## Research

### Physiological effects of a companion robot on blood pressure of older people in residential care facility: A pilot study

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**Aim:** To investigate the effects of interacting with the companion robot, Paro, on blood pressure and heart rate of older people in a residential care facility.

**Methods:** This study used a repeated measures design. Twenty-one residents in rest home and hospital level care had their blood pressure taken three times; before, during and after interacting with the seal robot.

**Results:** Four residents who did not interact with the robot were excluded from the final analysis (final n = 17). The final analysis found that systolic and diastolic blood pressure changed significantly over time as did heart rate. Planned comparisons revealed that systolic and diastolic blood pressure decreased significantly from baseline to when residents had Paro (systolic, P = 0.048; diastolic, P = 0.05). Diastolic blood pressure increased significantly after Paro was withdrawn (P = 0.03).

**Conclusion:** Interacting with Paro has a physiological effect on cardiovascular measures, which is similar to findings with live animals.

**Key words:** blood pressure, human–robot interaction, Paro, robotics.

### Introduction

Research has found that animals can have a positive effect on health [1–3]. In particular, patting an animal can reduce blood pressure, improving cardiovascular health [4–6]. Subsequent research has found that pet owners, in comparison to those who do not own pets, have significantly lower levels for plasma triglycerides, circulating cholesterol and systolic blood pressure [7]. The presence of pets can buffer the cardiovascular responses to anxiety and stress. In an experimental setting, the presence of a pet dog or cat resulted in lower levels of heart rate and blood pressure, relative to the presence of a friend or a spouse, when people were exposed to a psychological stressor and a physical stressor [8–10]. This indicates that a pet can help reduce stress and calm people. Other research has found that not only does blood pressure decrease when interacting with a dog, but there are improvements in neurochemicals such as oxytocin, norepinephrine, phenylethylamine, dopamine and cortisol levels that are believed to enhance feelings of well-being, mood and relaxation [11].

Research with older people has found similar benefits from pet ownership on physical health. It has been found that older people with pets have lower levels of serum triglycerides, which are associated with a decreased risk of heart attack [12]. Other research has found owning an animal is associated with fewer doctor visits, less medication and less deterioration of daily activity levels [13–15]. Finally, research has found that mortality was higher for former pet owners than current owners, and pet ownership was a significant predictor of maintaining higher levels of self-reported health over four years [16]. To date, little research has been conducted with older people who reside in residential care facilities, focusing particularly on physical outcomes. Research has shown that bringing an animal into a residential care facility has a number of positive effects on the social environment and psychological outcomes [17,18].

Often people who reside in residential care facilities are not permitted to have personal pets. Resident and visiting animals are often incorporated into residential care life, but despite the benefits of animal interactions, the inclusion of real live animals has some downsides. Animals can cause problems in an elder care setting; they may be a trip hazard, may scratch or bite, may introduce parasites and infectious diseases to the environment, and require extra care considerations on top of daily staff duties [19].

Residential care facilities often incorporate animals into their care by encouraging visiting animals or by having resident pets who are cared for by the staff [19,20]. Many organisations have detailed guidelines for introducing animals to new environments to ensure that the health of both the residents and the animals is protected [20]. However, in some cases, resident and visiting pets can cause problems. An alternative to a real animal may be a robotic pet. At present, a number of different companion robots are being developed and trialled throughout the world. Companion robots take the form of a pet or cuddly creature and have been designed to act like a pet [21]. For example, the companion robot, Paro, takes the form of a white baby harp seal [22] and AIBO is a robotic metallic dog [23]. These two robots have been used in the majority of research in this field, although other robots are in...
development [24]. Companion robots have an advantage over real animals, especially in settings such as hospitals and residential care facilities because they require little attention in terms of feeding and care and cannot scratch, bite or bring infections to people. Research conducted with companion robots has found that they have similar benefits to pets in creating a positive social atmosphere, beneficial psychological outcomes and have been found to improve health outcomes [24,25]. However, the research that has been conducted with robots, such as Paro, using physiological measures has been limited to the measurement of stress hormones. Research looking at health effects of Paro in older people have found that Paro is able to reduce stress hormones in urine, indicating better vital organ functioning [26,27].

Methods

Setting
The study was conducted at Selwyn Heights retirement home, in Hillsborough, Auckland, New Zealand, operated by the Selwyn Foundation, a not-for-profit provider of aged care services. Selwyn Heights offers a number of different levels of care including 36 rest home beds, 66 hospital care beds, as well as 116 apartments, units and villas for independent retirement living. It was conducted in the hospital and rest home care areas of the facility and not the independent living units.

Participants
This study was conducted as part of a larger randomised controlled trial looking at the effects of a companion robot in a residential care facility [25]. Residents suitable for the study (capable of completing the study questionnaires) as indicated by the staff, were approached and informed about the trial. If residents were not capable of providing informed consent, next of kin were approached. Ethics approval was obtained from the University of Auckland Human Participants Ethics Committee. Forty residents were randomly split into two groups after recruitment was completed. This was to assess the effects of the robot in people who interacted with it for 12 weeks in comparison to a control group who did not (results published elsewhere) [25]. After the randomised controlled trial was completed, Paro was left at the village and residents from both groups could interact with it. In total, blood pressure data were collected from 21 residents (14 from Paro group, 7 from the control group: 14 women, 7 men: 10 from the hospital and 11 from the rest home). The mean age for this group was 84.9 (7.5), ranging from 71 to 95 years.

Design
This study used a repeated measures design where blood pressure was measured at three time points for each resident; five minutes before seeing the robot, after 10 minutes of interacting with the robot and five minutes after the robot was taken away.

Procedure
The researcher approached residents individually to gain informed consent for the sub-study. She explained that the aim was to investigate the effects of Paro on blood pressure and heart rate and the procedure. The researcher asked residents to make themselves comfortable and rest for five minutes while she waited in the room quietly. She then measured their blood pressure with the portable blood pressure machine, CardioScope II, developed by Pulsecor. This machine has been developed to non-invasively provide a cardiovascular assessment from a standard blood pressure cuff. It measures heart rate, blood pressure, central arterial stiffness and cardiac function, and displays these measurements immediately on screen. The blood pressure cuff was placed on the residents’ non-dominant arm above the elbow according to the instructions of the machine. At each time point, systolic and diastolic blood pressure was recorded as well as heart rate. After taking and noting the resident’s initial blood pressure reading, the researcher brought Paro into the room and turned it on. She placed Paro on the person’s lap, or if they were unable to hold it on their lap, on a table in front of them so they could pat it. The residents had Paro for 10 minutes, during which time the researcher sat with the resident and observed. This period of time was selected as other studies have used similar periods of time and found that blood pressure decreases after interacting with an animal [11]. At the end of 10 minutes, the researcher measured the blood pressure again. She then took the robot away from the room and sat and observed while the resident rested for five minutes before taking their blood pressure for a final time.

Paro
Paro is an advanced interactive robot developed by the Intelligent Systems Research Institute (ISRI), a leading Japanese
industrial automation pioneer [22] (see Figure 1). Paro is modelled after a baby Canadian harp seal and is covered in white fur. It weighs approximately 2.7 kg. Paro has four senses; sight, hearing, balance and touch, meaning that Paro responds to contact, as well as to other stimuli in its environment by moving or imitating the noises of a baby harp seal. Paro operates by using the three elements; its internal states, sensory information from its sensors and its own diurnal rhythm, to carry out various activities during its interaction with people.

Analysis
Repeated measures analyses of variance were conducted to determine whether there were significant changes in residents’ systolic and diastolic blood pressure and heart rate over the three time points. Planned comparisons for repeated measures were also conducted to determine whether there were significant changes in physiological measures between specific pairs of time points (i.e. from baseline to Paro interaction or from Paro interaction to follow-up). Polynomial planned comparisons were used to analyse heart rate as the statistics indicated a downward trend from baseline to follow-up.

Results
Figure 2 shows an older resident interacting with Paro. Data from all residents are shown in Table 1. This table shows that there were no significant changes in blood pressure over the three time periods. However, residents interacted with the robot differently, with some patting the robot a great deal while others patted the robot less frequently. Four of the residents did not interact with or touch the robot and so were subsequently excluded from the analysis. By taking these participants out, it is possible to see the effects of stroking and interacting with the robot on physiology. The results (when these four residents were excluded) show that there were significant changes in systolic and diastolic blood pressure over time (see Table 2). Planned comparisons for repeated measures revealed that when the residents had the robot, systolic blood pressure significantly decreased from baseline, $F(1,16) = 4.6, P = 0.048, \eta^2_p = 0.2$. When the robot was taken away, systolic blood pressure did not significantly change, $F(1,16) = 0.06, P = 0.8, \eta^2_p = 0.004$. Repeated planned comparisons revealed that when the residents had the robot diastolic blood pressure also significantly decreased from baseline, $F(1,16) = 4.4, P = 0.05, \eta^2_p = 0.2$. When the robot was taken away, diastolic blood pressure significantly increased, $F(1,16) = 6.0, P = 0.03, \eta^2_p = 0.3$.

Table 2 shows that there was a significant change in heart rate over time. Polynomial contrasts indicate a significant linear trend $F(1,16) = 6.3, P = 0.02$, partial $\eta^2 = 0.3$. This linear trend suggests that average heart rate decreased over time.

Discussion
This pilot study found that after sitting with and stroking the seal robot, blood pressure decreased compared to baseline
Contrary to the findings of the current study, but since the softness of the robot’s fur was part of the reason for this active and Paro inactive) with six participants aged 25–30 years. They found that with Paro in an active state, participants to Paro in a laboratory setting with four different researchers in Japan [28]. They looked at physiological measures with older people and Paro. The only other research to look at physiological measures was conducted by Robinson H, MacDonald B, Broadbent E. They included that physical interaction with Paro made people active and Paro inactive. More research is needed to determine why systolic blood pressure decreased from baseline to when the residents interacted and stroked the robot. When the robot was taken away, diastolic blood pressure rose again after just five minutes while systolic did not. Previous research has found that blood pressure decreases after stroking an animal [3], animals buffer cardiovascular reactions to stress [9] and attaining a pet and pet ownership has long-term health benefits and reduces the risk of heart disease [1]. However, studies have not looked at physiological changes when the animal is taken away and, hence, it is difficult to determine the amount of time blood pressure remains lowered after the animal is removed. More research is needed to determine why systolic and diastolic blood pressure reverted to baseline measures at a different rate.

There has been very little research looking at cardiovascular measures with older people and Paro. The only other research to look at physiological measures was conducted by researchers in Japan [28]. They looked at physiological reactions to Paro in a laboratory setting with four different stimuli (a roll of soft fur similar to Paro, a roll of vinyl, Paro active and Paro inactive) with six participants aged 25–30 years. They found that with Paro in an active state, participants had changes in heart rate and respiration, indicating an increase in sympathetic nervous system activity. They concluded that physical interaction with Paro made people active and cheered them up as indicated by a measure of mood, and the softness of the robot’s fur was part of the reason for this as well as the interaction with the robot. Their finding is contrary to the findings of the current study, but since the previous study was conducted with younger people in a laboratory setting, this is not surprising. In the current research, it was noted that many residents commented that they were content, happy and relaxed when they were with the robot rather than excited. Hence, their blood pressure decreased and sympathetic nervous activity decreased, although they were still in a positive mood. The residents also commented on how lovely and soft the robot was to touch, which again reiterates how the robot was a comfort to stroke. The results are further supported when considering the results after residents who did not stroke or pat the robot were excluded. When these residents were taken out of the analysis, a significant effect was evident showing the stroking and bonding with the robot in this was may explain changes in blood pressure. The touch and feel of the robot is especially important in this population where older people may not experience a great amount of personal comfort.

Research has found that the presence of a pet can provide non-evaluative social support that buffers stress reactions [31]. Hence, it may be that the presence of a companion robot, like a pet, may be able to prevent older people from experiencing high levels of stress. This is particularly important when taking into account the transition into a residential care facility where an older person experiences a number of losses and may lack in close emotional support from those around them. A robot in this environment may be more beneficial than a real pet because the robot will sit and be stroked and react when a person talks to it or touches it, and thus will act as a companion, whereas a dog or a cat may not sit with a person for a long period of time. Four of the residents were excluded from the final analysis because they did not touch the robot. This is partly reflective of the population that this research was conducted with, as some people were fatigued or not well enough to touch the robot. Others did not feel they needed to touch the robot, just as they would not have patted a pet. In the future, it would be interesting to explore the reasons why older people refrained from engaging with and touching the robot.

This study has a number of limitations. Firstly, because blood pressure was measured in residents who had previously been

| Table 1: Changes in blood pressure and heart rate with Paro with overall F and P values for all residents (n = 21) |

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>F</th>
<th>d.f.</th>
<th>P</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure, mm Hg: mean (SD)</td>
<td>131.9 (26.3)</td>
<td>125.5 (29.9)</td>
<td>124.9 (21.6)</td>
<td>2.2</td>
<td>2.40</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg: mean (SD)</td>
<td>70.2 (14.9)</td>
<td>64.0 (21.0)</td>
<td>69.7 (11.2)</td>
<td>2.3</td>
<td>2.40</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Heart rate, beats per minute: mean (SD)</td>
<td>74.4 (12.6)</td>
<td>72.5 (12.7)</td>
<td>70.2 (12.8)</td>
<td>5.5</td>
<td>2.40</td>
<td>0.008</td>
<td>0.2</td>
</tr>
</tbody>
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| Table 2: Changes in blood pressure and heart rate with Paro with overall F and P values for residents who did not interact with the robot excluded (n = 17) |

<table>
<thead>
<tr>
<th></th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>F</th>
<th>d.f.</th>
<th>P</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure, mm Hg: mean (SD)</td>
<td>128.9 (25.0)</td>
<td>120.5 (29.8)</td>
<td>121.5 (21.8)</td>
<td>3.3</td>
<td>2.32</td>
<td>0.048</td>
<td>0.2</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg: mean (SD)</td>
<td>69.5 (12.2)</td>
<td>69.8 (16.2)</td>
<td>69.0 (7.6)</td>
<td>3.6</td>
<td>2.32</td>
<td>0.04</td>
<td>0.2</td>
</tr>
<tr>
<td>Heart rate, beats per minute: mean (SD)</td>
<td>71.6 (11.5)</td>
<td>69.7 (11.2)</td>
<td>67.6 (12.3)</td>
<td>3.7</td>
<td>2.32</td>
<td>0.04</td>
<td>0.2</td>
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</table>
in the larger trial, it may be that people who had spent more time with the robot reacted differently to those who had not. However, further checks showed no significant differences between groups in blood pressure changes over time. Other limitations of this study include a small sample size, lack of randomisation and a control group. Unfortunately, due to attrition in the larger trial, it was difficult to recruit a higher number of people to participate in this sub-study. The lack of a control group means it is unknown whether a live pet, a soft toy or the presence of the researcher alone would have a similar effect on cardiovascular measures. Finally, the researcher was present during all of the process. This means that the researcher may have had an impact on how residents interacted with the robot and the presence of the researcher alone may have impacted cardiovascular measures.

To conclude, this study looked at the cardiovascular response to Paro in a residential care facility, finding that the robot significantly lowered blood pressure. For older people in a residential care facility, health is very important and needs to be monitored closely. Benefits in cardiovascular functioning may make a great difference to a person’s health and reduce the risk of heart failure and this study shows that a companion robot may have physiological health benefits. However, this was an exploratory study conducted with a small sample size and as this is the first study to be conducted with Paro and cardiovascular outcomes with older people, these results need to be replicated. Future research should aim to build on these findings to explore the health effects of Paro over a longer period of time and in comparison to live pets.

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Key Points
• Previous studies have shown that pet animals can have beneficial physiological effects, including reduced blood pressure.
• Little research has investigated the physiological effects of pet-like robots.
• This study shows that interacting with a pet-like robot can reduce blood pressure in older people.

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