their elder “recipients”.

The volunteers we interviewed were all women in their 20s (all trainees that we met were also female), and they all described their relationships with their recipients as friendships rather than service relationships. Volunteers visited their recipients once a week for approximately 1-2 hours. Recipients ranged in age from 60 to 97 and were mostly (75%) female. All had mobility and other health problems, keeping three of them mostly at home except when their volunteers took them for walks during visits.

According to the volunteers, the recipients do most of the talking during visits, with storytelling by the elder taking up a significant portion of most interactions. When they are visiting in the elders’ homes, the televisions are typically turned on, and chat topics include: storytelling, small talk (weather, etc.), topics occasioned by the television (during co-watching), reports of recent events and future plans (“relationship continuity” behaviors [16]), sports, the recipient’s health, and the recipient’s family. Two of the volunteers reported that their recipients craved more social contact with their family and friends, but that they didn’t want to impose, so rarely initiated contact.

4 WOZ Study: What do Older Adults Want to Talk About with a Companion Agent?

To further understand how older adults would want to interact day-to-day with an in-home agent companion, we developed a virtual conversational agent that could be placed in the home and be remotely controlled by a researcher for a one-week duration. Since our primary objective was to understand the range of topics that older adults would want to talk about, we designed a research platform in which users could interact with the agent using unconstrained speech and nonverbal behavior.

4.1 The Remote Wizard of Oz System

The system runs on a dedicated computer in an older adult’s home and is connected to the Internet. The agent talks using synthetic speech and synchronized nonverbal behavior, while the older adult converses using natural speech and non-verbal behavior that is captured via the computer’s integrated microphone and webcam (Figure 1). The real-time audio and video of the older adult are streamed to a Wizard of Oz station, where a research assistant controls the agent responses by choosing pre-selected utterances and/or animation commands from the control-station software, or by manually

typing utterances which are transmitted to the agent for real-time synthesis and animation.

Wizard commands are sent to the agent using an XML command language over a TCP/IP connection. Commands include specifications for spoken utterances, along with coordinating nonverbal behavior (hand gestures, eyebrow raises, head nods, posture shifts, gaze-aways) and facial displays of affect. Nonverbal behavior is generated using BEAT [17] or manually specified by the Wizard. Live audio and video of the participant was streamed to the Wizard using the Skype4Com¹ API, and archived using VodBurner². All interface actions taken by the Wizard were also logged with timestamps.

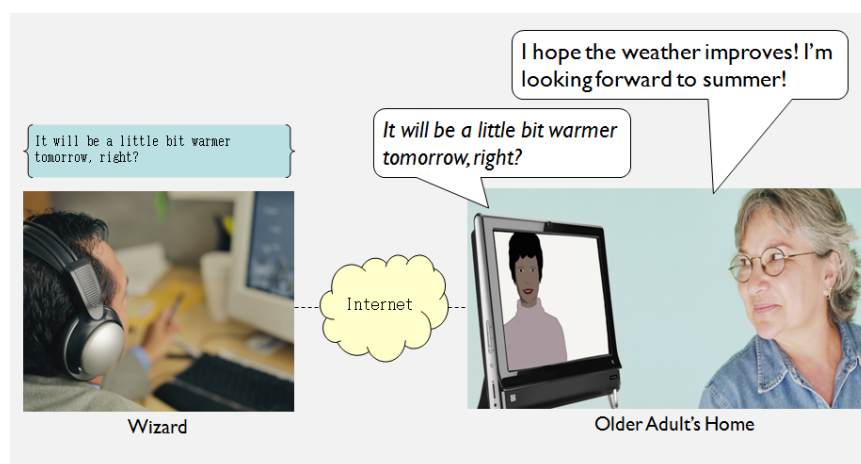


Fig. 1. Wizard-Agent Setup

4.2 Methods

Participants were recruited via an online job recruiting site. In order to be eligible, participants needed to be 55 or older, speak English, live alone, and have a high-speed Internet connection. A research assistant met participants in their home to obtain informed consent, collect baseline measurements, install the agent computer and connect it to the Internet via the participant's existing network connection. Participants went through a simple introductory conversation with the agent with the research assistant, to make sure they were comfortable with the experience.

Participants were told that they could have daily conversations with the agent during a pre-scheduled 90-minute time window (when the wizard would be standing by). At the end of the week, a research assistant revisited the older adult in their home, to administer final measures, conduct a semi-structured interview about their experience,

¹ <http://developer.skype.com/accessories/skype4com>

² <http://www.vodburner.com/>

and collect the study computer. Study measures included socio-demographics, and the UCLA Loneliness Questionnaire [18] at intake, and an Agent Satisfaction Questionnaire at termination.

Four research assistants played the role of the Wizard. In keeping with the exploratory nature of the study, Wizards were given no instructions regarding what they should talk about with participants, only that they should have a “conversation”.

Privacy and Ethical Issues. Since the agent computer could be remote-controlled to begin video streaming by the wizard, participants were told how to tell the camera was active (an illuminated LED), and how to cover the camera if they wanted to ensure privacy. Although active deception is commonly used in Wizard of Oz studies so that participants think they are interacting with a fully automated system, we felt that carrying on such deception in a participant’s home, over an extended period of time, was unwarranted. Participants were told in advance that the agent was not autonomous, but rather remote-controlled by a person at all times.

4.3 Participants

Twelve older adults (10 women, 2 men), aged 56-73 ($m=62$) participated in the week-long study. Participants were mostly Caucasian; two were African-American. Participants were generally well-educated (all but one had some college) and came from diverse working backgrounds. Five participants were retired. Participants scored between 26-53 ($m=38.6$, $sd=8$) out of a possible 80 on the UCLA loneliness measure, indicating that most participants reported low levels of loneliness.

4.4 Results

Participants had between 1 and 5 conversations with the agent ($m=3.5$), with conversations lasting between 1.95 to 122.31 minutes ($m=28.33$, $sd=20.73$).

Conversational Topics. Audio from all agent-participant dialogues was coded for high-level topics of conversation, along with the start and end of each topic boundary. A preliminary list of topics was created by consensus of the researchers following preliminary review of the dialogues. Coders added topics to the list if they felt that none of them adequately described a dialogue segment they were reviewing. In total, 70 distinct topics were discussed during the 41 agent-participant interactions (Appendix I).

We find that the agent-participant conversations were highly individualized and that topics varied greatly, ranging from discussions of *Family* and *Friends* to *Music*, *News* and *Fashion*. Fifty-nine percent of all topics were not discussed by more than one participant (Table 1).

Despite this, there were many topics in common across participants. Table 2 presents examples of the most common topics. The three topics discussed by nearly all participants (other than greetings and farewells) were: *Family*, *Weather* and *Storytell-*

ing. Discussion of *Future Plans* and asking *Questions to the Agent* also took place by more than half of the participants, ranging from inquiries about the agent’s functionality to questions about its development trajectory and future applications. We also examined topics that were common across multiple conversations and found that, *Storytelling*, *Weather*, *Future Plans*, and *Family* were brought up in at least half of all Agent-Participant conversations.

Table 1. Agent-Participant Conversation Information

Participant	Num Conversations	Avg Conv. Length (Minutes)	Top Topics	Time Spent on Topic
1	4	41.62	Storytelling	26.30%
			Miscellaneous	19.13%
			Food	6.84%
2	4	12.34	Miscellaneous	31.12%
			Report	14.16%
			Future Plans	10.20%
3	5	14.87	Storytelling	14.62%
			Wizard of Oz	13.19%
			Future Plans	10.08%
4	4	17.33	Storytelling	60.12%
			Future Plans	9.97%
			Opinions	6.68%
5	5	50.05	Television	12.45%
			Greeting	12.44%
			Storytelling	9.70%
6	3	22.66	Sports	41.44%
			Agent	11.95%
			Weather	6.14%
7	2	24.55	Travel	15.36%
			Daily Activities	11.94%
			Habits	11.34%
8	3	20.10	Questions to Agent	12.31%
			Storytelling	12.03%
			Goodbye	11.22%
9	3	17.53	Questions to Agent	27.96%
			System	13.99%
			Greeting	9.33%
10	4	26.28	Storytelling	21.56%
			Wellness	16.30%
			Family	13.18%
11	4	47.59	Storytelling	18.50%
			Agent	16.01%
			Exercise/Wellness	14.21%
12	1	54.77	Family	35.10%
			Agent	21.38%
			Miscellaneous	9.39%

Table 2. Examples of frequent conversation topics (*Tanya* is the name of the agent)

Topic	Example
Family	<i>"I'm the oldest in my family ... I have a younger sister ..."</i> – P7 <i>"I had to mail my grandson his weekly letter..."</i> –P10
Weather	<i>"I'm doing well – I just came back and it's freezing out! I had to go out and do a bunch of errands and it's so cold out!"</i> –P10
Storytelling by elder	<i>"Would you like me to tell you about working on my Great-Aunt's tobacco farm when I was a kid? ..."</i> – P1
Future Plans	P11: <i>"Would you like to talk again tomorrow?"</i> Agent: <i>"Yes I would."</i> P11: <i>"So would I."</i> Agent: <i>"What time are we on for?"</i> P11: <i>"Well the afternoon, ..."</i>
Questions to the Agent	<i>"Tanya, did the computer school design you? Or whose project are you?"</i> –P8 <i>"Do you have facial expressions, Tanya?...oh, a smile, great!"</i> - P11

Conversation Topics of Specific Importance to Older Adults. Several topics were identified that are of particular importance to the design of companion agents for older adults (Table 3).

Activity identification and planning. Participants discussed activities as past events, new activities and future plans. While all participants mentioned lifestyle activities (e.g. reading, walking, seeing friends) those who scored as the least lonely (P11, P9) demonstrated more activity planning (Table 3. 1a & 1b). Some planning statements included specific details connoting commitment, such as picking up bus schedules or reaching consensus with activity partners, while other planning statements expressed positive or negative sentiment about an event, either in anticipation or reflection. Studies in psychology and neuroscience have demonstrated the broad health benefits of cognitive enrichment activities and physical exercise for aging adults [19,20]. While a generic increase in activity improves health, amplified benefit is obtained by tailoring for engagement [21], variety of cognitive demand [22] and framing health messages in interactive systems for older adults [23]. Personalization of activity planning by virtual agents to best support older isolated adults requires detailed re-search into activity planning habits of older adults. As virtual agents are engaged in long-term interactions with users, enabling detailed user models, activity recommendations can be honed in support of the greatest individual health benefit.

Character strength disclosures and attitudes toward aging. Participants offered repeating statements revealing their character strengths [24]. Attitudes toward aging were less explicit than character strength disclosures (Table 3, 2a & 2b). Distancing from negative attributes of aging was more prevalent than direct statements about positive aging. Three participants distanced themselves from "old people" who were sedentary or ruminative about their physical ailments. Identification of positive and negative attitudes towards aging would present an opportunity for intervention. Longevity studies show that a positive attitude toward aging (e.g., that aging offers wisdom and more

free time rather than memory loss and loneliness) increases life expectancy by 7.5 years on average [25].

Family history and social ties. Our connections to others can be expressed in many forms, from personal narratives to calendars and to-do lists (Table 3, 3a & 3b). Participants recounted stories about family and friends providing fodder for reconstructing their social networks. Personal narratives included self-explanation of physical proximity, frequency of interactions, and social support akin to network connections in the covey model [26]. Connectedness of some participants was closely linked to community-based, scheduled events. For older isolated adults, being able to understand and utilize networks of support can mitigate isolation [27]. Six participants explicitly defined others as sources of and recipients of help, further defining the roles of people in their social network. Virtual agents may be to help older adults create new social ties and maintain existing ones to meet their health needs.

Table 3. Topics Important for Older Adults

Topic	Example Utterances
1a. Activity identification	<i>"When I'm traveling I enjoy shopping, ..." - P11</i> <i>"Now it's golf, which is a lot easier for me. Well not to do well in but at least to participate in" - P6</i>
1b. Activity planning	<i>"...once it gets cold, it's a whole different kind of a flow in terms of planning and travel!" - P5</i> <i>"Maybe that could be my goal...to make sure I go to the dancing tonight. Is that okay" - P11</i>
2a. Character strengths	<i>"I have to be on the move." (Vitality)- P1</i> <i>"I went to a fundraiser for charity to raise money for an orphanage." (Altruism)- P9</i>
2b. Attitudes toward aging	<i>"... some seniors have nothing better to do than to just sit around and just gossip and you know." - P1</i> <i>"Being retired is new to me. That's why I roam around so much." - P2</i> <i>"I think in this country unlike other countries older people aren't as valued and aren't as much a part of the community" - P9</i>
3a. Family and friend histories	<i>"My mother's sister was married to a man in western mass and they had a truck farm". - P1</i>
3b. Social ties	<i>"I just lost my dog Sam who is a Lab at age 13 about six months ago and he was my best pal. - P8</i> <i>"It is interesting I don't know them particularly but I think we feel a commitment to each other in the sense that if something happens I'd feel comfortable calling any of them saying I'd need help, and they'd be right there, even though we don't socialize. - P11</i>

Participant Reactions to the Agent. Participants reported high levels of satisfaction with the agent and indicated that they were comfortable having her in their home (Table 4).

Table 4. Agent Satisfaction Measures and Scores

Question	Anchor 1	Anchor 7	Mean (SD)
How satisfied were you with Tanya?	Not at all	Very satisfied	6 (1.09)
How much would you like to continue working with Tanya?	Not at all	Very much	5.36 (1.68)
Would you rather have talked to a person than Tanya?	Definitely prefer a person	Definitely prefer Tanya	4.08 (1.78)
I feel comfortable having Tanya in my home.	Disagree completely	Agree completely	5.7 (1.05)

We also conducted in-person, semi-structured interviews with participants to further explore their experience with the in-home agent. These interviews were audio-recorded, transcribed, and coded for themes.

All participants had something positive to say about their experience with the agent (Tanya); four participants (P1, P2, P10, P12) had extremely positive reactions. For many, Tanya provided a sense of companionship and support.

“Yeah and I thought that I was going to cry because it was like losing a friend after talking to her for so many days” –P1

“I was very pleasantly surprised to find that there was such a connection to what I knew was actually a computer generated human being ... It did not feel like fantasy land although I didn't have the delusion that I was really talking to a human person there. I mean I was and I wasn't but I felt a connection and as I told you before I feel that there was an accountability built in there. And support.” – P2

Eight participants (P1, P3, P4, P5, P6, P7, P8, P12) reported some negative comments regarding their experience with Tanya. Most of the negative reactions had to do with the lack of realism, the static nature of the interactions and the simplicity of Tanya's abilities. A few participants simply did not feel a connection to Tanya, and one participant (P8) reported that the interactions with Tanya made her feel worse, because they made her realize that she lacked the human interactions and the friendships that she desired for her life.

Privacy. Four participants (P1, P4, P5, P6) expressed no privacy concerns with the agent in their home. On the other hand, 7 participants expressed strong privacy concerns (P3, P6, P7, P8, P9, P10, P12). These concerns mostly revolved around the use of the webcam and uncertainty about whether or not they were recorded. Another factor that increased concerns about privacy was that the computer screen was on at all times, though dimmed most of the time. One participant (P6) ended up turning the

computer to the side when it wasn't in use, in order to prevent the webcam from having any possible view of his home. Two other participants (P1, P12) stated that they strategically placed the computer in a location where the camera would only be able to view a very small space of their home.

The Wizard Effect. Participants reported that throughout the study, they were cognizant of the Wizard of Oz component. For a few (P1, P2, P4, P9), the wizard component was in the background, and they viewed their experience as interacting with Tanya. For several others, the wizard component was in the foreground, and for some, not knowing who was *truly* behind the interaction caused anxiety.

“Well, rationally, I knew that there was a person controlling Tanya but it didn't feel like that.” – P2

“I didn't know if it was one or more people behind the scenes. It made me uncomfortable that I didn't know who was listening or watching.” – P6

Always On. Finally, we asked participants about their potential desire to interact with the agent throughout the day, instead of during a restricted time frame. While many participants found it convenient to have a specific interaction time, a few expressed positive reactions to interacting with the agent freely throughout the day. However, many of those participants also cautioned that they would want a sense of control over the interactions and the ability to turn the system off, if necessary.

“I would just like to make sure that there is an understanding – such as, when you call someone on the phone and they tell you that this is not a good time to talk, you can call back at a time that is good to talk. The thing for me is that if [the agent was] here all the time I would like that accessibility to be able to have the companionship all the time, but I would like to make sure that it is set up so that I don't have to rearrange my schedule to talk to her. I would like to be able to start and stop talking whenever I want to.” – P5

5 Conclusion

We found high levels of acceptance of and satisfaction with the in-home social support agent by older adults in the WOZ study, with many participants stating that it provided them with a sense of companionship. Across both field studies, we found that elders would like to tell stories to and discuss the weather, their family, and their future plans with a live-in companion. *Storytelling* is particularly interesting because it is the topic that elders in both studies spent the most time on. In the WOZ study, participants spent between 1.8 and 43.87 minutes ($m = 16.98$, $sd = 15.98$) telling stories to the agent. This indicates that the ability of agents to share in a storytelling experience would be valued and utilized by older adults. We also found that discussion of topics important for the social support of elders—including *Activity Planning*, *Attitudes Towards Aging*,

and *Social Ties*—may require especially nuanced dialogue, although WOZ participants did volunteer much of this information on their own.

As discussed in Section 4, this work does have limitations. The in-home video recording utilized for WOZ purposes made eight participants somewhat uncomfortable, thus, the data collected might not be representative of completely anonymous conversations with an agent.

Despite this limitation, these studies provide a research agenda of dialogues to emulate in companion agents designed to provide social support for older adults. Our next steps involve implementing and testing an autonomous companion agent that is able to conduct many of these conversations without the support of a human Wizard, integrating information from the Internet (weather conditions, sports scores) and sensors (motion, vision, prosody) to develop a system that is able to provide adaptive, tailored social support over months or years of operation.

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References

1. Bassuk S, Glass T, Berkman L (1999) Social Disengagement and Incident Cognitive Decline in Community-Dwelling Elderly Persons. *Annals of Internal Medicine* 131 (3):165-173.
2. Berkman L, Syme L (1979) Social networks, host resistance, and mortality: A nine-year follow-up study of Alameda county residents. *American Journal of Epidemiology* 109 (2):186-204.
3. Dickens A, Richards S, Greaves C, Campbell J (2011) Interventions targeting social isolation in older people: a systematic review. *BMC Public Health* 11 (1):647.
4. Grenade L, Boldy D (2008) Social isolation and loneliness among older people: issues and future challenges in community and residential settings. *Aust Health Review* 32 (3):468-478.
5. Plaisant C, Clamage A, Hutchinson H, Bederson B, Druin A (2006) Shared family calendars: Promoting symmetry and accessibility. *ACM Trans Comput-Hum Interact* 13 (3):313-346.
6. Chen C-Y, Kobayashi M, Oh L ShareComp: sharing for companionship. In: CHI '05 extended abstracts on Human factors in computing systems, Portland, OR, USA, 2005. ACM, pp 2074-2078.
7. Leite I, Mascarenhas S, Pereira A, Martinho C, Prada R, Paiva A "Why can't we be friends? An empathic game companion for long-term interaction." In: Proceedings of the 10th international conference on Intelligent virtual agents, Philadelphia, PA, 2010. Springer-Verlag, pp 315-321.

8. Wada K, Shibata T Robot Therapy in a Care House - Change of Relationship among the Residents and Seal Robot during a 2-month Long Study. In: Robot and Human interactive Communication, 2007. RO-MAN 2007. The 16th IEEE International Symposium on, 26-29 Aug. 2007 2007. pp 107-112.
9. Klamer T, Ben Allouch S Acceptance and use of a social robot by elderly users in a domestic environment. Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2010.
10. Cavazza M, Raul Santos de la C, Turunen M How was your day?: A companion ECA. In: Proceedings of the 9th International Conference on Autonomous Agents and Multiagent Systems: Volume 1, Toronto, Canada, 2010. International Foundation for Autonomous Agents and Multiagent Systems, pp 1629-1630.
11. Kelley JF (1984) An iterative design methodology for user-friendly natural language office information applications. *ACM Trans Inf Syst* 2 (1):26-41.
12. Bradley J, Benyon D, Mival O, Webb N Wizard of Oz experiments and companion dialogues. In: Proceedings of the 24th BCS Interaction Specialist Group Conference, Dundee, United Kingdom, 2010. British Computer Society, pp 117-123.
13. Dow S, Mehta M, MacIntyre B, Mateas M Eliza meets the wizard-of-oz: blending machine and human control of embodied characters. In: Proceedings of the 28th international conference on Human factors in computing systems, Atlanta, Georgia, USA, 2010. ACM, pp 547-556.
14. Bickmore T, Caruso L, Clough-Gorr K, Heeren T (2005) 'It's just like you talk to a friend' relational agents for older adults. *HCI and the Older Population* 17 (6):711-735.
15. Bickmore T, Schulman D, Yin L (2010) Maintaining Engagement in Long-term Interventions with Relational Agents. *Applied artificial intelligence* : AAI 24 (6):648-666.
16. Gilbertson J, Dindia K, Allen M (1998) Relational Continuity Constructional Units and the Maintenance of Relationships. *Journal of Social and Personal Relationships* 15 (6):774-790
17. Cassell J, Vilhjálmsón H, Bickmore T BEAT: The Behavior Expression Animation Toolkit. In: SIGGRAPH '01, Los Angeles, CA, 2001. pp 477-486
18. Russell D, Peplau LA, Curtrona CE (1980) The revised UCLA loneliness scale: concurrent and discriminant validity evidence. *Journal of Personality and Social Psychology* 39:472-480
19. Teri L, Lewinsohn PM (1982) Modification of Pleasant and Unpleasant Events Schedule for use with elderly. . *Journal of Consulting and Clinical Psychology* 50:444-445
20. Mahncke HW, Bronstone A, Merzenich MM (2006) Brain plasticity and functional losses in the aged: scientific bases for a novel intervention. In: Aage RM (ed) *Progress in Brain Research*, vol Volume 157. Elsevier, pp 81-109.
21. Sheldon KM, Lyubomirsky S (2006) How to increase and sustaining positive emotion: The effects of expressing gratitude and best possible selves. *The Journal of Positive Psychology* 1:73-78
22. Carlson M, Parisi J, Xia J, Xue Q, Reobok G, Bandeen-Roche K, Fried LP (2012) Lifestyle Activities and Memory: Variety may be the spice of life. *Journal of the International Neuropsychological Society* 18:286-294
23. Bickmore T, Schulman D, Yin L (2010) Maintaining engagement in long-term interventions with relational agents. *Applied artificial intelligence: AAI* 24 (6):648

24. Peterson C, Seligman MEP (2004) Character strengths and virtues: a handbook and classification. Oxford University Press, Inc., New York, NY
25. Levy B (1996) Improving memory in old age through implicit self-stereotyping. *Journal of Personality and Social Psychology* 71 (6):1092-1107.
26. Antonucci TC, Akiyama H (1987) Social Networks in Adult Life and a Preliminary Examination of the Convoy Model. *Journal of Gerontology* 42 (5):519-527.
27. Hooyman N, Kiyak H (2009) *Social Gerontology: a multidisciplinary perspective*. 9th edn.

Appendix I: Full List of Conversational Topics

Topic	Num Distinct Participants	Avg duration (seconds)
Agent	3	139.62
Books	4	161.14
Boston	2	56.88
Boston/New England	6	92.46
Computers and Older Adults	1	250.69
Daily activities	5	56.48
Education	1	40.95
Exercise and wellness	3	172.33
Family	11	150.02
Fashion	1	37.13
Fitness	1	59.26
Food	5	153.75
Friends	5	91.72
Future plans	9	53.39
Goodbye	12	43.92
Greeting	12	66.52
Habits	5	44.48
Health	4	59.00
Hobbies	1	17.02
Job	1	109.87
life lessons, morals, ethics	3	135.26
Loneliness	1	36.80
Medical	3	119.38
Miscellaneous	7	94.07
Miscellaneous (articles)	1	161.08
Miscellaneous (cartoons)	1	76.14
Miscellaneous (casino)	1	138.13
Miscellaneous (children)	2	168.64
Miscellaneous (christmas)	1	48.32
Miscellaneous (colors)	1	72.85
Miscellaneous (computers)	1	48.57
Miscellaneous (current events)	1	56.91
Miscellaneous (flashmob)	1	327.72

Miscellaneous (halloween)	1	21.35
Miscellaneous (holidays)	1	238.07
Miscellaneous (internet)	1	109.64
Miscellaneous (plants)	1	71.41
Miscellaneous (poker)	1	104.99
Miscellaneous (Richmond)	1	93.53
Miscellaneous (smiling)	1	41.18
Miscellaneous (weekend)	1	36.31
Movies	3	192.99
Music	1	69.68
New England	1	35.80
New England/Boston	1	122.26
News	1	77.94
Opinions	5	59.13
Participation in Research	1	35.70
Personal	4	58.36
Personal history	3	56.42
Pets	2	167.54
Politics	2	120.75
Questions	2	39.53
Questions for the agent	8	67.67
Report	6	60.61
Research on Computer Agents	1	135.63
Sports	6	180.15
Storytelling	10	161.71
Surfing Internet	1	41.93
Technology	3	80.70
Television	4	102.84
Thanksgiving	1	18.48
Travel	6	64.49
Weather	11	40.23
Wellness	5	87.81
Wellness Follow-up	1	76.69
Wellness: Goal Setting	1	114.74
Work	4	109.00
WOZ	5	78.61
WOZ: Ideas for use of system	2	80.66