Addressing Loneliness and Isolation in Older Adults

Proactive Affective Agents Provide Better Support

Lazlo Ring[1], Barbara Barry[1], Kathleen Totzke[2], Timothy Bickmore[1]
College of Computer and Information Science
Northeastern University
Boston, MA, USA
[1](lring, bbary, bickmore) @ ccs.neu.edu, [2]kathleen.totzke@gmail.com

***Abstract*—** Loneliness and social isolation are significant problems in older adult populations. We describe a conversational agent-based system designed to provide longitudinal social support to isolated older adults. Results from an exploratory pilot study indicate that when the agent proactively draws elders into interactions, 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

I. 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 [1], and this has been linked with a variety of health problems, including increased risk of cardiovascular disease and death [2]. 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 older adults is projected to triple to 1.5 billion in 2050, according to US Census Bureau projections.

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 [3]. Several studies have also shown that the perception of social support can benefit health beyond actual received support [1].

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 tread of early loss of independence, illness, and death among the elderly. In this paper we report on an exploratory design study we have conducted over the last year on a conversational agent developed to provide social support and wellness counseling to the 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, and a few studies have shown short-term efficacy in incorporating user affect into practical applications, such as in tutoring systems [4], the "killer application" for affective computing has yet to be found. We believe that social support systems for older adults may represent such an application, in which affect detection and management is not only important, but also could be instrumental in saving lives.

II. 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" [5]), 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 [6], to full-blown cognitive behavioral therapy [7], to the buffering effects of positive psychology interventions [8] for psychosocial longevity [9]. 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 [10]. 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 [10], and lack of physical activity has a significant impact on mortality in this age group [10].

III. RELATED WORK

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

978-0-7695-5048-0 2013

DOI 10.1109/ACII.2013.17

A. 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 [11]. Bickmore et al. investigated exercise promotion in older adults through the use of an ECA that played the role of a virtual exercise coach [12]. In a randomized controlled trial where both groups wore a pedometer for two 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 usage of ECAs has also been briefly explored. Bickmore et al. created a virtual laboratory to study users reactions to ECAs in a longitudinal setting [13]. 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.

B. 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. used AIBO, a robotic dog, in the UTOPIA project (Usable Technology for Older People: Inclusive and Appropriate) to provide artificial companionship for older adults [14]. 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".

Vardoulakis et al. also investigated the use of an agent to provide social support and wellness counseling for older adults [15]. In a preliminary study volunteers that provided social support through visitations to isolated older adults were interviewed to get a better understanding of their roles. Based on these interviews a Wizard of Oz system was constructed that allowed research assistants to control an ECA placed in an older adults home in real time. Qualitative analysis of the interactions identified multiple topics that older adults liked discussing with the agent and general design principles towards building future companion agents for older adults.

C. Agents that Assess and Respond to User Affect & Mood Over Time

Several studies have shown the positive effects of conversational agents at reducing negative affect [16]. However, all such studies to date have only investigated transient affective states in short lab studies. Few agent systems have been developed and tested that assess user affect in a longitudinal context, and no prior studies have investigated longitudinal interventions. Ring, et al, conducted a series of relevant studies on this topic [17]. In one study, videotaped longitudinal interactions between a human and an embodied conversational agent were assessed for both valence and arousal by judges. The study demonstrated inter-rater reliability in the assessments, and that a significant portion of the variance in user affect observed could not be accounted for by either inter-subject or intra-conversation variance—i.e., that a stable inter-conversation affect factor of "mood" predicted the changes in affect observed. In a second study, Ring demonstrated that persuasive messages tailored to user mood are significantly more effective for health behavior change, compared to the same messages delivered randomly.

D. Agents that Manage User Mood

The CASPER affect-management agent developed by Klein, was demonstrated to provide relief to users experiencing frustration [6]. 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 the length of time users were willing to continue working with a computer after a frustrating experience. Bickmore and Schulman 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 [18].

Of the many computerized interventions developed to treat depression, only two have been conversational [19]. "Overcoming Depression" features a typed text dialogue interaction with a virtual therapist, but the only evaluation study was flawed and 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.

IV. A Conversational Agent to Provide Social Support to Older Adults

We developed an 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 agent (Figure 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 [20].

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/gesture back its response to the user.

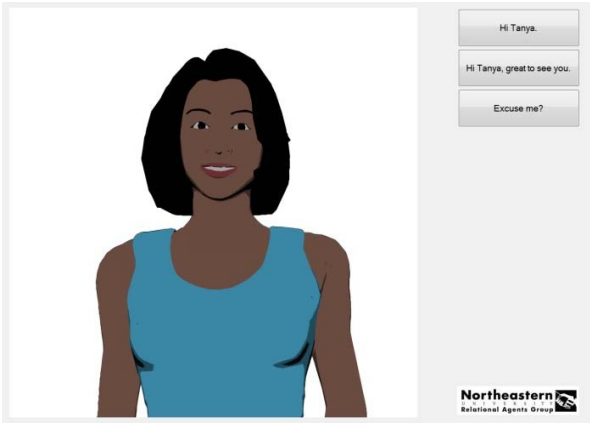

Fig. 1. Screenshot of Agent interaction.

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

1. *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 the local sports to try and build a sense of companionship.

2. *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 has 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 9am to 9pm 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.

V. 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.

A. 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 [21].
Affective State, State Loneliness, Satisfaction with Agent, Relationship Status and Comfort Using Agent: were all assessed using 5 point self-report scale measures (Table II) in the diary that participants were asked to complete following each conversation with the agent.
Open-Ended Feedback: Was collected following each conversation via the diary, and at the end of the week-long study via a semi-structured interview.

B. Method

Participants were recruited via an online advertisement. To be eligible, participants 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). 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.

VI. Results

Fourteen participants (3 Male, 11 Female) were recruited for the study (7 for the sensor condition, 7 for non-sensor condition), with twelve (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.

A. 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).

B. 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 1). Thus H1 was not supported.

TABLE I. *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)

However, there was a trend for participants in the Proactive group to have a significantly 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 on average 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 where 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 system 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 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.

Upon comparing the Proactive and Passive conditions averaged across all interactions per participant using a Welch Two Sample t-test, significant differences were found in reported loneliness, happiness, satisfaction and comfort between the two conditions (Table II). When interacting with the Proactive version of the system, participants reported feeling less lonely, $t(154) = -3$, $p < .05$, happier $t(154) = -0.98$, $p < .05$, more satisfied $t(154) = -4.04$, $p < .05$ and more comfortable talking with the agent $t(153) = -1.87$, $p < .1$ compared to the Passive version. These results show that proactive engagement by the agent significantly improved the affective response towards the system.

TABLE II. *COMPARISON BETWEEN DIARY MEASURES BETWEEN SENSOR AND NON SENSOR CONDTIONS (REPORTED MEAN AND STANDARD DEVIATION).*

Diary Measure *(Likert Scales)*	**Proactive**	**Passive**
Comfort: *1 - Very Uncomfortable* *5 - Very Comfortable*	4.59 (.8)	4.33 (.85)
Satisfaction: *1 - Very Unsatisfied* *5 - Very Satisfied*	3.95 (1.08)	3.14 (1.26)
Happiness: *1 - Very Sad* *5 - Very Happy*	3.89 (.9)	3.26 (1.17)
Loneliness: *1 - Very Lonely* *5 - Not at all lonely*	4.02 (.87)	3.54 (1)

C. Qualitative Results

Qualitative analysis was conducted using the grounded theory method [22] 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 participants about the supportive role of the agent, position of the agent in their social network, and feelings of personal connection to the agent.

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) [23] and Fredrickson's categories of positive affect (amusement, awe, feeling cared for, inspiration, joy, pride, serenity) [24] (Table III). 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 [25], 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.

TABLE III. *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]

Social Support: Social support utterances were re-coded to uncover sub-themes. Dominant sub-themes were prosocial, friendship, and comforting presence utterances (Table IV). 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. Two participants introduced the agent into their social network by remarking about the agent's personality or situation to friends or family (e.g. "Tanya has her own room"). Curiosity about the agent - who she was and what she knew - acted as an interaction motivator for 4 out of 12 participants. While not present in our emotion coding ontology, curiosity is a strength in positive psychology that is being explored to understand its specific benefits [26].

TABLE IV. *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)

In addition to thematic coding, deductive coding was implemented to understand satisfaction with the agent. 6 out of 7 sensor participants would recommend use of the agent to a friend, while only 2 out of 5 non-sensor participants would offer a recommendation.

These findings will help inform future design of the agent to most effectively prompt positive affect and strengthen social connectedness over longitudinal interactions.

VII. DISCUSSION

In this study we have shown that an in-home conversational agent is not only accepted by isolated older adults but can also be used to intervene on loneliness. Through our results we found that the system could both assess and manage affect in users through dialogue. This suggests that an agent could be designed with an affectively sensitive dialogue system, a system that reacts to the participant's affective state through dialogue in real time, to provide mood management and potential treatment for affect related disorders.

Furthermore we tested the basic framework proposed in Section II by showing that participants felt a sense of companionship with the agent, and that her presence evolved into companionship by the end of the study for the majority of participants. Exercise promotion and anecdotal stories were also reported to reduce perceived loneliness in participants.

We also found that allowing our agent to proactively start conversations with users significantly increased the effectiveness of the system. Several studies have shown that lonely people lack social skills, and are often passive and unresponsive in interaction [27]. An agent that reaches out to such individuals may compensate for these deficiencies.

Our system and small pilot study had many limitations. Although the agent assessed momentary user affective state during every interaction, it did not integrate information across sessions to determine changes in longer-term mood. As seen in Figure 2, there is significant daily variation in affect, indicating that assessment and management of mood is possible.

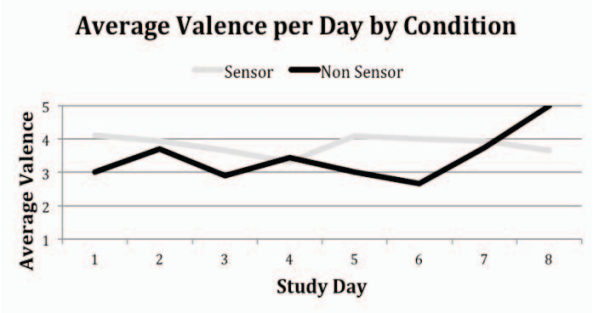

Fig. 2. Change in reported valence between the Proactive and Passive conditions.

VIII. Future Work

Addressing isolation and loneliness in older adults represents an important opportunity for affective computing. We were able to demonstrate significant reductions in loneliness through mood management (empathic feedback) based on self-reported affective state. We believe that a conversational agent could provide more nuanced and comprehensive counseling if user affect could be automatically sensed. The longitudinal context also provides the opportunity for detailed assessment of baseline behavior and physiology that is required for robust and accurate detection and classification of changes in affect [28, 29]. Given the significant relationship between isolation and morbidity in the elderly, this domain represents an opportunity for affective computing to move beyond the laboratory and have significant positive impacts on people--possibly even saving lives.

An important function of a social support agent is to facilitate social connectivity. A future direction of research is to have the agent facilitate communication between the older adult and their social network to strengthen and maintain relationships. To address this issue, we are in the process of developing and testing a new variant of the system to provide the video Skype calls with the elder's friends and family. By doing this we hope to further evolve the participant's relationship with the agent, moving it from presence to friend to gateway to the outside world.

Acknowledgment

We thank Candace Sidner and the entire of the WPI team for their collaboration on the AlwaysOn project. This material is based upon work supported by the National Science Foundation under Grant No. 1012086. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] A. Dickens, S. Richards, C. Greaves, and J. Campbell, "Interventions targeting social isolation in older people: a systematic review," *BMC Public Health,* vol. 11, p. 647, 2011.

[2] C. Perissinotto, I. Cenzer, and K. Covinsky, "Loneliness in older persons: A predictor of functional decline and death," *Archives of Internal Medicine,* vol. 172, pp. 1078–1083, 2012.

[3] T. A. LaVeist, R. M. Sellers, K. A. Brown, and K. J. Nickerson, "Extreme social isolation, use of community-based senior support services, and mortality among African American elderly women," *American journal of community psychology,* vol. 25, pp. 721-32, 1997.

[4] S. D'Mello, R. Picard, and A. Graesser, "Toward an affect-sensitive AutoTutor," *IEEE Intelligent Systems,* vol. 22, pp. 53-61, 2007.

[5] T. Bickmore and J. Cassell, "Small Talk and Conversational Storytelling in Embodied Conversational Characters," in *AAAI Fall Symposium on Narrative Intelligence*, 1999.

[6] J. Klein, Y. Moon, and R. Picard, "This Computer Responds to User Frustration: Theory, Design, Results, and Implications," *Interacting with Computers,* vol. 14, pp. 119-140, 2002.

[7] K. Colby, "A computer program using cognitive therapy to treat depressed patients," *Psychiatric Services,* vol. 46, pp. 1223-1225, 1995.

[8] M. Tugade and B. Fredrickson, "Resilient individuals use positive emotions to bounce back from negative emotional experiences," *Journal of Personality and Social Psychology,* vol. 86, pp. 320-33, 2004.

[9] G. E. Vaillant, "Positive aging," *Positive psychology in practice,* pp. 561-578, 2004.

[10] J. Blumenthal, M. Babyak, K. Moore, and e. al, "*Effects of exercise training on older patients with major depression," *Arch Intern Med,* vol. 159, pp. 2349-2356, 1999.

[11] Cassell, J., Sullivan, J., Prevost, S., & Churchill, E. (Eds.). Embodied Conversational Agents. Cambridge, MA: The MIT Press. (2000).

[12] Bickmore, T., Silliman, R., Nelson, K., Cheng, D., Winter, M., Henaulat, L., Paasche-Orlow, M., "A Randomized Controlled Trial of an Automated Exercise Coach for Older Adults." J*ournal of the American Geriatrics Society.* (to appear).

[13] T. Bickmore and D. Schulman, "A virtual laboratory for studying long-term relationships between humans and virtual agents," presented at the Proceedings of The 8th International Conference on Autonomous Agents and Multiagent Systems - Volume 1, Budapest, Hungary, 2009.

[14] C. S. Mival O, Benyon D., "Personification Technologies: Developing Artificial Companions for Older People.," in *CHI Fringe*, 2004, pp. 1-8.

[15] L. P. Vardoulakis, L. Ring, B. Barry, C. L. Sidner, and T. Bickmore, "Designing relational agents as long term social companions for older adults," in *Intelligent Virtual Agents*, 2012, pp. 289-302.

[16] H. Nguyen and J. Masthoff, "Designing empathic computers: the effect of multimodal empathic feedback using animated agent," in *Proceedings of the 4th International Conference on Persuasive Technology*, 2009, p. 7.

[17] L. Ring, T. Bickmore, and D. Schulman, "Longitudinal Affective Computing: Virtual Agents that Respond to User Mood," presented at the Intelligent Virtual Agents conference (IVA), Santa Cruz, CA, 2012.

[18] T. Bickmore and D. Schulman, "Practical Approaches to Comforting Users with Relational Agents " presented at the ACM SIGCHI Conference on Human Factors in Computing Systems (CHI), San Jose, CA, 2007.

[19] I. M. Marks, K. Cavanagh, and L. Gega, *Hands-on help: Computer-aided psychotherapy* vol. 49: Cambridge Univ Press, 2007.

[20] J. Cassell, H. H. Vilhjálmsson, and T. Bickmore, "BEAT: the behavior expression animation toolkit," in *Proceedings of the 28th annual conference on Computer graphics and interactive techniques*, 2001, pp. 477-486.

[21] D. Russell, L. Peplau, and M. Ferguson, "Developing a measure of loneliness," *Journal of Personality Assessment,* vol. 42, pp. 290-294, 1978.

[22] J. Corbin and A. L. Strauss, *Basics of qualitative research : techniques and procedures for developing grounded theory*. Thousand Oaks [etc.]: Sage, 2008.

[23] P. Ekman, "Basic Emotions," in *Handbook of Cognition and Emoiton*, T. Dalgleish, Power, M. , Ed., ed Sussex, UK: John Wiley & Sons, 1999.

[24] B. L. Fredrickson, "What Good Are Positive Emotions?," *Rev Gen Psychol,* vol. 2, pp. 300-319, Sep 1998.

[25] R. Martin, *The Psychology of Humor: An Integrative Approach*. London, England: Elsivier Academic Press, 2007.

[26] T. B. Kashdan and F. D. Fincham, "Facilitating Curiosity: A Social and Self-Regulatory Perspective for Scientifically Based Interventions," in *Positive Psychology in Practice*, ed: John Wiley & Sons, Inc., 2004.

[27] C. Solano and N. Koester, "*Loneliness and communication problems: Subjective anxiety or oobjective skills?," *Personality and Social Psychology Bulletin,* vol. 15, pp. 126-133, 1989.

[28] R. W. Picard, E. Vyzas, and J. Healey, "Toward machine emotional intelligence: Analysis of affective physiological state," *Pattern Analysis and Machine Intelligence, IEEE Transactions on,* vol. 23, pp. 1175-1191, 2001.

[29] J. A. Russell and L. F. Barrett, "Core affect, prototypical emotional episodes, and other things called emotion: Dissecting the elephant," *Journal of personality and social psychology,* vol. 76, pp. 805-819, 1999.