The Effect of Interaction with a Robotic Seal on Adolescents' Stress Level

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Abstract

Early adolescence clearly represents a critical period of development during which the risk of stress-related problems is heightened and can be an important time to intervene to prevent mental health problems. Increased levels of stress for adolescents can lead to many negative outcomes, including a decline in academic performance, an increased rate of school dropout, and an increased risk of mental health problems. Previous research has found that interaction with social robots can reduce symptoms of stress in adolescents and that interaction with a robotic seal, PARO, can improve the quality of life in the elderly. A visual facial anxiety measurement (VFAS), blood pressure, heart rate, and GSR were used to assess anxiety levels in 21 adolescents (10th to 12th grade) before and after a 15-minute interaction with PARO. The results of the study found no significant difference in HR and BP before and after interacting with PARO. A 43% decrease in adolescents' VFAS scores was observed after interacting with PARO. These results demonstrated that interacting with PARO decreased adolescents' momentary anxiety levels.

Introduction

Feelings of stress are created when internal or external stimuli ("stressors") trigger a biological response. This feeling called the "stress response," refers to the emotional, cognitive, behavioral, and biological responses to stress exposure and is the result of an individual's evaluation of the stressor (Kokka 2023). Depending on the type, timing, and severity of the stimulus applied the body's biological response can range from homeostatic changes to life-threatening levels. Stressors are an inevitable part of human life, and biological responses to stressors, such as increased breathing and heart rate, and improved vision and hearing, are necessary for survival. However, chronic activation of the body's normal stress response can alter immune function, increase the risk of cardiovascular disease, and increase levels of anxiety and depression (Yaribeygi 2017).

In response to an acute stressor, two main pathways are activated: the hypothalamic-pituitary-adrenal (HPA) axis and the adrenal medullary system (SAM). As components of an interrelated response to stress, the SAM and HPA are hypothesized to work together to facilitate adaptation to stress. SAM activation, also known as the "fight or flight" response, utilizes the nervous system to immediately increase heart rate, blood pressure, respiratory rate, and other functions necessary to deal with a dangerous situation. Because the SAM pathway requires such a large expenditure of energy, one of the primary functions of the HPA is to synthesize and release cortisol, which quickly mobilizes energy stores. Cortisol enhances the overall stress response by increasing the heart rate and blood pressure. Finally, cortisol plays a role in extinguishing the stress response and returning the organism to baseline by regulation of the SAM pathway. The coordination between the hypothalamic-pituitary-adrenal axis and the adrenal medullary system is finely tuned and well-suited to acute stressors that resolve relatively quickly (Wadsworth 2019).

Kokka (2023) defined chronic stress as the exposure to stressful stimuli which, when perceived as prolonged, results in protracted cortisol release, leading to adverse secondary outcomes. The side effects of chronic stress discussed by Aellius Galenus date back 200 years: "Melancholic women are more likely to have cancer than women who were more positive and exposed to less stress" (Yaribeygi 2017). Modern research has shown that chronic stress has detrimental effects on a variety of physical and mental health disorders (Yaribeygi 2017), such as structural changes in different parts of the brain (Lupien, 2009), and atrophy of brain mass and weight (Sarahian, 2014). These changes appear to alter cognition, memory, and even responses to subsequent stressors (Lupien, 2009). These changes appear to occur due to the high density of glucocorticoid receptors in the hippocampus, where these abilities are located (Yaribeygi 2017). In addition to mental health, negative physical effects of chronic stress include the risk of kidney damage, cardiovascular disease, high blood pressure, and high blood sugar (Yaribeygi 2017).

According to Bethune (2014), teenagers in the U.S. showed significantly higher levels of stress during the school year compared to adults, exceeding standards considered healthy. According to the 2021 Youth Risk Behavior Survey (YRBS) conducted by the Centers for Disease Control and Prevention (CDC), from 2011 to 2021 the rate of mental health disorders and suicidal thoughts significantly increased. This survey also includes students who have attempted suicide or have considered attempting suicide. In addition, data from the YBRS showed that 29% of high school students reported poor mental health in the past month, and 42% of high school students reported that they stopped regular activities due to having persistent feelings of sadness for more than two weeks. Looking at trends from 2011 to 2021, the same survey found that women were more likely than men and that Hispanic and multiracial students were more likely to experience persistent feelings of sadness or hopelessness than white students. According to the 2022 Youth Behavioral Risk Survey, they were concerned that having bad mental health would cause serious negative consequences for their development. (YBRS 2022).

A 2018 poll conducted by GlobeNewswire found that 45% of teens say they “always” feel stressed, while 6.3% say they “never” feel stressed. When asked about the cause of stress, 27% of respondents answered 'relationships' and 24% answered 'teachers', including ‘other’ (21%), ‘parents’ (13%), ‘college plans’ (9%), and ‘friends’ (4.2%). Because many of these sources occur within educational settings, schools should be open to the services many youth need. To increase access to needed services, schools can provide health, behavioral, and mental health services and establish referral systems to connect with sources of care in the community (YBRS 2022).

Adolescence is one of the most stressful and stress-sensitive developmental stages in life, and exposure to stress for a long time can lead to chronic dysregulation of physical and mental homeostasis, with detrimental consequences that continue into adulthood (Kokka 2023). Adolescence represents a period of developmental neuroplasticity due to extensive synaptic and cellular remodeling, where the environment is flexible in sculpting circuits and experiences (Sheth 2017). The SAM-HPA system in our bodies can be easily triggered by stress, and it doesn't always calm down quickly, especially in kids who face abuse or other tough situations. This can cause their stress system to stay active for a long time, leading to chronic activation. Symptoms of chronic stress can lead to depression, anxiety, and other psychological problems in our body, and can also lead to problems such as cardiovascular, immunological, metabolic, and central nervous system effects. Additionally, adolescence is an important time to intervene to prevent mental health problems because chronic stress during adolescence can lead to high blood pressure and cardiovascular problems (Sheth 2017).

Chronic stress can be measured in many different ways. For example, in a study by Unver (2020), the Visual Facial Anxiety Scale (VFAS) was used to measure) how anxious children and their parents were before and after playing group games. The VFAS consists of six facial expressions scored from associated numbers 0 to 5, with higher scores indicating higher levels of anxiety (Unver 2020). The galvanic stress response (GSR) measures changes in sweat gland activity that reflect emotional arousal (Villarejo et al., (2012)). In 2012, Villarejo et al examined stress response using GSR, and with a success rate of 90.97%, it was able to detect differences from a relaxed state. Previous research has shown that high blood pressure is associated with cardiovascular disease. A 2006 study by researcher Sonya found that adolescents who were exposed to chronic, negative life events had higher systolic blood pressure (Sonya et al., (2006)). In addition, heart rate also has a strong correlation with stress. Acute stress increases HR, whereas chronic stress decreases HR (Schubert, C et al. (2008)).

To reduce stress levels, researchers have found that animal-assisted therapy (AAT) can improve mood, reduce stress, stabilize blood pressure, and serve as a connection to new people (Shibata 2014). However, because AAT is not always available for various reasons (Wang 2021), animal robotic therapy has been used in addition to animal therapy since 1993 (Shibata 2014). Based on research on several animal forms, Shibata (2014) chose a robot design in the form of a seal, which is unfamiliar to humans but still easily acceptable. In 1993, the social robot PARO (Baby Harp Seal Robot) was designed for pet therapy for elderly people with dementia (Shibata 2014) and has been used in several countries for more than a decade (YU 2015). PARO is a Class II Neurotherapy device among biofeedback medical devices and the first cognitive therapy robot approved by the U.S. FDA in 2009 (Shibata 2014). In addition, PARO has excellent senses of touch, vision, hearing, temperature, and balance, so it behaves like a real animal. Physical interaction with PARO stimulates the user's senses and brain and elicits knowledge and emotions experienced in the past (Shibata 2014).

PARO promotes a positive mood and quality of care experience. Improvement in dementia patients' mood and behaviors through interaction with PARO was observed (Shibata (2021). Caregivers reported that PARO helped individuals become more active, feel relaxed and comfortable, laugh more often, and have brighter facial expressions (Shibata 2021). Exposure to PARO reduced negative emotions and behavioral symptoms in dementia patients. Clinical trials on patients with dementia have shown that the use of PARO reduces Behavioral and Psychological Symptoms of Dementia (BPSD) such as physical and verbal symptoms of agitation (Shibata 2021). PARO was installed at the Ikebukuro Public Health Center in Toshima-city, Tokyo on 11 May 2020 to support the telephone counselors with mental health issues arising from their stressful working environment. Interestingly, from the participant's feedback, it was reported that PARO helped them smile, experience calmness, and feel emotionally healed. Others noted that the presence of PARO in the workplace promoted small talk among coworkers and that it helped them relieve stress (Shibata 2021). Also, cerebral blood flow measured in dementia patients using PARO showed increased blood flow and regional activation in the prefrontal and temporal lobes (Shibata 2014). In 2017, Petersen et al. examined people in aged care facilities by measuring participants' pulse rate, pulse oximeter, and GSR before and after a 20-minute exposure to the robotic pets. PARO increased residents' social interaction, decreased stress and loneliness, and even increased immune system response (Petersen et al.,(2017)). Researchers found significant differences in pulse rates and pulse oximetry readings before and after interacting with PARO(Wang et al.,(2021)). In summary, interacting with PARO promoted psychological and physiological well-being and improved quality of life.'

Stress during adolescence can lead to various physical and emotional issues, like mental health problems, poor school performance, and even dropping out. When asked how they manage stress, teens said online apps and resources were the most helpful source (44.04%), while only 2.54% answered resources provided by their school. Even more shocking is the fact that more than one-third (34.53%) of teens say they do “nothing” to manage stress (Youth Behavioral Risk Survey). Digital technology is a big part of teens' lives, so using it to help them cope with stress at school can also be a good idea. Some recent studies suggest that social robots can actually help reduce anxiety and encourage social interaction among teens. This shows that using technology that teens are comfortable with might be a useful way to support them in school. In 2010, Bjourling conducted an experiment letting participants interact with each of three platforms - physical, digital, and virtual reality- to study whether adolescent stress could be reduced by sharing thoughts and feelings with robotic devices (Bjorling et al., (2020)). Regardless of type of robot, 69% of participants experienced a decrease in momentary stress after interacting with the robot. Among them, the physical robot reduced the stress the most. One of the study participants said that they liked interacting with physical robots because they got used to speaking and the process of expressing their feelings (Bjorling et al., (2020)). Kim (unpublished) examined whether interacting with PARO can decrease stress and anxiety in high school students in a school-based setting. To assess the level of stress, the VFAS was used. The faces were scored 0 to 5 (left to right) with a higher score indicating a higher level of anxiety. Before interacting with PARO, the average VFAS score was 1.67; after interacting with PARO, there was a 76% decrease in the average VFAS score 0.40 (p=0.00086). None of the participants chose a lower VFAS score after their interaction with PARO. This study investigates whether PARO can reduce stress and anxiety in high school students in a school-based setting. The study hypothesized that the participants’ momentary level of anxiety, as measured by the VFAS, BP, Pulse Rate, and GSR, would decrease after the interaction with PARO.

Method

This study was conducted in the BioScience Center of Excellence at Shattuck-St. Mary's School (SSM) in Faribault, Minnesota. This study was approved by SSM's Research Ethics Review Board and was conducted through a convenient sampling of 21 (10th, 11th, and 12th-grade) student volunteers recruited from SSM. Each participant reviewed and signed a consent form prior to participation in this study.

To evaluate the student’s level of stress, this study examined one of the symptoms of stress, which is anxiety, using the VFAS. The VFAS consists of six facial expressions, each depicting a different level of anxiety. The faces were scored from left to right with a higher score indicating a higher level of anxiety. Participants circled the face that best represents how they felt currently. Blood pressure and pulse rate were measured using a Generation GUARD (model number GM-500W) cuff. In addition, GSR was measured using a Neulog sensor (model number NUL-217). A social interactive robot PARO (model number MCR-900) was used to observe whether interacting with it decreased the stress levels in students.

Each participant was given verbal instructions and then left alone in a quiet room while they completed the VFAS. The subject then placed it in an unmarked manila envelope. The researcher returned to the room to measure blood pressure and pulse rate. After measuring their blood pressure and pulse rate, a researcher applied sensors to the 2nd and 3rd phalanges on the nondominant hand to measure GSR for 1 minute. The researcher left the room during this 1-minute time interval. Then the researcher returned, gave further instructions about PARO, and left the participant alone to interact with PARO as they wished. After 15 minutes, the researcher prompted the participant to complete a second copy of the VFAS. The VFAS was then placed in a manila envelope, and the envelope was sealed and given to the researcher. Then, the researcher remeasured the participants' pulse, blood pressure, and GSR. The researcher was not present while either VFAS was filled out, or while the participant interacted with PARO.

To determine whether there was a significant difference in HR, BP, GSR, and VFAS before and after interacting with PARO, a T-Test for 2 Dependent Means was used.

Results

This study examined 21 high school students before and after interacting with PARO. There was no significant change in the average heart rate before (79bpm) and after (76bpm) 15 minutes of interaction with PARO (p-value=0.198)(Table 1). Similarly, there was no significant change in the blood pressure. For systolic blood pressure, there was no significant change before (115.67mmHg) and after (116.29mmHg) interaction with PARO (p-value=0.77). For diastolic blood pressure, there was no significant change before (73.95mmHg) and after (74.52mmHg) interaction with PARO (p-value=0.77). Individual participants' VFAS and GSR data before and after interacting with PARO are listed in Table 2. The VFAS scores showed a 43% decrease from an average of 1.095 before interacting with PARO to an average of 0.476 afterward(p-value=0.00213). The P-value indicates that there is only a 0.213% probability that the difference in the average pre- and post-interaction VFAS scores is due to chance. There was a significant change in the average GSR before (2.13uS) and after (4.53uS) 15 minutes of interaction with PARO (P- value<0.00001). Thus, the difference is likely due to the interaction with PARO. This supports the hypothesis that school-based interaction with PARO decreases high school students' momentary level of anxiety, and thus their general level of stress as determined by the VFAS scores.

Table 1: Heart Rate and Blood pressure measurement before and after interaction with PARO

	Heart Rate(bpm)		Systolic Blood Pressure(mmHg)		Diastolic Blood Pressure(mmHg)	
	Pre	Post	Post	Post	Pre	Post
Average	79	76	115.67	116.29	73.95	74.52
T-value	-1.33		0.18		0.30	
P-value	0.198		0.86		0.77	

Table 2: VFAS and GSR measurement before and after interaction with PARO

	VFAS		GSR(uS)	
	Pre	Post	Pre	Post
Average	1.095	0.476	2.13	4.53
T-value	-3.53		8.67	
P-value	0.00213		< 0.00001	

Discussion

There was no significant difference in heart rate before and after interacting with PARO. This is in contrast to Peterson et al., (2017) who observed a significant drop in heart rate in elderly patients interacting with PARO three times a week for 20 min for 3 months. One possible reason for this difference is because subjects in Peterson's study interacted with PARO significantly longer than in the current study. Another possible reason why there were no differences in HR in the present study is that HR needs to be in homeostasis to ensure that the cardiovascular system functions properly and efficiently. The participants only interacted with PARO for 15 minutes, and HR was only measured before and after, so any change in HR within that 15 minutes would not be observed. Usually, HR and BP have a direct relationship, so it was no surprise that there was no change in BP before and after interacting with PARO. Similar to HR, BP also has to be in homeostasis, which is crucial for several reasons including heart health, preventing damage to blood vessels, kidney function, and brain health. Therefore, a 15-minute time period with PARO may not have been long enough to see a difference in HR and BP.

Previous research has shown that GSR is useful for detecting changes in sweat gland activity, which may reflect the participant's emotional state(Villarejo et al., (2012)). There was a significant difference in GSR before and after interacting with PARO; GSR after interacting with PARO was much higher. This is an unexpected result and is most likely not because participants were experiencing anxiety as the VFAS data shows a significant decline in VFAS scores after interacting with PARO. Possible reasons could be due to participants interacting with PARO in a small warm room. In addition, the fur on the robot could also have contributed to the higher GSR.

It has been previously observed that using VFAS is effective for measuring stress anxiety in adolescents (Unver 2020). There was a significant difference in VFAS before and after interacting with PARO. Kim (unpublished) also used VFAS to measure anxiety levels before and after interacting with PARO for 15 min. Kim (unpublished) demonstrated a 76% decrease in VFAS scores from an average of 1.67 before interacting with PARO to an average of 0.4 afterward. A decrease in momentary stress was also observed in Bjorling et al., (2020), although a slightly different scale was used. They measured momentary stress before and after interacting with a physical robot, digital robot, and virtual robot. The Visual Analog Scale(VAS), which is a computer-based visual scale that has an analog scale from 0 to 100, was used to check the stress level when interacting with robots. They found that adolescent participants had a significant reduction in momentary stress with all three robots, but particularly with the social robots. The Kim and Bjorling study as well as the current study supports the finding that interacting with a social robot, such as PARO, reduces momentary anxiety in adolescents.

This study has a number of limitations, such as the small number of participants and the use of volunteers as convenience samples, which makes it unclear how well the sample population represents the actual student population. To reduce these, the study should be expanded to include more participants who represent a random sample of students. Another consideration is that there is no control to determine if the anxiety level would have decreased after 15 minutes of rest without PARO. In addition, participants were doing their study in a small room, which warmed up quickly

In future studies, a different physiological measure could be used, such as salivary cortisol to measure anxiety. We can also put a GSR sensor somewhere else other than a finger, and we can also make several PARO available in the infirmary, classrooms, dormitories, and training room and examine whether interaction with PARO reduces anxiety level in students.

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