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Physiological and Emotional Responses of Human and Robotic Companionship during Everyday Activities

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***Abstract*— The use of robotic companions in everyday environments is increasing as these systems are developed to support social interaction and assist with routine activities. However, there is still a limited understanding of how the presence of robotic companions influences humans during everyday activities. This study investigated how different forms of companionship—none, human, and robot—affect emotional responses, physiological measures, and gait during a shared walking activity and routine task. Participants completed three trials consisting of five minutes of walking followed by folding a basket of clothes under each companionship condition. Emotional responses were measured using a questionnaire, while heart rate and spatiotemporal gait parameters were recorded using a smartwatch and motion capture suit, respectively. Results showed significant differences in emotional responses between human and robot companionship, with the robot condition consistently eliciting less desirable responses. No significant change in heart rate was found during both the walking and task completion portions of the experiment. Participants also altered their gait when walking with the robot compared with walking with a human, including a decrease in walking speed and walking speed variability, along with increases in stride time, stride time variability and stride width variability. These findings suggest that robotic companionship can influence both emotional experience and physiological behaviours during everyday activities.**

I. INTRODUCTION

Robot companions are becoming increasingly common in a variety of social and assistive environments, where they are designed to support human interaction, engagement, and well-being. These robots are being implemented in settings such as classrooms, where they can assist with learning and student engagement [1], and in elder care facilities, where they are used to promote social interaction and reduce feelings of loneliness [2] [3]. Many of these systems aim to provide social support, encouragement, or companionship during everyday activities.

Previous studies have implemented stationary platforms; however, their use is constrained to fixed settings and predictable interactions. As robotic systems become more mobile and capable of navigating human environments, new opportunities arise for robots to participate in shared activities such as walking, exercise, or daily household tasks. Mobile robots have the potential to provide companionship during dynamic activities, yet little is known about how people emotionally, physiologically, and behaviourally respond to these systems in everyday contexts.

Emotional responses play an important role in determining the success of human–robot interactions. When individuals interact with a robotic companion, their perceptions, comfort level, and overall emotional reactions can influence how effectively they engage with the system and whether they are willing to continue interacting with it [4]. Research in human–robot interaction has shown that factors such as perceived social presence, trust, and perceived companionship significantly influence user acceptance and engagement with robotic systems [5] [6]. Positive emotional responses, such as enjoyment, trust, or companionship, can promote engagement and acceptance of the robot, while negative responses may lead to discomfort, disengagement, or rejection of the technology.

While emotional responses are important, interactions with robots may also influence physical behaviour. When people share space or activities with robots, they may adjust their movement patterns or coordination to accommodate the robot's presence or motion. Understanding how people interact physically with robots can help inform the better design of mobile robots to operate alongside humans in everyday environments.

Our study aimed to determine how different forms of companionship can affect emotional and physiological responses in people during a shared walking experience and routine task performance. We designed a situation where companionship might influence how individuals experience otherwise routine activities. Spatiotemporal measures, heart rate and a quantitative questionnaire were used to evaluate the change in gait behaviour and participants' experience. We hypothesized that robot companionship would not be as enjoyable as human companionship; however, it would be more enjoyable than no companionship at all.

II. RELATED WORKS

A. Social and Companion Robots

Socially assistive robots have been developed to support interaction, companionship, and emotional well-being in a variety of settings [7]. Social robots have seen success in eldercare homes to encourage social interaction and help mitigate feelings of loneliness or isolation [8] [9]. Social robots have also been used to promote reading in children [10] and used in other educational settings, both in children [11] and higher education [12]. Much of the research in this area has focused on stationary or semi-stationary platforms

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that interact with users through conversation, gestures, or expressive behaviours. While these systems can effectively facilitate interaction in structured settings, they are less suited for scenarios that involve mobility or shared physical activities.

B. Human Behaviour During Shared Locomotion with Robots

Recent work has begun to explore how humans behave when moving alongside robotic systems. One example involves studies in which participants walked side-by-side while holding hands with a wheeled humanoid robot companion [13]. In this work, researchers developed a software architecture capable of estimating the forces applied by the participant to guide the robot's motion, enabling the robot to respond to physical interactions in a manner similar to human–human hand-holding during walking.

Other studies have looked at changes in human gait while walking alongside quadrupedal robots without any physical interactions. Those studies have shown that the presence of a robot has a quantifiable impact on gait behaviour [14]. Participants slowed down when walking with a robot compared to when they were alone. Another study found that if the robot walked faster or slower, the participants would adjust their speed accordingly. However, robot height and distance from the participant did not yield an effect [15]. These studies looked at the mechanical changes that humans adapt when walking with a robot, but did not take into account the emotional state of the participants as they walked with a robot. Understanding these combined effects is important for the design of mobile robotic companions intended to operate alongside humans in everyday environments and is the main contribution of this work.

III. METHODS

To study the impact of different forms of companionship on walking experience and task performance during a routine task, healthy adult participants walked for five minutes and completed a mundane task afterwards. These tasks were completed three times per participant, once alone, once with a human companion, and once with a wheeled humanoid robot, Pepper (Softbank, Japan). While completing each trial, participants wore an inertial sensor-based motion capture suit to quantify spatiotemporal changes in human gait. Participants also wore a smartwatch to measure heart rate. To analyze the emotional response during the experiment, participants completed a questionnaire after each trial.

A. Experiment

Healthy adults (N=18, 6 female, 12 male, weight 64.61$\pm$12.62 kg, height 171.32$\pm$9.22 cm, age 21-36 years) participated in this study. Participants walked for five minutes over flat ground and then completed a laundry folding task which included folding five t-shirts, five pants, and five pairs of socks. Participants completed each trial while wearing an inertial sensor suit (MTw Awinda, Xsens, Enschede, The Netherlands) composed of 17 wireless sensors along with a smart watch (Fitbit Charge 6, USA). All participants provided their informed consent prior to the study, and ethical approval was granted by the university's Institutional Review Board.

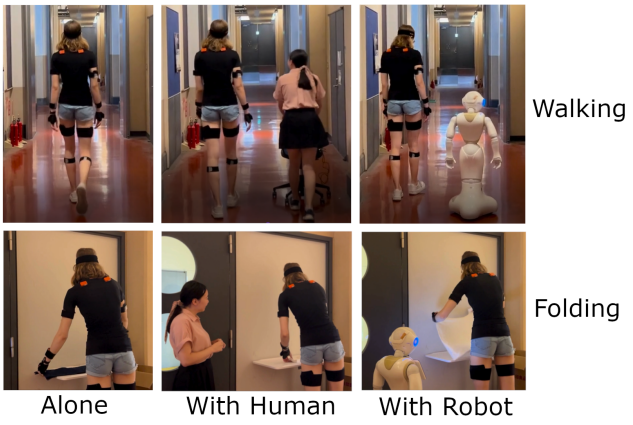


Fig. 1. Participants walked for five minutes and then completed a clothes-folding task. They performed this task alone, with a human companion, and with a robot companion. Participants wore inertial sensors to measure their gait behaviour.

Pepper was programmed to be teleoperated using a gamepad (BIGBIGWON CHOCO gaming controller, Hong Kong). Pepper was programmed with simple voice lines that could be played using the different buttons on the gamepad. Each participant completed three trials: Alone, With Human, and With Robot (Fig. 1). The order of trials for each participant was counterbalanced using a balanced Latin square. During the Alone trial, the participant walked and completed the clothes-folding task by themselves.

During the With Human trials, the participant walked and completed the clothes-folding task while accompanied by a human, the researcher. The researcher started by introducing themselves as the pair started walking. The researcher also made small talk with simple questions like "How are you?" "What do you study?", etc. and had a response to the participant's answers. For example:

Researcher: How are you today?
Participant: I am doing well.
Researcher: That's great!

Similarly, during the clothing folding task, the researcher encouraged the participant by saying "Good job" or "Nicely done".

During the With Robot trials, participants walked alongside Pepper while the researcher followed five meters behind, controlling the robot. Pepper first introduced themselves with "Hello, my name is Pepper, I will be walking with you today". During the walk, Pepper asked participants simple questions such as "What do you do for fun?" or "How are you enjoying the weather today?" and followed up with a simple reply such as "How interesting" or "Nice!". Similarly, during the clothing folding task, Pepper encouraged the participant by saying "Good job" or "This is fun!". The small talk during the With Human trials was designed to be similar to the small talk conducted by Pepper.

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B. Analysis

To study the change in gait behaviour, several spatiotemporal gait parameters (walking speed, stride time, stride length, and stride width) along with their variability were computed using the data collected from the Xsens suit. Stride length was calculated as the anterior–posterior distance between consecutive right heel strikes. Stride width was calculated as the mediolateral distance between the heel positions at right and left heel strikes. All measurements were normalized using leg length L and gravity g. Stride time was divided by $\sqrt{L/g}$ (0.31s), stride length and width by L (0.93m), and walking speed by $\sqrt{Lg}$ (3.02 ms^{-1}). For gait analysis, one participant's With Human trial was excluded due to motion capture recording error. Heart rate changes were tracked using the smartwatch, which collected the participant's BPM every six seconds. The BPM of the participants were split into the two phases of the experiment, walking and folding, and then averaged.

Prior to the experiment, a shortened version of the experiment was conducted (N=2, 2 females) with a semi-structured interview. Participants walked for 150 meters, once alone, once with a human companion and once with Pepper. After the three walks, participants completed a semi-structured interview with the researcher. From the semi-structured interview, keywords from the interview were used to create a post-trial survey that was used in the experiment.

The post-trial survey consisted of five questions that assessed the participant's emotional response based on attention needed, boredom, comfort, experience and pleasantness of the trials. These categories were chosen from the semi-structured interview as they were mentioned several times throughout each of the interviews. Participants rated each of these categories from a scale of one to seven. For example, for the level of attention needed to walk with the robot, one referred to 'much less attention' and seven denoted 'much more attention' (see Fig. 2). Participants were also asked at the end of the questionnaire to provide any additional feedback they would like to give.

To compare the three different conditions, we used repeated measures ANOVA and post-hoc t-tests with Holm-Sidak correction (α=0.05). This analysis was performed for each of the spatiotemporal gait parameters along with their variability to assess the gait changes with each type of companionship. The same analysis was applied to the average heart rate of the two phases of the experiment. The same statistical procedure was also completed on the results of the post-trial questionnaire.

IV. RESULTS

With respect to emotional responses, we found that in all categories tested, there was a significant difference between human companionship and robot companionship. With the robot, the results leaned toward the less desirable option in each category (Fig. 2). For the amount of attention needed on average, participants needed more attention compared to both Alone (p = 1.3e-05) and With Human ($p = 0.012$). Similarly, people were more uncomfortable with the robot compared to being alone ($p = 0.015$) and with the human companion ($p = 0.008$). For pleasantness of the experiment, participants found that being with the robot was less pleasant than being with a human (p = 8.4e-4). Participants also found it was more boring to be with the robot compared to being with a human (p = 3.1e-4). The overall experience was reported to be more frustrating With Robot compared to both Alone ($p = 0.019$) and With Human (p = 2.1e-05).

Despite the changes found in the emotional responses, no significance was found in the average heart rate during both the walking portion ($p = 0.342$) and the task completion portion ($p = 0.284$) of the experiment (Fig. 3).

Participants also altered their gait when walking with the robot compared to both walking by themselves and walking with another human (Table I). Specifically, significance was found in walking speed, stride time, stride time variability, stride length and stride width variability. Significance was also found for walking speed variability between walking with the robot and walking with a human (Fig. 4). For walking speed, there was a 73.3% decrease from walking alone to walking with the robot and a 72.5% decrease from walking with a human to walking with the robot. We also found a 43.5% decrease in walking speed variability from walking with a human to walking with the robot. Participants had a 67.4% longer stride time when walking with the robot compared to walking alone and 72.9% longer than walking with a human. Similarly, there was an increase in stride time variability when walking with a robot, 107.5% compared to walking alone and 98.3% compared to walking with a human. Stride length decreased by 86.2% when walking with the robot compared to walking alone and 53.2% when walking with the robot compared with walking with a human. No significance was found in the stride length variability. Lastly, no significance was found in stride width, while there was 82.1% increase in stride width variability when walking with a robot compared to walking alone, and 56.5% compared to walking with a human.

V. DISCUSSION

Our experiment aimed to determine how the presence of different types of companions—human, robotic, or none—affects individuals' emotional responses, physiological state, and gait characteristics during walking and completion of a mundane task. Our findings indicate that the type of companion present can influence both psychological and physical aspects of human behaviour, particularly during locomotion. Specifically, participants reported less positive emotional responses when accompanied by the robot compared to a human companion, suggesting that the nature of the companion can shape how individuals perceive and experience shared activities. In addition, participants altered their locomotion when walking with the robot, notably exhibiting a slow walking speed, indicating that the presence and movement of a robotic partner can affect how individuals physically coordinate their movement in shared spaces.

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TABLE I

MEASURES SHOWN AS MEAN±S.D. ACROSS PARTICIPANTS (N = 18) AND REPORTED IN DIMENSIONLESS UNITS. STATISTICAL SIGNIFICANCE OF EACH MEASURE IS INDICATED BY AN ASTERISK (*) FOR $p < 0.05$

Gait parameters	Alone (mean±s.d)	With Human (mean±s.d)	With Robot (mean±s.d)	p
Walking speed	0.383±0.068	0.372±0.069	0.102±0.022	4.312e-21*
Walking speed variability	0.051 ±0.029	0.060±0.027	0.034±0.017	0.012*
Stride time	3.849±0.327	3.728±0.467	6.444±0.936	1.573e-18*
Stride time variability	0.557±0.430	0.583±0.294	1.560±0.255	1.166e-06*
Stride length	1.436±0.267	1.338±0.268	0.627±0.150	1.847e-14*
Stride length variability	0.220±0.177	0.207±0.090	0.198±0.061	0.856
Stride width	0.095±0.117	0.108±0.114	0.149±0.091	0.306
Stride width variability	0.061±0.020	0.071±0.026	0.111±0.045	5.519e-05*

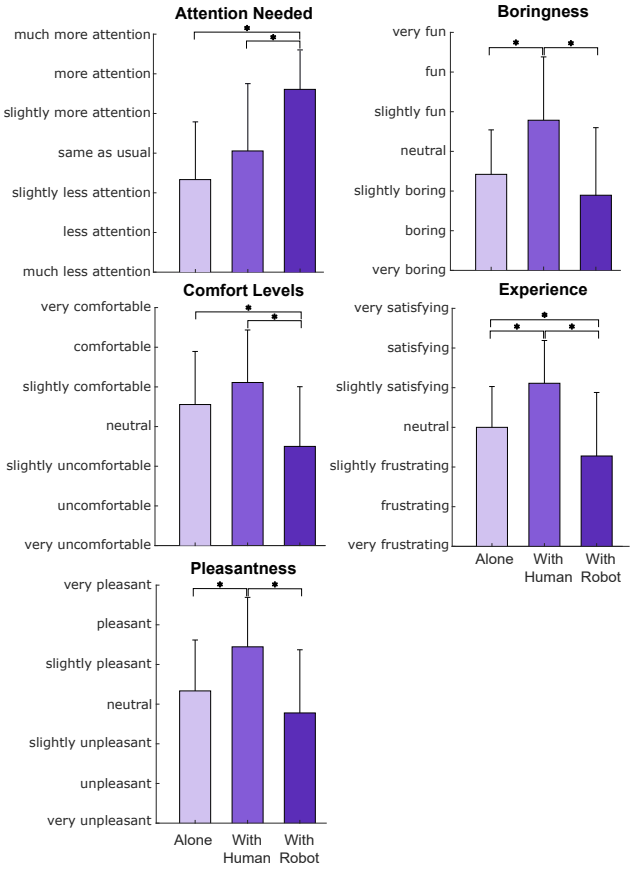


Fig. 2. Average participants' emotional response in five different categories: attention needed, boredom, comfort, experience and pleasantness in response to the different forms of companionship. Standard deviation bars are indicated. Statistical significance indicated by an asterisk (*) for $p < 0.05$.

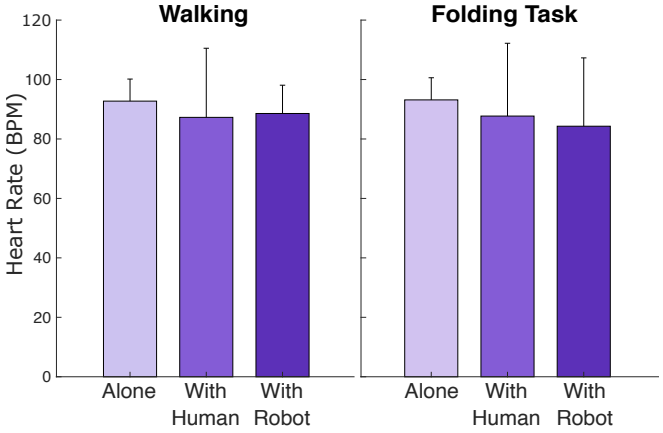


Fig. 3. Average participants' heart rate during the two phases of the experiment, walking and folding. Standard deviation bars are indicated. No significance was found between the different types of companionship in both walking and the folding task.

A. Emotional Responses to Companionship

Participants in this study reported significantly different emotional responses when interacting with a robotic companion compared to a human companion, with the robot condition generally associated with less positive ratings across measures. Participants found that having a robot companion required more attention, was more uncomfortable, more unpleasant, more boring and a more frustrating experience compared to having a human companion. The negative response to the robot could be due to its slowness, possibly provoking impatience in people. Pepper's maximum speed is around 0.8 m/s [16], while the average walking speed of the participants when walking alone was 1.2 m/s. The frustration with the slowness of the robot is also reflected by some of the comments made by individuals in the open question of the post-trial questionnaire. One participant commented, "The slowness of the robot was unpleasant and made the experiment boring." Another commented, "It was very stop and go since the robot is much slower than I usually walk. During laundry folding being watched by the robot was mildly unsettling." Additionally, the robot's ability to interact with participants was limited due to a small set of pre-programmed voice lines, which were constrained by the number of available inputs on the controller. These results suggest that, within the context of a simple daily activity, human companionship may provide emotional benefits that are not currently replicated by robotic companions. Human partners can provide advice and social support that can contribute to feelings of comfort or engagement [17]. In contrast, the robot companion used in this study, despite its demonstrated usefulness in past research to promote social interactions and form communities [18], did not have the capabilities to respond in a socially responsive way, which could negatively influence people's perception of it. These findings align with broader trends in human–robot interaction research, suggesting that while robots can support task performance, they can still cause unease in people compared to having a human companion [19].

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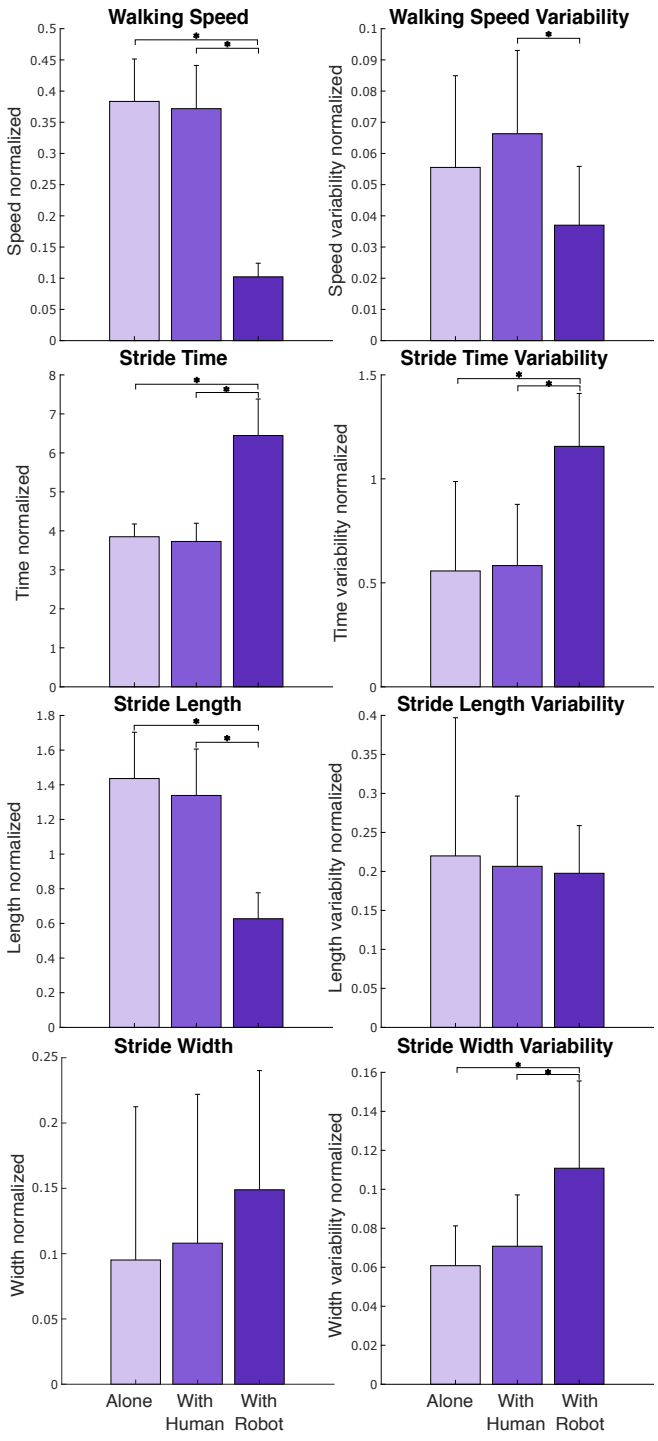


Fig. 4. Average spatiotemporal measures of walking speed, stride time, stride length, stride width and their variability in response to the different forms of companionship. Standard deviation bars are indicated. Statistical significance indicated by an asterisk (*) for $p < 0.05$.

B. Physiological Responses to Companionship

Heart rate analysis revealed no significance during both walking and task completion (Fig. 3). This result may suggest that the activities performed in this study were not physically demanding enough to produce measurable physiological differences between conditions, or that the presence of a companion did not substantially influence participants' cardiovascular response.

Walking with the robot resulted in significant gait changes compared to both the alone and human conditions, including walking speed, stride time, stride time variability, stride length, and step width variability. Walking speed variability also differed between the robot and human conditions. These findings indicate that participants adapted their locomotion patterns when coordinating movement with the robot. Reduced speed and altered stride characteristics could be due to adjustments made to maintain synchronization with a slower or less predictable walking partner as humans have a tendency to synchronize with their walking partner in side-by-side walking [20]. Increased variability in stride time and stride width between Alone and With Robot may reflect participants continually correcting their movement to match the robot's pace or trajectory, a possible additional mental load that would be aligned with the observed negative emotional responses.

C. Implications for Human–Robot Interaction

These findings highlight important considerations for the design of socially assistive or companion robots intended to accompany humans during everyday activities. If robots are to function as walking companions, their movement dynamics, specifically walking speed, may play a critical role in user comfort and natural interaction [21] [22]. Robots that cannot match human walking patterns may inadvertently introduce physical or cognitive burdens on users. Additionally, the observed emotional differences suggest that simply providing physical presence may not be sufficient to replicate the perceived benefits of human companionship. Future robot designs may need to integrate more responsive social behaviours, adaptive pacing, and improved awareness of human movement to create more natural and supportive interactions.

D. Limitations and Future Work

Several limitations should be considered when interpreting these findings. First, the robot's maximum walking speed was 33.3% slower on average compared to the participant, which likely influenced both physiological outcomes. Future studies should examine robots with faster speeds and capable of dynamically adjusting their pace to match individual users. Additionally, the robotic companion used in this study was a wheeled platform rather than a bipedal robot. Human locomotion is characterized by legged movement, and a wheeled robot may be perceived differently from a bipedal companion in terms of social presence, naturalness, and movement coordination. The robot's motion characteristics may therefore have influenced both participants' emotional responses and

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gait adaptations. Future work should investigate whether similar effects are observed with humanoid or bipedal robotic companions whose movement more closely resembles human locomotion. The experimental task also involved a relatively short interaction period, which may not capture how perceptions and adaptations change over longer-term exposure to robotic companions. Lastly, emotional responses may have been influenced by participants' novelty effects or prior attitudes toward robots. Future research should explore longer interactions and different robot behaviours to better understand how robotic companions influence emotional, physiological, and biomechanical responses during everyday activities.

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