PARO's Stress-Reduction Potential for Older Adults

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As the proportion of older adults in the United States is growing, there is a need to develop methods that enable older adults to maintain well-being in their own homes. Stress, if not managed properly, can hinder older adults' ability to maintain well-being. Efforts focusing on the development of novel methods of stress reduction have identified pet-type robots as being potentially efficacious. The present research will test this effect in one such robot absent of other social interactions and will disentangle the robot attributes that contribute to stress-reduction. Data collection is ongoing, but current results suggest that PARO may reduce stress, but the specific stress-reducing attributes are still unclear. Upon study completion, the results of this research will provide insights into PARO's potential to be a therapeutic tool for older adults and inform design of such robots to maximize their stress-reduction capabilities.

INTRODUCTION

The proportion of older adults in the United States is growing rapidly, largely due to increases in life expectancy and the aging of the "baby boomer" generation (Ortman, Velkoff, & Hogan, 2014). People ages 65 and older are expected to comprise over 20% of the U.S. population by the year 2050. The rapid growth of this segment of the population will have consequences on the hospital-based health care system, resulting in a need for home health solutions that allow older adults to age healthily in the comfort of their own homes (Mitzner, Beer, McBride, Rogers, & Fisk, 2009). Using robots as home-health aids is one promising solution to support older adults' needs for support. However, more attention has been given to designing robots to help with physical tasks than to socio-emotional issues, which are also in need of support. To maximize the potential for robots to be effective agents in a home health system it is critical to first understand key socio-emotional issues that older adults need assistance with, the type of robot that is likely to meet this need and, which characteristics of the robot's design are contributing to the socio-emotional benefits.

Stress and Aging

One key socio-emotional issue is stress. Stress is a complex process that manifests in life as a system of inputs (stressors), appraisals (mentally evaluating and managing these stressors), and outputs (physical, emotional, or behavioral effects of stressors; Salas, Driskell, & Hughes, 1996). One can cope with or manage stress but not ameliorate potential stressors altogether. Of the 22 percent of Americans who report experiencing extreme stress, 66 percent consider managing stress to be important (Anderson et al., 2012). If stress is not properly managed, it can have a negative impact on physical health (Lawrence & Schigelone, 2002), emotional well-being (Watson & Pennebaker, 1989), and task performance (Salas et al., 1996) even when performing simple activities of daily living (Hardy, Concato, & Gill, 2002)

Older adults' may be in particular need of stress reduction because normal changes that are often coupled with aging can compound the negative effects of stress or be stressors in themselves. These include social stressors such as bereavement, but can also be cognitive stress due to age-related slowing on abilities such as fluid intelligence (Bashore, Ridderinkhof, & van der Molen, 1998).

The accumulation of stress throughout the lifespan is also important to consider. Chronic stress has been shown to negatively impact hypothalamo-pituitary-adrenal (HPA) axis functioning which, among other important processes, aids in emotion regulation (Pariante & Lightman, 2008). Because of these regulation deficits, potential stressors that may have been appraised as innocuous earlier in life might have a negative impact on emotions in older adulthood (McEwen, 1998). This creates a dangerous loop in which one physiological mechanism that is being negatively impacted by stress, namely the HPA axis, is the same mechanism that is used by older adults to cope with the emotional impact of stressors.

Because of these widespread influences on a variety of domains, stress may be an ideal target for interventions aimed at extending older adults' healthy tenure in their own homes. Non-robotic interventions do exist and have been shown to be effective, such as cognitive-behavioral stress interventions that teach individuals appraisal techniques that help minimize the negative impacts of stress (Saunders, Driskell, Johnston, & Salas, 1996). However, even relatively healthy older adults might not have all the cognitive resources available to them as they once did, so it is also important to identify therapeutic methods that are not entirely dependent on these resources.

Animal-Assisted Therapy: Pets and Robots

Animal-assisted therapy (AAT) is one method that has been used to reduce stress and increase feelings of positivity. Research in this area has indicated that interacting with live animals can have beneficial effects on quality of life and well-being (Ballarini, 2003). Interacting with pet dogs can lower blood pressure and lead to an increase activity of neurochemicals associated with relaxation and bonding (Odendaal & Meintjes, 2003). Having a pet may also be able to reduce the negative impact of specific stressors such as bereavement (Garrity, Stallones, Marx, & Johnson, 1989). Interestingly, the presence of an unfamiliar dog has been

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shown to attenuate stress (operationalized by salivary cortisol output) and heart rate during a socially stressful situation to a larger extent than having a human friend present (Polheber & Matchock, 2014). However, owning a pet might not be a realistic option for older adults. Pets can be expensive, time-consuming, and physically demanding. For an older adult experiencing pain or general weakness, it may not be feasible to bend over to feed a pet or walk a dog several times per day. Also, pet ownership may be excluded altogether in certain living environments.

A pet robot may be a viable alternative to owning a live animal, because they do not require the time or physical effort involved in taking care of a cat or dog. However, to be a realistic alternative to AAT, pet robots need to be capable of eliciting similar benefits as animal interactions. Indeed, attempts have been made to replicate the effects of AAT and with promising results. When interacting with the dog-mimic AIBO (Banks, Willoughby, & Banks, 2008), dementia patients reported reduced feelings of loneliness. Additionally, interacting with the robotic cat NeCoRo (Libin & Cohen-Mansfield, 2004) lead to increases in pleasure by nursing home residents.

Despite these findings, many of the pet robots used in these studies were not specifically designed for therapeutic purposes and there have been reports that they tend to break (Tamura et al., 2004) or do not sufficiently promote interaction (Shibata & Wada, 2010) when used as AAT substitutes. To increase the likelihood that older adults will accept and use robots as stress-reduction tools in the home, it is important that the robot agent in the human-robot interaction is actually designed for interaction. The robotic seal PARO *was* specifically designed for therapeutic interactivity (Shibata & Tanie, 2001). Namely, its function is to elicit positive emotions such as happiness and relaxation, and it has a coat of soft fur meant to promote engagement. Furthermore, because it is a seal rather than a common household animal, users are able to interact with it without having pre-existing expectations about its behavior (Shibata, Kawaguchi, & Wada, 2012; Shibata & Tanie, 2001).

Previous research on PARO's effect on mood has shown that it indeed may have the potential to increase positivity in those who interact with it. In one study highlighting this finding, PARO was shown to increase happiness, reduce depressive symptoms, and decrease stress (Wada, Shibata, Saito, & Tanie, 2004). However, this effect was examined in a nursing home, where two PARO robots were placed in communal rooms and residents were allowed to engage freely with PARO. Because this was a socially uncontrolled setting, it is unclear if the stress-reduction was due to PARO or due to increased interaction between the residents (which was in fact reported) as a result of PARO being present. Thus, to fully realize PARO's stress-reduction potential, a systematic, empirical investigation of the effect of PARO on stress absent of social interaction with other people is required. Furthermore, beyond understanding if PARO can reduce stress in this demographic (without other people present), to enable designers to maximize the benefits of these types of robots, it is also essential to gain information about the characteristics of the robot that are responsible for the stress-reduction. Specifically, if the presence of PARO turned on while completing a stressful task decreases stress to a greater extent than PARO being turned off in the same situation.

Overview of this Study

The main purpose of the present research is to assess whether PARO can decrease temporary stress in older adults while they engage in a cognitively demanding task and if this effect persists over a period of time. An additional goal is to disambiguate the stress-reducing benefits of PARO's physical attributes (e.g., soft, white fur) from its interactive capabilities (e.g., looking at the user and making sounds, moving its paws and tail). Thus, the primary research questions in this study are as follows: 1) Compared to baseline, does older adults' perceived stress decrease if PARO is present while performing a cognitively stressful task? 2) Is the stress-reducing factor the robot itself (i.e., when it is turned off) or the reciprocal interaction with it (i.e., when it is turned on)? 3) Does the stress reduction persist after PARO is removed?

Based on previous research, that interacting with robotic animals has been shown to have similar benefits as interacting with live animals, it is hypothesized that these older adults' perceived stress *will* be lower when PARO is present during a cognitively demanding task versus when PARO is not present and the same task is completed. Furthermore, we expect that this effect will be stronger for the group in which PARO's power status is "ON", but that there will be a stress-reduction effect for both groups. The third research question (on a lasting stress-reduction effect) is more exploratory, and thus, a specific hypothesis will not be made. It is plausible that PARO's potential stress-reducing capability will only persist while PARO is present, and that stress will increase again once PARO is removed from the environment. This research study has the potential to provide insights into the ability of a robotic pet to reduce stress in older adults without the potential confound of social interaction with others and also into the specific characteristics of the robot that are leading to stress-reduction. The results of this research can inform design of and interventions with animal-type robots as therapeutic agents.

METHOD

Participants

Data collection for this research study is currently in progress. To date, 18 older adults (11 female, 7 male), aged 65 to 77 ($M = 71$, $SD = 3.29$) have been recruited from the metro community in Atlanta, GA, USA. Participants were all generally healthy and living independently (i.e., not in a nursing home or assisted living).

Stimuli

PARO. PARO has tactile sensors on its endoskeleton, which is covered in soft fur to promote interaction. In addition to touch, PARO has sensors for light, sound, and posture. PARO is able to move its neck vertically and horizontally, its front and rear fins, and its eyelids (Fig. 1). It is able to interact with people by interpreting its internal states and sensory information from the environment. PARO also has a diurnal rhythm that provides the basis for its physiological behavior in the form of sleep and wakefulness (Shibata et al., 2012).

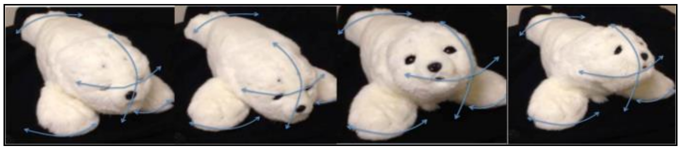

Figure 1: PARO's Range of Motion.

Materials

Ability tests. Participants' near and far vision was assessed with the Snellen Visual Acuity exam. Memory span was measured using the Reverse Digit Span test (Wechsler, 1997), and perceptual speed with the Digit Symbol Substitution task (Wechsler, 1997). The Shipley Vocabulary test (Shipley, 1986) was administered as a measure of verbal ability.

Demographics. Basic demographic information including health and technology experience was collected using materials developed by the Center for Research and Education on Aging and Technology enhancement (CREATE; Czaja, Charness, Fisk, Hertzog, Nair, Rogers, & Sharit, 2006).

Raven's Progressive Matrices Test (RPM). The RPM (Raven & Court, 1998) was selected as the cognitively demanding, stress-inducing task because it is a fluid intelligence test, known to be stressful for older adults. It is a 60-item multiple choice test, typically arranged in progressive order of difficulty. Each question presents a design matrix from which a part has been removed, and the test taker has to correctly select the answer that shows the missing piece in the matrix. For this study, the order of the questions was randomized so that all of the stages were of equal difficulty.

State-Trait Anxiety Inventory (STAI). This measure was used to assess participants' perceived stress before, during, and after completing the stressful task. The test consists of 40 items that measure trait and state anxiety (Spielberger, Gorsuch, & Lushene, 1970). Trait stress was assessed before participants completed the RPM, and state stress was assessed five times throughout the experiment. These scales include items such as "I am tense" and "I feel calm," and are assessed on a 4-point scale (1 = *almost never*, 4 = *almost always*).

NASA Task Load Index (TLX). The 'mental demand,' 'effort,' and 'frustration' subscales of the NASA TLX were used to assess subjective cognitive workload due to the RPM test. The NASA TLX consists of one question for each subscale ("how mentally demanding was the task", etc.) Participants placed an 'x' to indicate their answer on a scale from *very low* to *very high*. This was administered partially as a check to ensure the randomization of the RPM items did not create differentially difficult task sessions and also because it was expected to relate to cognitive stress.

Pre- and Post-Interaction Attitudes Interviews. To gain a general sense of participants' attitudes toward the robot, participants were also asked about their initial overall impression of PARO (before the first STAI and after the last STAI), what they thought it would be useful for, and if they could envision having it in their everyday lives.

Perceived Benefits of PARO Questionnaire. Participants answered a brief questionnaire about the perceived benefits of PARO. This was administered after the final STAI and NASA-TLX, and contained three items asking the participant to what extent they found PARO relaxing, distracting, and stress-reducing during its presence. Questions were answered on a 6-point scale (0 = *not at all*, 5 = *a lot*).

Procedure

Participants came to the Human Factors and Aging Laboratory one at a time and were randomly assigned into the PARO-ON and PARO-OFF conditions. After reading and signing the informed consent form, participants completed the demographics questionnaire, followed by the STAI (both state and trait) and the NASA TLX. Participants were then introduced to the first 20 items of the RPM and were given five minutes to complete as many items as they could, but were told they would likely not finish them. Once the five minutes were up, individuals completed the STAI (state) and NASA TLX again. After the questionnaires were completed, participants were given a 3-minute break. When the 3 minutes lapsed, PARO (either turned on or off) was introduced to the participants and they were given the Pre-Interaction Attitudes Interview. Participants then completed the second set of 20 items from the RPM for 5 minutes while PARO remained in the room, and then completed the STAI (state) and NASA TLX. Another 3-minute break followed. Once the break was over, PARO was taken away and participants were given the STAI (state) and NASA TLX again. Finally, participants were asked questions about their opinions of PARO and were later informed of PARO's abilities, debriefed, and compensated for their participation. See Figure 2.

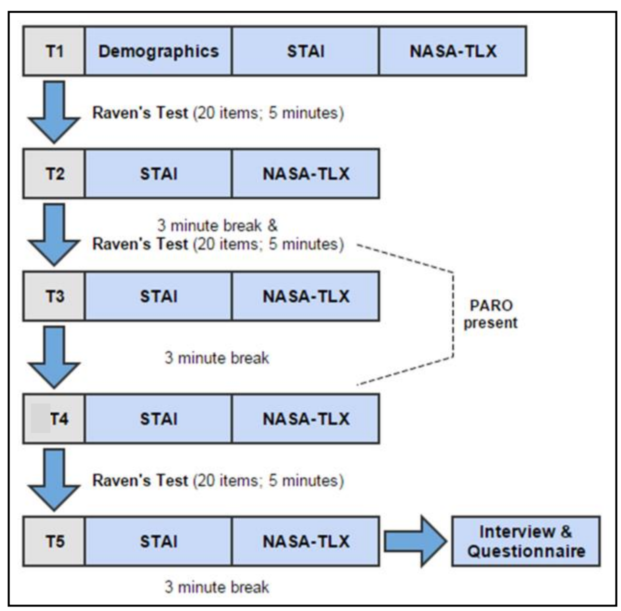

Figure 2: Procedural flow of the study. (T1, T2, etc. = Time 1, Time 2, etc.)

RESULTS

The results of the stress assessments are the focus of this paper. Means and standard errors for stress over the course of the study for both groups are presented in Figure 3. Upon study completion, formal analyses using a Split Plot Analysis of Variance (ANOVA) will be conducted. The potential effect of PARO on cognitive workload (NASA-TLX) and the relationship between stress and cognitive workload will also be analyzed upon study completion. Additionally, the qualitative interview questionnaires will be transcribed and coded to identify response trends.

As seen in Figure 3, there were no between-group differences in stress at baseline (Time 1). As expected, stress increased for both groups (although only slightly for the ON group) after engaging in the Raven's task (Time 2) indicating that the RPM was indeed stressful. After engaging in another Raven's task, but this time with PARO present in the room (Time 3), both groups decreased in perceived stress and continued decreasing after a 3-minute break with PARO (Time 4), indicating PARO's potential to reduce stress during and after a cognitively demanding task. After the final Raven's task, which was completed without PARO present, stress increased for both groups. Of note is that for both groups at Time 5, stress increased again but was still lower than Time 2 (again, only slightly for the ON group), indicating that there may have been a slight lasting effect of PARO. Once the full sample has been obtained, formal analyses will be conducted to assess the statistical significance of the potential effect of PARO on stress.

To provide an overall sense of these older adults' perceptions of PARO's potential usefulness thus far, means have been obtained for the Perceived Benefits of PARO questionnaire items (See Figure 4). Irrespective of PARO power status, the older adult participants tested to date found PARO to be moderately stress-reducing and relaxing, and a little distracting.

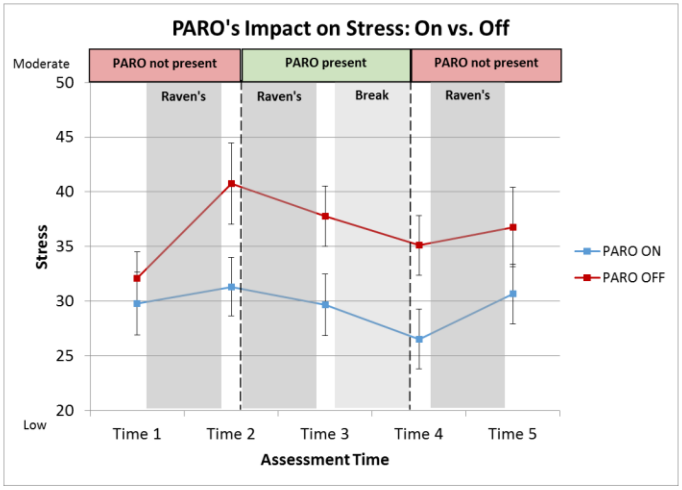

Figure 3: PARO's impact on stress for the PARO ON vs. PARO OFF groups. Error bars represent standard error.

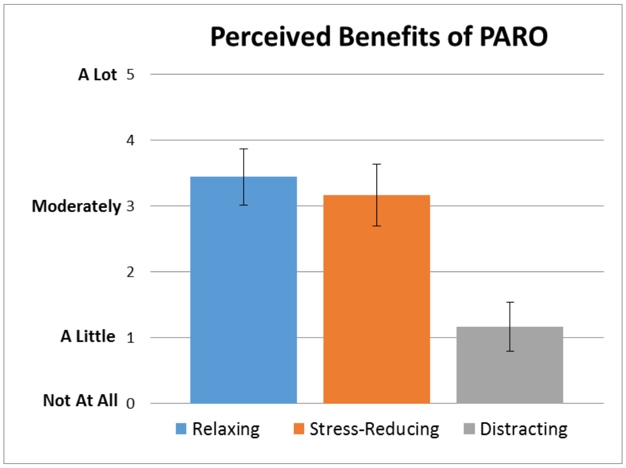

Figure 4. Perceptions of PARO's benefits (n=18). Error bars represent standard error.

DISCUSSION

Older adults experience stress in daily life for a variety of reasons and when not managed properly, stress has widespread detrimental effects on well-being and general performance (Hardy et al., 2002; Lawrence & Schigelone, 2002; Salas et al., 1996; Watson & Pennebaker, 1989). One potential stress management method that has been used has been interacting with live animals (Ballarini, 2003; Polheber & Matchock, 2014). A newer extension of this method that may be more practical for an older adult home is using pet-type robots in the ways that live animals have been shown to be beneficial (Banks et al., 2008; Shibata & Tanie, 2001; Tamura et al., 2004). Previous research on pet-type robots' potential health benefits is promising. However, regarding stress-reduction these studies have been limited in not being able to parse effects of the robot versus effects due to social interaction with other people. Furthermore, to maximize the efficiency of the human-robot stress-reduction system, it is critical to also understand what it is about the robot that facilitates this effect.

The trends in the data collected thus far suggest that PARO may indeed be able to reduce stress during a cognitively demanding task without the aforementioned confound of social interaction with other people. However, the general pattern of stress over the course of the study was similar for both the PARO ON and PARO OFF groups. Thus, PARO's interactivity may not necessarily be the driving force behind the stress-reduction, but it is possible that group differences will emerge in the full sample. An unexpected result in the present sample is that although the groups were similar in stress at baseline (Time 1), the groups' reactions to the Raven's task were much different such that the OFF group increased more dramatically in response to the Raven's and remained higher for the duration of the study. It could be the case that the participants in our OFF group were just more stressed overall, but this will also be analyzed directly in the full sample. Furthermore, future coding of the qualitative interviews will allow for identification of trends in responses that provide information about *why* the results of the quantitative assessments may have been obtained. For example, one could hypothesize that maybe PARO only reduced stress for those individuals who generally liked PARO. We will also assess the relationship stress had with cognitive load for both groups once data collection is complete.

In the present sample, informative patterns have begun to emerge regarding PARO's effect on stress. The results of this study will provide insights into PARO's potential to reduce older adults' stress during a cognitively demanding task, and the specific characteristics of robot (physical attributes vs. interactivity) that are driving this potential effect, enabling designers of robots to maximize therapeutic robots' potential to meet the needs of the aging population.

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