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Brittany Verret
University of New Orleans

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Gender Differences in Autonomic Nervous System Reactivity to Stress

An Honors Thesis

Submitted to the Honors Department of the University of New Orleans
In partial fulfillment of the Requirements for the degree of Bachelor of Science
In Psychology

By
Brittany Verret
bverret@uno.edu
University of New Orleans
Department of Psychology
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Gender Differences in Autonomic Nervous System Reactivity to Stress

Abstract:

The purpose of this study was to disentangle the psychobiological mechanisms and social-evaluative conditions that mediate the process by which the Autonomic Nervous System reacts in male and female humans. We used the original Trier Social Stress Test, as well as two modifications to this original social stressor: a punishment modification and a reward modification. We obtained measures of autonomic (heart rate and respiratory sinus arrhythmia; HR and RSA respectively) reactivity before, during and after the stress test. To distinguish the contribution of the different modifications and any additional difference in reactivity due to gender, the participants were randomly separated into the three modifications, where N=35 (17 male) for the no modification group, N=12 (7 male) for the punishment condition, and N=13 (8 male) for the reward condition. All participants exhibited ANS reactivity to the stressor; females exhibited the most magnified response to all modifications. Overall, the most ANS reactivity was found within the reward condition, with the no modification group showing less reactivity, and the punishment group exhibiting the least amount of reactivity. This suggests that the reward paradigm was the most salient of all the stressors. Evidence indicated that the ANS stress response system is highly sensitive to potential for gain and reward, especially in females.

Key words: Autonomic Nervous System, Trier Social Stress Test, heart rate, respiratory sinus arrhythmia, social evaluation, evolution, “tend-and-befriend,” gender differences, stress.
Introduction:

Behavioral and biological differences between males and females span from the obvious, to the subtle, to the non-existent (Leonard et al., 2008). Genetically, gender differences emerge from the very beginning of life; through the process of meiosis and fertilization, each individual (with rare exceptions) is created with either two X chromosomes, becoming female, or one X and one Y chromosome, becoming male (Campbell & Reece, 2008). Anatomically, the most obvious differences are associated with the systems involved in reproduction, specifically in the hormonal (endocrine) systems and their behavioral and physiological effects, including gonadal differentiation of external and internal genital, differential breast development, muscle mass, height and weight (Campbell & Reece, 2008). By adulthood, anatomical gender differences are obvious, including stature, body fat percentage, pelvic structure, and strength. Males are approximately 6 inches taller than females on average, with females being an average of 5’4, and males being about 5’9 on average (Gustafsson & Lindenfors, 2004). Males tend to weigh about 15% more than females on average, with females weighing an average of 163 pounds and males weighing an average of 190 pounds (Ogden, Fryar, Carroll, & Flegal, 2004). Females typically have a higher body fat percentage than males (Gustafsson & Lindenfors, 2004), and also have a larger hip section as an adaptation for birthing large skulled infants (Campbell & Reece, 2008). One study found that the strength of females ranges from 42-63% of males (Frontera, Hughes, Lutz, & Evans, 1991), showing that males are generally stronger and have more muscle mass on average than females even when adjusting for differences in total body
mass (Maughan, Watson, & Weir, 1983), though it has been recognized lately that the gender gap in strength has recently become smaller (García-Pallarés, López-Gullón, Torres-Bonete, & Izquierdo, 2012). Neuroanatomically, male brains are generally larger on average than female brains. One study found that even after correcting for body height, men’s brains are about 100 grams heavier than women’s (Ankney, 1992), though female brains are more compact with more densely packed neurons, particularly in the region responsible for language (Witelson, Glezer, & Kigar, 1995). Men also appear to have larger visuo-spatial and primary visual association areas in the parietal lobes (Leporé, et al., 2009). These differences may lead to fascinating questions and present day implications in the evolution of differential human brain development between the genders, such as the highly noted distinction wherein women typically possess superior language skills (Harasty, Double, Halliday, Kril, & McRitchie, 1997), and males generally demonstrate more strength in visuo-spatial processing (Leporé, et al., 2009). More subtle gender differences may also be apparent in other physiological systems or processes, though the nature of such subtle gender differentiation is poorly understood; the purpose of the present study is to examine if males and females physiologically respond to stress in different ways.

*What is stress?*

Despite the fact that many research articles have been written about stress and stress-related diseases, no *scientifically* accepted definition of stress or a stressor exists. Pacák and Palkovits (2001) define stress as a state of physical threat
or perceived threat to homeostasis, which is the regulatory system in living organisms that adjusts the internal environment, maintaining a stable and constant condition of properties such as temperature, pH, and heart rate (Cannon, 1929, 1932). Recently, the term “allostasis” has been introduced into stress research; allostasis implies the ability to maintain stability through change, which means that no single set point is optimal for an organism, but that any optimal or adaptive physiological set point can, and indeed may need to, differ across contexts (McEwen, 1998). If allostatic responses are efficient, adaption occurs, and the organism is protected from damage; but if allostatic responses are inadequate, over-stimulated, or prolonged beyond the point of adaption, the resulting allostatic load can cause damage to various organs and may even lead to physical disease and/or mental disorder (McEwen, 1998; Schulkin, McEwen, & Gold, 1994). It is fundamentally important to understand the interaction between biology and stress, as well as the possible risks and benefits of such interactions, because of the innumerable positive and negative implications on human health, some of which are further extrapolated upon later in this article.

We now know that not all events which elicit a stress response are inherently negative (Berk et al., 2001). There has been a definite differentiation made between what is traditionally thought of as “stress” and what has been recently termed as “eustress;” stress denotes negative situations that are harmfully stressful, while eustress defines positively-valenced situations capable of triggering an adaptive stress response that may actually help the responder to attain the possible benefits within the present situation (i.e. attain the reward). Simply put, the difference lies in
whether the stressor produces a maladaptive or adaptive response. In these potentially rewarding situations, the stress response system has been reported to play a role in and respond to circumstances such as sports competition (Bateup, Booth, Shirtcliff, & Granger, 2002; Gonzales-Bono, Salvador, Serrano, & Ricarte, 1999; Kivlighan, Granger, & Booth, 2005) and laughter (Berk, Felten, Tan, Bittman, & Westengard, 2001), in addition to social situations involving accessing skills that could potentially aid the responder in better coping to ultimately achieve his/her given goal. Putatively positive or “rewarding” experiences can be physiologically arousing if the context requires mobilization of physiological resources for individuals to achieve their end, even if it is those very same resources enacted here that are reactive to contexts that are not so positive or “rewarding”.

*The Autonomic Nervous System*

Cardiovascular disease is the foremost cause of mortality and morbidity in the United States, and more than 1 million Americans suffer a heart attack every year (National Heart, Lung, and Blood Institute, 2012). Autonomic Nervous System (ANS) reactivity to stress may offer a window into the mechanism underlying various heart diseases in males and females, and is hence relevant to our study for several reasons. The ANS, the forerunner of stress reactivity, is part of the Peripheral Nervous System that directly affects heart rate, perspiration, salivation, urination/defecation, digestion, respiration rate, pupil diameter and sexual arousal. The ANS is a visceral internal organ control system that operates mainly below the conscious or voluntary levels, though a few of its actions, such as breathing and
urination, can also work in harmony with the conscious mind. The ANS is comprised of two sub-systems that generally function in opposition to each another; however, these systems can operate in a dynamic equilibrium rather than antagonistically (Berntson, Cacioppo, & Quigley, 1991). These two branches, the sympathetic and parasympathetic nervous systems (SNS and PNS, respectively), exhibit a variety of activation patterns (Berntson, Cacioppo, & Quigley, 1991).

The SNS is considered the accelerator of the ANS, whose sympathetic nerves are autonomic branches of the Peripheral Nervous System that descend from the Central Nervous System to the lower-spine region. The SNS is responsible for activities that, and also stimulates functions which, require rapid “fight-or-flight” responses for dealing with immediate threats, including responses such as increasing heart rate (HR), dilating the eyes’ pupils and the lungs’ bronchioles, constricting blood vessels, activating sweat secretion, inhibiting digestion, as well as promoting ejaculation. That being said, it is also continuously active at the basal level to promote the up- and down-regulation of homeostasis. Increases in HR, for instance, facilitate acute psychological (vigilance and arousal) and physical (dilation of pupils and blood sent to peripheral muscles) changes that provide the individual with the ability to deal with an immediate threat. Increased HR in response to a challenge is considered an adaptive coping strategy; in fact, decreases in HR in response to a challenge can indicate behavioral dysregulation, including aggression (Gottman et al., 1995) and antisocial behavior (Ortiz & Raine, 2004). HR is a widely accepted and validated measure of SNS activation (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004), and as such, our study will be measuring HR as
an indicator of acute physiological arousal in the ANS, primarily as a measure of the SNS.

The PNS is conversely considered the brake of the ANS, stimulating “rest-and-digest” functions, and as suggested, is activated when the body is at rest, which includes responding to less imperatively immediate activities in the lack of a threatening presence by promoting functions such as slowed/relaxed breathing, salivation, urination/defecation, digestion, lacrimation (tear formation) and sexual arousal (Porges, 2011). The parasympathetic nerves are autonomic branches of the Peripheral Nervous System that descend from the Central Nervous System to the upper-spine region. Respiratory Sinus Arrhythmia (RSA) refers to fluctuations in heart rate related to the respiratory cycle. RSA is an index of the PNS control over positive and negative environmental demands, with acute changes in RSA occurring in conjunction with emotional experiences or self-regulatory efforts (Beauchaine, 2001); therefore, we will be measuring RSA as it is an indicator of PNS activation, as it is widely and validly accepted as such (Berntson, Cacioppo, & Quigley 1991; Berntson, Cacioppo, & Quigley, 1993; Berntson et al., 1997; Masi, Hawkley, Rickett, & Cacioppo, in press). Increases in RSA support social engagement behaviors by promoting a form of relaxation adaptive to such a context, whereas decreases in RSA support the metabolic requirements for sympathetic activation (i.e., increases in HR). HR and RSA are often inversely related, almost working like a symphonic crescendo respective to decrescendo, where decreases in one measure supports activation in the other (RSA drops/“rest-and-digest” deactivates, and HR rises/“fight-or-flight response” allows for mobilization; and vice-versa), though
there are noted exceptions (Allison et al., in press). While the “fight-or-flight”
response is typically attributed to increased SNS control (Sapolsky, 1998), both SNS
and PNS are crucial for regulating stress-induced behavioral adaptation (Hastings et
al., 2012; Allison et al., in press); and with RSA being a hallmark of the PNS, and HR
being a classical marker of SNS, both measures are fundamentally necessary to
create a more complete and comprehensive picture of ANS functioning.

Evolutionary Theories of Gender Differences

Gender differences appear to exist for a plethora of evolutionary reasons, and
evolution proponents often intend to imply physical, behavioral, physiological, and
mental differences as related to gender. Current theoretical models aimed at
understanding physiological processes, and more specifically, gender differences in
physiological processes, have increasingly used evolutionary theoretical models for
a variety of reasons: (a) the distal mechanisms implied by evolutionary models are
likely instantiated in very old physiological systems, such as the ANS, which are
conserved phylogenetically across higher order species; (b) stress physiology would
have been a process that informed survival and would have strong pressures
throughout human evolutionary heritage through natural selection; (c) sexual
selection, how traits are selected through reproduction and offspring survival,
permits specific hypotheses about why males and females differ rather than just
cataloging how they are different (Bjorklund & Kipp, 1996; Taylor et al., 2000). In
this study, evolutionary theory is used to guide an understanding of the biological
systems involved in stress responses, but in no way is meant to discount or
contradict or minimize the important role that proximal social or cultural factors
play. Indeed, describing physiological responses to proximal social contexts (such as the presence of social evaluation, reward or punishment) profoundly illustrates the importance and pervasive influence of social context.

Traditionally, the survival mechanism of “fight or flight,” both physiologically and behaviorally, has been more-or-less applied to both males and females as a universal truth (Cannon, 1932), but recently Taylor and colleagues (2000) criticize the stress field for primarily limiting studies to only males and then haphazardly extrapolating and generalizing these results to females. Taylor and colleagues instead suggest that male’s and female’s survival mechanisms, and consequently present day stress coping, are inherently different, such that during times of stress, males are more prone to the mechanism of “fight or flight” and females are more likely to rely on the juxtaposing mechanism of “tend-and befriend.” “Tending” refers to nurturing activities designed to protect oneself and offspring, which promote safety and reduce distress; “befriending” is the creation and maintenance of social networks that may also aid in tending (Taylor et al., 2000). Taylor and colleagues use this evolutionary model to point out that the fight-or-flight response would not have been adaptive for females who may have been pregnant, lactating, or with small children for much of their reproductive years, and also that because of the smaller stature of females on average, they would not have been as successful as males at using their physical prowess to survive. Instead, females may have had to develop a different set of skills sculpted through natural and sexual selection, and it is because of this uniquely increased necessity to practice these skills, that females would have consequently excelled at them more so than males. Accordingly, Taylor
points to the female advantage of social information processing and social skill application as a skillset for which females consequently had more ample opportunity to sharply develop and select for over evolutionary time, and that this may likely point to the gender differences witnessed in present day society. 

Applying this model to stress physiology, a stress response that elicited aggressive or fleeing behavior may have been somewhat or more adaptive for males, yet, as previously stated, it may not have been an appropriate response to the challenges faced by females (Taylor et al., 2000); these gender differential responses may well have been learned from direct experience, and/or may have been taught from someone’s previous direct learning experienced, and perhaps even gradually passed down culturally as an effective means of differential survival (Eagly & Wood, 2009). For example, a mother’s attack on or flight from a predator might render offspring fatally unprotected, and would therefore be considered an inappropriate behavior and maladaptive to the context (Taylor et al., 2000). This being noted, it is not to say that “fight or flight” does not characterize the primary physiological responses of both genders or that males desire less social support or even that males do not also rely on “tend-and-befriend.” Instead, it is meant to indicate that compared to males, females do not rely as much on dominating others, challenging situations, risk taking, and/or escaping overwhelming challenges. This gender difference is born out of present-day behavioral observations that males are 10 times more likely to engage in risky and dominant behavior than are females (Moffitt, Caspi, Rutter, & Silva, 2001). This theory (Taylor, 2000) emphasizes a stronger focus for females toward not only calming offspring and/or moving them
to safety as to more likely aid in survival, but also affiliating with others, usually other females, who will also help care for their children as well and deal with other survival challenges through alliance building and managing interpersonal relations (Booth, Granger, & Shirtcliff, 2008). Since there were greater selection demands on prehistoric females than males to restrain inappropriate behavior in some contexts, it is not a far reach to consequently observe remnants of such differential selection demands in modern-day men and women (Bjorklund & Kipp, 1996).

What Taylor and colleagues (2000) propose is that, over time, males and females evolved distinctly different, primary modes of coping with stress, and that this is reflected by the gender differences in the stress responsivity noted today. Female's and their offspring's survival was increased if females “stuck together” as a collective defense against predators more so than did the survival of males (Taylor et al., 2000). Because females inherently evolved to require more social support to survive than males, one would expect a strong tendency among females today to seek social support under conditions of stress. Human and animal data is consistent with this trend, where females show a greater propensity to associate with each other during stress than do males, who instead prefer a more individualistic orientation (Bell & Barnard, 1977; Bull et al., 1972; Luckow, Reifman, & McIntosh, 1998; Taylor et al., 2000). This may have resulted in a gender disparity, such that females will preferentially engage in and benefit from the rewards of social associations, since the loss of this has meant possible death to their ancestors.

Based on this evolutionarily determined gender difference in stress reactivity, we hypothesize that females will show a heightened stress response to a
paradigm that involves social reward because they will be forced to access social skills, which involves relying upon the already well established, evolutionarily advantageous “tending-and-befriending” to manipulate their social observers (Taylor, 2000). One might initially expect that males will show a more heightened stress response to punishment paradigms, rather than one of reward, because theoretically, they will be forced to rely upon the mechanism of “fight-or-flight” in response to the threat to avoid punishment (Taylor, 2000). However, we do not anticipate that males are completely devoid of social understanding (Geary & Flinn, 2002), but can also rely on the same mechanism of “tend-and-befriend” during the reward paradigms. Contrary to the idea that males solely rely on the mechanism of “fight-or-flight,” we maintain that this study will evidence the human species' flexibility in depending upon whichever mechanism is most beneficial to the situation (Taylor et al., 2000). Since the core of the stressor is one of social evaluation, it requires a social coping mechanism, one that both males and females are capable of accessing. We thus hypothesize that males, just as females, are inclined to adjust to the situation to bring forth whatever is needed to produce the most desired result, and are thereby both capable of managing stress through “tending-and- befriending,” and as a result, both will likely display heightened responsivity to the reward paradigm.

**Gender Differences Investigated**

A valid question emerges as to whether these distal, small, evolutionary underpinnings of gender differences actually translate into observable gender
differences in behavior, health and psychopathology. In their 2001 report targeting the biological contributions to human health, the Institute of Medicine (IOM) attempted to tackle the question, “does sex [gender] matter?” Their investigation culminated in three key findings: (1) gender does matter; (2) the study of gender differences needs to transition from descriptive to experimental; and (3) any barriers in the analysis of gender differences need to be eliminated. Small, reliable gender differences in physical health and psychological well-being indeed are documented. Males and females are capable of different immunological responses, retain dissimilar patterns of metabolism and energy storage, and are differentially susceptible to disease (Wizemann & Pardue, 2001). These dynamics contribute to differences in health outcomes, including noteworthy gender differential rates in bacterial diseases (Michael, Bundy, & Grenfell, 1996), autoimmune diseases (Beeson, 1994), risk for and effects of hypertension (National Center for Health Statistics, 1999), and presentation of coronary heart disease (National Center for Health Statistics, 1999). These heart health differential outcomes are especially relevant to the present study as we are investigating the ANS, which, as previously stated, includes coronary measures and reactivity.

Stress related health issues are often inseparably tied with mental health. Psychopathological mental illnesses also display clear gender differentiation, with males being 4-7 times more likely than females to be diagnosed with autism spectrum disorders (Harwood, Miller, & Vasta, 2008), 3 times more likely to be diagnosed with ADHD (Gershon, 2002), and 2-4 times more likely to be diagnosed with conduct disorder (Moffitt, Caspi, Rutter, & Silva, 2001). Females, on the other
hand, are twice as likely to be diagnosed with major depressive disorder (Nolen-Hoeksema, & Keita, 2003) and 8-10 times more likely to be diagnosed with an eating disorder (Lewinsohn, Seeley, Moerk, & Striegel-Moore, 2002). The mechanisms behind these outstanding gender differences are not yet understood, but, as the IOM report confirms, experimentally investigating the origin of gender differences is imperative, as it will contribute to the scarce poverty of knowledge on the subject and perhaps consequently aid in differentially preventing and treating such gender-specific maladies.

*The Trier Social Stress Test*

Various laboratory and experimental stressors have been developed and standardized in order to empirically study the biological stress response system (McRae et al., 2006). A meta-analysis of laboratory stressors by Dickerson and Kemeny (2004) revealed that tasks involving uncontrollability and social-evaluative elements were associated with the largest increases in cortisol (a hormone released in times of stress), as well as the longest recovery times. The Trier Social Stress Test (TSST) is the most effective and widely used laboratory social stressor in the world (Kirschbaum, Pirke, & Hellhammer, 1993). The test consists of an anticipation period, a test period (which contains a social evaluative factor and uncontrollability) involving public speaking and mental arithmetic, and a recovery period. Social evaluation is considered a salient and reliable pathway to physiological reactivity (Dickerson & Kemeny, 2004), and valid and reliable measures of this reactivity are relatively easy to obtain. Dickerson and Kemeny’s (2004) meta-analysis of the TSST provided a conceptual model to explain why the stress test so reliably activates
physiological systems. They assert, in line with the self-preservation theory, which argues that threats to the social-self initiate psychological, physiological and behavioral responses as coping mechanisms, that potential or actual negative evaluation results in robust and reliable activation of the stress response systems. The evolutionary motive of the social human species is to form and maintain attachments and interpersonal relationships (Boomsma, Willemsen, Hawkley, & Cacioppo, 2005), and this human tendency to shape social connections extends from kin and close friends all the way to real and imagined others (Epley, Waytz, & Cacioppo, in press); therefore, any threat to these social connections being severed or damaged (via potential or actual negative evaluation, for example) is highly relevant to the stress response, and one’s physiology is highly attuned to this social information.

Though the TSST is now a common laboratory stressor and much is known about its effect on physiology in many individuals, there is still some unexplained inter-individual gender variability in physiological response profiles. The TSST contains the elements of social evaluative threat and unpredictability, but it is also currently unknown if the truly effective mechanism of the TSST is the social evaluation test or the element of unpredictability. The present study allows for this entanglement to be deciphered- though unrelated to the present hypotheses, it is interesting to note that since the present study is a mix of achievement stress with social evaluation, it could now be ascertained as to whether the gender difference in reactivity is attributable to social evaluation or the uncontrollability factor, as the modifications include a heightened social-evaluative factor but do not modify the
uncontrollability from the original TSST. Of particular interest to the present investigation are the consistent gender differences reported; males generally display higher cortisol hormonal responses to the TSST than females (Kudielka & Kirschbaum, 2005). In line with this, Stroud and colleagues (2002) found that males tend to physiologically react more to tasks designed to evaluate achievement or performance, such as mathematics and verbal tasks; females, on the other hand, are more physiologically responsive to tasks that involve potential or actual social rejection or judgment. Since this laboratory task is inherently an achievement-oriented, social-evaluative stressor, these findings cement the reported gender differences in TSST reactivity (Kudielka & Kirschbaum, 2005).

**Aspirations of the Present Study**

It is immeasurably important to identify whether males and females respond similarly to different types of stressors because of the innumerable health implications. Equally imperative is investigating if there are gender differences in the differential environmental conditions that elicit ANS reactivity because such insights will contribute to an understanding of the specific physiological impact of the stressful context and could perhaps illuminate a more effective, gender-specific prevention and/or treatment of such stress responses. This study sought to do so by modifying the original TSST to include a reward or punishment paradigm to tap into what kinds of stress (social evaluation, eustress, uncontrollability, reward, punishment, etc.) most reliably activate this sensitive, yet powerful, responsivity system in males and females respectively. This may result in a clearer
understanding of what kinds of stress can promote or hinder productivity and human health; therefore, investigating alterations in ANS reactivity (i.e., HR and RSA responses) during stress is particularly imperative due to the link between increased cardiovascular reactivity and various other heart diseases.

The objectives of the present study are to determine whether (1) males and females show similar responses in HR and RSA during an acute laboratory stress test; (2) the threat of punishment or the possibility of reward alters HR and RSA stress reactivity; (3) males and females show similar responses in HR and RSA to threats of punishment and to the possibility of reward.
Methods:

Participants:

60 participants (32 male), ages 18-25, were recruited to participate in an ongoing study at the University of New Orleans in the SPIT (Stress Physiology in Teens) laboratory. Individuals were recruited from the Greater New Orleans area via announcements and flyers to take part in the Trier Social Stress Test, a well-validated and very salient laboratory stressor (Kirschbaum, Pirke, & Hellhammer, 1993). Participants were only recruited if they expressed a desire to do so. They were subsequently compensated $15 upon participation and could possibly receive extra course credit per their instructor's discretion. The sample size of the present study included N=35 (17 male) for the no modification group, N=12 (7 male) for the modification 1/punishment group, and N=13 (8 male) for the modification 2/reward group. The no modification group was substantially larger than the other groups due to time constraints and because the modifications were not implemented until later in the overall study. Gender was determined upon a self-report basis. 44% percent of the sample was Caucasian. The research protocol was approved by the UNOIRB.

Procedure:

Via phone or email communication, participants were scheduled for a laboratory visit specifically from 2-4:30pm (2.5 hours) in order to control for the naturally occurring and time-sensitive circadian variations in physiological functioning.

Upon arrival, participants were amicably greeted by the experimenter (who was generally gender-matched to the participant), given a bottle of water to prevent dry mouth, and presented with the Informed Consent to read and sign if they agreed to the terms and conditions. If the experiment was run under modification 1 or 2, the participants were given $10 at this point, and if no modification was present, no monies were yet dispersed.

ANS data was collected continuously throughout the duration of the laboratory visit via Mindware Technologies LTD hardware. Electro- and impedance cardiography was utilized to obtain noninvasive indices of ANS activity. By applying sterile electrodes to the participant in 9 upper body locations (after using alcohol wipes to sterilize the application areas), physiological information was transmitted to a small ambulatory monitoring device (MW1000a, Mindware Technologies LTD).
This device was worn by the participant to continuously measure HR and RSA. An inactive microphone was also attached to the collar of the participants’ shirt to enhance the psychological impact of the stress test.

Routine to the TSST, minor deception was used in order to facilitate the stressfulness of the TSST tasks: participants were told that a panel of judges, in front of whom they would speak, were experts in verbal and non-verbal behavior, and to imagine that this was a job interview for their own very lucrative dream job, when, in fact, the panel was comprised of undergraduate and graduate students (Kirschbaum, Pirke, & Hellhammer, 1993). The participant was then given 10 minutes alone to prepare for the speech. The preparation period was designed to heighten the effect of anticipation, and the task itself was designed to enhance the stress response via social evaluation (Kirschbaum, Pirke, & Hellhammer, 1993). Participants were also videotape recorded during the TSST tasks (Kirschbaum, Pirke, & Hellhammer, 1993).

The participant was then led out to the interview room, where they stood on a raised platform stage with bright spotlights shining on them, and 3 stern-faced confederates (student interviewers) were seated directly in front of them, for the socially evaluative part of the TSST protocol, in which the confederates instructed the participant to speak for the entire 5 minutes. If the participant paused throughout the task for more than 3 seconds, one of the confederates unemotionally prompted the participant every time by saying, “You still have time. Please continue [speaking]” (Kirschbaum, Pirke, & Hellhammer, 1993). After the 5 minutes of the speech task passed, one of the confederates instructed the participant to stop speaking, and the TSST protocol was adapted to one of three modifications at this point in the procedure:

(0) **No modification.** The participant was immediately instructed to perform a working memory/mental math task for the remaining 5 minutes of the stress test, which involved subtracting the number 13 from 6,233 aloud (i.e. 6,233-13=6,220), and continuing to subtract the number 13 from the remainder (i.e. 6,220-13=6,207; 6,207-13=6,194...) until time was up. If the participant incorrectly subtracted, he/she was then instructed to start over from 6,233 (Kirschbaum, Pirke, & Hellhammer, 1993).

(1) **Modification 1 (punishment/loss potential).** The confederates whispered to each other immediately after the 5-minute speech task, appearing to discuss the participant’s performance. The participant was then informed that his/her performance was not meeting the desired standards, and that he/she would lose his/her monetary compensation if he/she did not improve. The participant
was then instructed to begin the mental math task described above.

(2) **Modification 2 (reward/gain potential).** The confederates similarly whispered to each other immediately after the 5-minute speech task, also appearing to discuss the participant's performance. The participant was then informed that his/her performance was not meeting the desired standards, but that he/she could increase his/her monetary compensation he/she improved. The participant was then instructed to begin the mental math task described above.

After the 5 minutes of the math task passed, the participant was told to return to the preparation room. From this point of the study, the participant did relatively non-stressful activities, such as filling out questionnaires, for approximately an hour and ten minutes. This promoted physiological recovery from the stressor, thereby returning the participant's reactivity equivalent to baseline physiological and emotional functioning. The participant was then disconnected from the electrodes, given compensation, and debriefed that his/her performance was never being judged (Kirschbaum, Pirke, & Hellhammer, 1993).

**Measures:**

We collected ANS activity via Mindware Software Technologies throughout each participant's laboratory visit with electrodes containing wires that detected the electrical signals from the heart, as well as breathing activity. These wires were connected to a PDA that uploaded the HR and RSA to a computer program. The measures collected include:

- **A.) Heart Rate (HR):** HR is defined as the number of heartbeats per unit of time (typically per minute) and is based on the number of ventricular (lower chambers of the heart) contractions (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004).
- **B.) Respiratory Sinus Arrhythmia (RSA):** RSA is a naturally occurring physiological phenomenon characterized by variation in heart rate patterns with respect to respiratory activity, and consists of increases and decreases in beat-to-beat intervals occurring at rates that correspond to pulmonary inspiration and expiration respectively (Berntson et al., 1997). This HR variability associated with RSA is believed to be an indicator of changes in vagus nerve activation of the heart, and this vagal innervation of the heart has been shown to be an index of PNS activation (Berntson, Cacioppo, & Quigley 1991; Berntson, Cacioppo, & Quigley, 1993; Berntson et al., 1997; Masi, Hawkley, Rickett, & Cacioppo, in press).
Data preparation and analysis

The continuous ANS data was separated into meaningful intervals in order to assess reactivity in a repeated measures design. These segments included:

- 5 minutes of baseline
- 5 minutes anticipation before TSST
- 10 minutes of stressor (speech and math tasks)
- 5 minutes of recovery after the TSST.

Average HR and RSA were calculated for each time segment, so that each individual had 4 HR values and 4 RSA values. Descriptive statistics (see Table 1, below) confirmed normal distribution of all variables, with the exception of one RSA value, which was winsorized.

Table 1. Descriptive Statistics for ANS Variables.

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>46.76</td>
<td>130.01</td>
<td>88.95</td>
<td>15.02</td>
</tr>
<tr>
<td>RSA</td>
<td>2.23</td>
<td>10.80</td>
<td>6.26</td>
<td>1.14</td>
</tr>
</tbody>
</table>

Repeated measures ANOVAs were used in order to assess HR and RSA (as the dependent variables) across the time intervals (as the repeated predictor variable across the 4 time intervals). Gender (0=boy, 1=girl) and modification (0=no modification, 1=reward, 2=punishment) were between-individual predictors of HR and RSA. If the ANOVA indicated a significant effect, follow-up t-tests were conducted.
Results:

Heart Rate (HR):

A Repeated Measures ANOVA was conducted in which HR was the outcome, and time interval, modification and gender were predictors. First, there was a main effect across time interval, such that heart rate rose significantly throughout the experiment (F= 46.184, p< .001). In addition, there was an interaction between time and modification such that HR rose significantly over time, but this rise was different dependent upon the modification (F =3.555, p=.003). Most interestingly, we found a three-way interaction between time, modification, and gender such that HR rose across time intervals differently per modification and depending on gender (F= 2.437, p=.030). Follow-up paired samples t-tests were conducted to understand this three-way interaction (see Table 2, p. 27 below).

Females responded more overall, and out of all the modifications, responded strongest to reward (see Figure 1, adjacent). HR significantly differed across time between individuals differently (F= 261.275, p< .001), such that the mean HR during the reward paradigm was highest (M= 98.53, SD= 12.76), followed by no modification (M= 96.30, SD=15.96), and finally the punishment paradigm as the lowest HR (M= 94.64, SD=14.26). There were no significant main effects of gender or modification.

- Throughout all modifications, females’ responsivity [red-line] was higher than males’ responsivity [blue-line].
- Interestingly, recovery to the stress test was delayed the most within the reward modification (meaning it took the longest to calm down after the stressor, with the stressor being the 10-minute stress test)—This shows that the stress response isn’t confined just to maximum reactivity within the stressor, but that the stress response is also active in the adaptive recovery/latter part of the experiment, which comes directly after stress test is completed.

Figure 1.

The vertical axes are HR in beats per minute (bpm); the horizontal axis views HR over time/throughout the entirety of the experiment.
Further Analysis (HR):

Vertical axes are HR in beats per minute (bpm).

- Women responded the strongest to all modifications, but most robustly to the reward modification [right graph (which displays HR reactivity between the genders)- for females: punishment-modification/left solid-red bar@91, no-modification/center red-outlined bar@93, and having the largest HR responsivity was reward-modification/right solid-orange bar@95].
- Out of all the modifications, men also responded strongest to the reward paradigm [right graph- for males: punishment-modification/left solid-dark-blue bar@85, no-modification/center blue-outlined bar@86, and having the largest HR responsivity was the reward-modification/right solid-turquoise bar@90].
- So between the genders, both men AND women responded most to the reward modification, with females responding considerably more, by +5bpm.
- Both men and women showed diminished responsivity to the punishment paradigm [left graph (which displays HR reactivity averages of both genders combined)-punishment-modification/left dark-blue bar is lowest @87; right graph-punishment-modifications/far left solid-blue & red bars are lowest for both genders’ other two modification-counterparts of reward & no-modification].
- The original unmodified TSST was actually less effective in creating a heightened stress response than was the reward paradigm [left graph- no-modification/center blue-outlined bar@89 is lower than reward-modification/right turquoise bar@91.5; right graph- no-modifications/center red & blue-outlined bars@85M and 92F are lower individually, even by gender, than their respective counterparts of reward-modifications/right turquoise & orange bars@90M and 95F].
Table 2. HR Across Time and Modification Conditions in Males and Females.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Modification</th>
<th>Interval</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MALES:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Modification:</td>
<td>Baseline to anticipation</td>
<td>-3.86</td>
<td>.001*</td>
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<tr>
<td></td>
<td>Anticipation to stressor</td>
<td>-1.11</td>
<td>.282</td>
<td></td>
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<tr>
<td></td>
<td>Stressor to recovery</td>
<td>7.84</td>
<td>.000*</td>
<td></td>
</tr>
<tr>
<td>Punishment:</td>
<td>Baseline to anticipation</td>
<td>-2.35</td>
<td>.057</td>
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</tr>
<tr>
<td></td>
<td>Anticipation to stressor</td>
<td>-2.032</td>
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<td>Stressor to recovery</td>
<td>3.56</td>
<td>.012*</td>
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</tr>
<tr>
<td>Reward:</td>
<td>Baseline to anticipation</td>
<td>-4.00</td>
<td>.005*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anticipation to stressor</td>
<td>-2.93</td>
<td>.022*</td>
<td></td>
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<tr>
<td></td>
<td>Stressor to recovery</td>
<td>4.53</td>
<td>.003*</td>
<td></td>
</tr>
<tr>
<td><strong>FEMALES:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Modification:</td>
<td>Baseline to anticipation</td>
<td>-2.06</td>
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<td></td>
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<tr>
<td></td>
<td>Anticipation to stressor</td>
<td>-7.70</td>
<td>.000**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stressor to recovery</td>
<td>6.66</td>
<td>.000**</td>
<td></td>
</tr>
<tr>
<td>Punishment:</td>
<td>Baseline to anticipation</td>
<td>-3.87</td>
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<tr>
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<td>Anticipation to stressor</td>
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<tr>
<td></td>
<td>Stressor to recovery</td>
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<td>.502</td>
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<tr>
<td>Reward:</td>
<td>Baseline to anticipation</td>
<td>-3.85</td>
<td>.018*</td>
<td></td>
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<td>Anticipation to stressor</td>
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<tr>
<td></td>
<td>Stressor to recovery</td>
<td>2.14</td>
<td>.099</td>
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</tr>
</tbody>
</table>

**p<.001
*p<.05
**Respiratory Sinus Arrhythmia (RSA):**

A Repeated Measures ANOVA revealed a main effect across time interval such that RSA changed significantly over time (F= 2.778, p= .050), with lowest values during the stressor task, wherein this low RSA indicates greater stress responsivity. A main effect of modification on RSA was found (F= 4.278, p=.019), such that the mean RSA during the reward modification was found to be highest (M= 5.61, SD=0.93; RSA rose highest; HR rose highest), then the no modification (M= 6.10, SD=1.13; RSA dropped second highest; HR rose second highest/ was in the middle), and finally the punishment modification with the highest mean (M= 6.44, SD=0.78; RSA dropped lowest; HR rose third highest/ was lowest). There was no main effect of gender and no significant interactions. Similar to HR, post hoc paired samples t-tests revealed that RSA dropped significantly across time intervals, and this was similar across males and females (see Table 3, p. 30 below). Both males and females followed similar RSA reactivity patterns (see Figure 2, adjacent).

- **Although the scaling of the HR and RSA graphs look similar, they are not--- the RSA graph values achieved are much lower numerically than those of the HR graphs.**
- A **high RSA value** means Parasympathetic Nervous System activation, which perhaps over-simply put, generally promotes a **more** behaviorally calm/relaxation response, where as **low RSA** means de-activation of the Parasympathetic Nervous System, which generally promotes a **less** behaviorally calm response/more stressed out (high RSA--calm / low RSA--stressed out).
- Notice the overall zig-zag pattern of most of the RSA responses of all three graphs: females RSA stayed generally steady throughout the reward modification [middle graph], meaning that they were fairly stable in relaxation.
Further Analysis (RSA):

- Referring to the left graph (which displays RSA reactivity of both genders combined), RSA (relaxation) was found to be lowest in the punishment-modification/left dark-blue bar@5.8, highest in the reward modification/right turquoise bar@6.8, and the no-modification/center blue-outlined bar@6.3 in between the other modifications.
- We did not expect however, that women’s RSA and HR, would be concurrently increased during the reward modification---So this indicates that although females were physiologically stressed out (increased HR, meaning they were alert), they were also simultaneously in a state of pseudo-relaxation (increased RSA, meaning they were behaviorally calm at the same time).
### Table 3. RSA Across Time and Modification Condition in Males and Females.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Modification</th>
<th>Interval</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MALES:</td>
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<td>.743</td>
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<td>Anticipation to stressor</td>
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<td>.982</td>
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<td>Stressor to recovery</td>
<td></td>
<td>-2.31</td>
<td>.000*</td>
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<tr>
<td>Punishment:</td>
<td>Baseline to anticipation</td>
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<td>Anticipation to stressor</td>
<td></td>
<td>2.47</td>
<td>.048*</td>
</tr>
<tr>
<td></td>
<td>Stressor to recovery</td>
<td></td>
<td>-2.19</td>
<td>.071</td>
</tr>
<tr>
<td>Reward:</td>
<td>Baseline to anticipation</td>
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<td>-1.28</td>
<td>.243</td>
</tr>
<tr>
<td></td>
<td>Anticipation to stressor</td>
<td></td>
<td>2.58</td>
<td>.036*</td>
</tr>
<tr>
<td></td>
<td>Stressor to recovery</td>
<td></td>
<td>-.710</td>
<td>.501</td>
</tr>
<tr>
<td>FEMALES:</td>
<td>No Modification:</td>
<td>Baseline to anticipation</td>
<td>-2.49</td>
<td>.023*</td>
</tr>
<tr>
<td></td>
<td>Anticipation to stressor</td>
<td></td>
<td>2.29</td>
<td>.035*</td>
</tr>
<tr>
<td></td>
<td>Stressor to recovery</td>
<td></td>
<td>-1.67</td>
<td>.112</td>
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<tr>
<td>Punishment:</td>
<td>Baseline to anticipation</td>
<td></td>
<td>.414</td>
<td>.700</td>
</tr>
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<td></td>
<td>Anticipation to stressor</td>
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<td>1.746</td>
<td>.156</td>
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<td></td>
<td>Stressor to recovery</td>
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<td>-1.55</td>
<td>.197</td>
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<td>Reward:</td>
<td>Baseline to anticipation</td>
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<td>.084</td>
<td>.937</td>
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<td></td>
<td>Anticipation to stressor</td>
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<td>.875</td>
</tr>
<tr>
<td></td>
<td>Stressor to recovery</td>
<td></td>
<td>.405</td>
<td>.706</td>
</tr>
</tbody>
</table>

*p<.05
Further Analysis (HR vs. RSA):

Vertical axis is **HR** in beats per minute (bpm).

Vertical axis is **RSA**.

- See reward-modifications/far-right orange & turquoise bars of both **HR** & **RSA** graphs:
  - Out of all the modifications, *both males and females showed highest RSA and HR* in reward, with females being a margin below males in RSA and considerably above males in HR.
  - It is interesting to note that *though* females and males displayed *similarly* increased HR and RSA, males were actually less physiologically stressed out (via substantially lower HR, -5bpm less) than females, and females were less physiologically calm (via just marginally lower RSA, -0.1 less) than males.
Discussion:

We found that both male and female humans responded strongest to the reward modification, which supports the hypothesis that females as well as males can both depend on whichever survival mechanism is relevant to the present context. Interestingly, this finding highlights this versatile capability of humans to be flexible in their adaptive skills to bring forth to the situation whatever is needed, here the mechanism most likely being that of “tend-and-befriend” because it is this mechanism that is inherently one of social navigation, and the TSST is inherently a social stressor. This finding also emphasizes the ability of both male and female humans to not be restricted to the typically assumed limitations of gendered roles and differential gender coping, including those notions of being tied solely to one survival mechanism for males, and another exclusively for females. We also found that females respond the most (compared to males) to each modification, which seems to support the hypothesis that females may have had to evolve more sensitive coping mechanisms to interpret even the most subtle of social cues.

First, we investigated whether males and females show similar responses in heart and breathing rate during the original TSST, without enhancement of reward or punishment. We found that heart rate and breathing rate showed responsivity to the stressor when compared to the at-rest condition, but males and females were remarkably similar in their responsivity all around. That is, there was no significant gender difference in responsivity in the no-modification condition. This finding is likely the first or one of the few of its kind because so little research, if any, has been done investigating gender differences in the branches of the ANS to the TSST. This
result fits our hypothesis in that we did not expect to find a difference in the no-modification condition. Our outcome echoes the psychological evolutionary perspective that males and females can react and rely upon the same coping mechanism if it is most advantageous and the context calls for it (Geary & Flinn, 2002).

Second, we investigated whether threats of punishment (modification 1) or the possibility of reward (modification 2) alters heart and breathing rate reactivity. We found that the rise in HR differed according to the modification, such that the reward condition caused the greatest increase in HR, which indicates highest alertness. Parallel results were revealed for breathing rate reactivity, such that the reward condition was associated with highest RSA, which indicates the greatest relaxation reactivity. Thus, within the reward modification, the two measures were concurrently related (both high RSA and HR). These results within the reward modification fit our expectations, suggesting that a potential for gain may result in activating one’s physiology to help better socially engage in the situation and thus aid the individual in attaining the desired goal (in this case, increased compensation). In this way, “stress reactivity” may actually be viewed as an adaptive response to such a circumstance, in which physiological, psychological, and social arousal may be initiated to help the individual achieve a positive outcome. This hypothesis also fits the bulk of literature, which emphasizes eustress as a positive motivator and, therefore, can be seen as an adaptive coping skill. Thus far, no research has been conducted with a reward or a punishment modification to the original TSST. As such, quite noteworthy was that all individuals responded even
more robustly to the reward modification than they did to the original unmodified TSST, which is a modification unique to only to this study and is completely unprecedented. It is quite remarkable that our reward modification was actually more successful in producing a greater stress response than the no-modification (the original TSST), considering that the original unmodified TSST is currently hailed to be the most reliable, salient laboratory stressor in the world (Dickerson & Kemeny, 2004). Maybe not so many years from now, this reward-modification version of the TSST will be even more globally used and recognized than the original TSST is today because of its comparatively increased salient power.

The threat of punishment, on the other hand, was associated with the smallest heart and breathing rate reactivity, even compared to the no modification condition, and this finding could be seen as possibly signaling a psychophysiological mechanism of surrender and defeat, much like that of learned helplessness (“giving up” when success is possible). In contrast to mobilizing resources to help achieve positive outcomes, within the punishment modification there is only the potential for a possibly negative outcome (keep or lose compensation) and no potential to better the outcomes (no opportunity to receive increased compensation). Mobilizing physiological resources in such a defeatist setting may not advance the individuals’ ability to succeed in the stressful setting or maximize their rewards, and can therefore be seen as a situation where “giving up” or having a lowered stress response might actually be adaptive.

This increased reactivity to the reward modification and decreased reactivity
to the punishment modification may be explained by generational gaps and their corresponding characteristics seen with in the “Silent Generation” and what has been recently termed as the “Millennial Generation” (Egri & Ralston, 2004; Pirie & Worcester, 1998; Sweeney, 2005). The Silent Generation, which consists of Americans born between 1925-1945 who grew up in the Great Depression of the 1930s and World War II, overall exhibited a high concern for security, and therefore, generally had a pervasive desire to do whatever was necessary to avoid risks and disasters previously witnessed in their youth. This generation was also characterized as dependable, hard-working and was supportive of conservative values. In contrast, most individuals of the “Millennial Generation,” which consists of Americans born between 1979-1994, have spent the bulk of their teenage years against a backdrop of an economic boom and rising stock market, and despite the fact that they have not seen the same level of job security as their predecessors and therefore understand that the idea of a lifetime employment is one found only the history books, they still continue to expect to have a higher standard of living than their parents. This generation also puts more emphasis on personal freedom and challenging work, and is overall heavily achievement- oriented, believes in merit-based work, has a reduced need to conform, is independent, flexible and expects “nomadic, anytime, anywhere communications”. Most namely, this generation is extremely vested in instant gratification, perhaps due to their upbringing in an increasingly convenient technological world; resulting, and even by their own admission, they are relatively impatient. They do not see the worth in expending energy that might be more wisely used elsewhere, which some have said could
possibly be seen as a marker of a new type of intelligence. Research findings show that Millennials get higher scores on both standard IQ tests and SAT examinations—perhaps they are even actually smarter than previous generations. They accordingly believe that “it’s cool to be smart.” Millennials also think differently in many ways, which is perhaps partly due to “gaming”, parental pressures, and perhaps also as an inevitable result of the immersion in technological evolution. In any case, it is not at all surprising that Millennials respect intelligence, as it can heavily influence achievement of their goals.

Thus within the reward modification and following accordingly with these generational trends in personal values, perhaps the Millennial Generation, which composes most of participants in the present study, recognized the challenge to receive increased compensation and answered the call to action to do so. The generation’s noted characteristics of putting more emphasis on challenging work, being achievement-oriented and believing in merit-based work could thus make sense as the distinct causal mechanism of their witnessed increased HR and RSA to the reward modification. Since this generation is one also marked by flexibility, it also makes sense that perhaps they were better able to deal with and “roll with the punches” of the unpredictability factor within this modification. In addition, their undeniable characteristic of instant gratification is already satisfied because they immediately received (some) compensation upon arrival at the beginning of the experiment, so they do not have to worry about delaying gratification as a distraction. Perhaps they also saw that expending more effort to receive more money was a wise endeavor as it is very likely that they characterized the reward
modification as a win-win situation, in which if they improved performance, they could get more money in addition to the money they already had, and if they didn’t improve, they would at least get to keep the little bit of money they already had, and saw that subsequently, there was no possible negative outcome of extending their energy.

Thus within the punishment modification and also accordingly to these generational trends in personal values, it is likely that the Millennial Generation (which, again, is the bulk of participants in the present study) saw that it was not worth expanding the energy (autonomic mobilization) to improve performance in the punishment modification because their only option was to either their compensation ($5) if they did not improve, or keep their minimal compensation ($5) if they did improve. Perhaps they characterized the punishment modification as a lose-lose situation and saw that the smart choice was to not care about losing $5, which is relatively small amount in our current inflated economy, and hence did not try to succeed, which can be seen empirically in their markedly decreased autonomic measures of HR and RSA. This markedly decreased autonomic responsivity could also be a marker of this generation’s propensity toward risk-taking and instant gratification, such that perhaps these individuals thought it better to risk not improving performances and were just “taking their chances” so to speak in the interest of not expending any unnecessary energy that would also involve delayed gratification for such a relatively small amount of money. Though it is unlikely that any autonomic measures could be achieved for the Silent Generation, it is probable that the individuals of this generation would have expended the energy
needed for improved performance to keep their compensation not only because this generation was extremely hard-working and highly valued security, including financial security, but also because they tended to avoid risks at whatever cost. These underpinnings may very well explain why the participants of the present study showed such remarkably diminished responsivity to the punishment.

Negative social evaluation is one of the most robust and reliable precursors to stress reactivity (Dickerson & Kemeny, 2004). Identifying the specific social situations that might render perception of evaluation is important considering that chronic or repeated activation of the physiological stress response has injurious effects on both mental and physical health, and often differs by gender. Therefore, we last investigated whether males and females show similar responses in heart and breathing rate to threat of punishment and to the possibility of reward. Beyond the observation that the TSST reliably activates the ANS in both males and females, we’ve identified a specific extrinsic condition that differentially activates the ANS between the genders. Females responded more than males to all of the modifications, though this heightened responsivity was most robust within the reward modification, which, as already discussed, may be a result of the social evaluative part of the stressor.

These results can be interpreted within an evolutionary framework in which the increased reactivity in females could be viewed as a possibly evolved adaptive psychophysiological mechanism in line with Taylor and colleague’s notion of “tend-and-befriend” (2000). Increases in HR in response to social evaluation and judgment
may reflect this increased awareness to social environments, and increases in RSA may reflect an increased ability to be socially calm, and this concurrent heightened reactivity may very well increase awareness and provide a higher probability of success as they rely on their evolved ability to navigate and more likely succeed in these complex social situations.

While useful, the “tend-and-befriend” idea does not expound much on how there can be individual differences in stress physiology or how these evolutionary influences are informed or shaped by proximal environmental conditions. Another evolutionary perspective, Ellis’ (2004) Life History Theory, does this by suggesting that the magnitude of gender differences and an individuals’ behavior is influenced by early life stress. Ellis (2004) focuses on female pubertal onset (and later extended these notions to stress physiology) to describe the trade-off between the division of resources for reproduction versus physical growth and the tradeoff between current and future offspring investment. Such selection pressures are keenly felt by females (more so than males), who actually carry, birth and can naturally feed their offspring. Overall, the life history theory seeks to explain events across the life span and the timing of reproductive development by proposing these as evolved strategies for the distribution of metabolic resources between the competing strains of reproduction, growth, and maintenance. Since these metabolic resources are limited, and energy and time used for one purpose cannot be used for another simultaneously, these trade-offs are inevitable, such that if resources are used for growth and development of an extended childhood, they cannot be used for reproduction at this same current time. It is the costs and benefits associated with
variations in the timing of reproductive development that manifest these trade-offs, and in response to ecological conditions, natural selection favors mechanisms that trade off resources that will enhance fitness during a species’ evolutionary history. Therefore, because females and males faced distinctly different pressures in primeval environments, they may also possess gender-specific evolved mechanisms, and perhaps as a result, they differ psychologically and tend to occupy different social roles.

The tendency of members of one gender group (here males) to stay in their birth group and members of the other gender (females) to migrate to another group is referred to as philopatry (Geary & Flinn, 2002). Because male associations are likely to be with kin and these relationships naturally require less reciprocity as do relationships with non-kin, it has been proposed that low-intensity investment in males’ befriending might be a consequence of male philopatry, whereas females are more likely to have a more motivated disposition to maintain same-gendered relationships (Geary & Flinn, 2002). As such, if males evolutionarily seemed to require less social support to survive and women require more, then this may also be a fitting explication of why females showed a more heightened stress response to all modifications—perhaps it is because they are more aware of the social situation per their same-gendered ancestors’ evolution and thereby are forced to rely upon the already well established, evolutionarily long-standing “tend-and-befriend” mechanism. This may also be an appropriate explanation as to why males showed a slightly reduced stress response to all modifications—perhaps because they are less perceptive of the social situation’s subtle cues per their same-gendered ancestors’
evolution and thereby find it slightly more difficult to fully access the less well
evolutionarily established “tend-and-befriend” coping mechanism that was less vital
to survival in their same-gendered ancestors.

A criticism of evolutionary theories comes from a well-known sociologist,
Wendy Wood, who claims that evolutionary psychology neglects the influence of
social structure (i.e. culture and cross-culture variation) as a determiner of gender
difference origination (Eagly & Wood, 2009). Wood asserts that while evolutionary
psychology claims that adaptations to the environment caused psychological gender
differences to evolve and originate, social evolutionary theories claim that it is
actually social structure that caused these psychological gender differences to
originally come about and that it was not simply just rote adaptations to the
immediate external environment that were causal; hence, making these two
theories seemingly in opposition to one another. Wood further claims that this
(supposed) debate about gender difference origins cannot be reduced to a simple
nature-versus-nurture dichotomy, but that it is the interaction between
evolutionary psychology and social structural theories of evolution that is important
and crucially needed to explain the origination of gender differences (Eagly & Wood,
2009).

In response, authors Ellis, Giudice, and Shirtcliff (2012) emphasize that
evolutionary psychology undeniably does advocate that the origins of gender
differences do not solely lie in rudimentary, naturally- ingrained, irreversible, rote
evolved dispositions that differ according to gender, but rather they highlight that
individual gender differences develop over time, according to biology, *and within specific social structures (including culture and cross-cultural variation) through differing placement of men/women within these social structures*. The authors dually clarify that these social structures are an important *part of* the environment, and explain that evolutionary psychological theories of gender differences emphasize that, along with many other factors, the nurture of external culture, unquestionably and without a doubt, profoundly interacts with the nature of inborn individual psychology. With this, evolutionary psychology also unreservedly asserts that the origin of differential gendered behavior is not just the indisputable interaction of culture and instinct, but that these evolved gender differences are anything but a rudimentary result of some simple interaction between rote environmental queues (nurture) and “unchangeable” inborn tendencies (nature). These interactions are openly recognized as far more intensely complex and unpredictable than has been formerly assumed in past decades; indeed, the nature-versus-nurture dichotomy as a simple and straightforward phenomenon has long been dispelled as a myth in the psychological community.

This article (Ellis, Giudice, and Shirtcliff, 2012) also defends that there is no single strategy that is optimal for survival or for gender roles, but that humans have evolved to acquire a *range* of available options that unfold and can be utilized according to and in response to what the context, or the social situation, requires. Thus, the authors (Ellis, Giudice, and Shirtcliff, 2012) emphasize evolutionary psychology’s inclusion of culture as undeniably *part of* the environment, and further note that since evolutionary adaptations are flexible to the context, if the social
structure of the environment changes, than these adaptations can also change accordingly because of adaptation’s inherent flexibility (i.e. cross culture variation-different cultures around the world prescribe different gender roles to male/females than some other cultures do). These notions further dispel the nature-nurture interaction as elementarily simple, and more importantly demonstrate how the imperative function of culture and cross-culture variation can profoundly impact the origin of evolutionary differences between the genders, not to mention that the results of present study that clearly show the undeniable influence that social evaluation, through the TSST, can have on one’s physiology.

These points seem to make Wood’s argument [which is that evolutionary psychology supposedly claims that the evolutionary origin of gender differences were just simply rote adaptations to the immediate external environment, looks like “evolve once-and-done” and doesn’t change according to the social context] not only null and void, but demonstrates a fundamental misinterpretation of evolutionary psychology theory, and in fact, one that is not a true representation of evolutionary psychology at all. Hence, evolutionary psychology clearly agrees and does not conflict with social structural theories’ because it recognizes, includes and emphatically states that social structure (culture and cross-culture variation included) is an undeniable part of the environment and, thus, is part of its influence on the origin of evolved gender differences. Therefore, within psychological theories of evolution, social structure (and all it encompasses) is very widely acknowledged as one of the many robustly influencing factors on the genesis of evolved gender differences. Evolutionary psychology also well recognizes that there is no such thing
as a simple nature-nurture interaction, and that the myriads of causal factors that contribute to evolution are practically innumerable.

In keeping with Wood’s call to action, Ellis, Giudice and Shirtcliff (2012) unmistakably emphasize that culture and cross-culture viewpoints are essential to evolutionary outcomes, and are inherently part of evolutionary psychology. The evolutionary psychological theory acknowledges that there are different contexts that are causal to behavior, and hence, the theory predicts, and actually relies upon, culture and all its variations as a part of the possible original causes in gender-differential evolution. Therefore, it is clear to see that evolutionary psychology anticipates (and actually sees as imperative and inseparable from environmental factors) cross-cultural variation, hence clarifying that the psychological evolutionary developmental theory is not separate or different from social evolutionary theories, but is actually exactly what Wood calls for--- a widely vindicated and evolutionarily essential interaction between culture and individual psychology, and that these two interacting counter-parts are actually only another part of the increasingly complex model of nature-and-nurture. Hence and in conclusion, psychological and sociological structural theories of evolution are not at all contradictory to one another, but almost mirror each other identically; they may only appear to be conflicting on an extremely surface-level of investigation.

It is furthermore interesting to note that, in conjunction with their increased HR reactivity in the reward condition, females exhibited almost no change in RSA during the reward condition, which signifies that while females were physiologically
“stressed-out” and experienced significant arousal as displayed in their increased HR, they were also physiologically “keeping it together” and also maintained physiological and behavioral calmness as their breathing rate remained at what can almost be seen as a relaxed state. This breathing rate finding for females during the reward modification was quite unexpected, as the trend between HR and breathing rate is often seen as an almost inverse relationship. Subsequently, this harmony of increased alertness and heightened state of relaxation may have acted as to potentially render them more likely to attain the possible reward. Simultaneously heightened activation of both HR and RSA may be an excellent marker of the mechanism of “tend-and-befriend” because high HR is equated with heightened alertness, which is required to accurately and masterfully interpret the present context, and high RSA is equated with heightened relaxation, which is needed to skillfully and appropriately react to the situation at hand. Both of these socially context dependent reactions of alertness and relaxation are essential to successful access to and effective employment of the mechanism of “tend-and-befriend.” As a result, they have notably heightened awareness to their context (increased HR), especially compared to males (females are above by 5bpm), and though females are just a margin below males in RSA (below by 0.1), it is the combination of these heightened HR and RSA measures and their behavioral effects (allowing them to socially and physiological respond advantageously) that perhaps allows females to better master the given social situation at hand, and to likely be relying upon the mechanism of “tend-and-befriend” since this mechanism is inherently a social survival mechanism. It can thus be interpreted that, evolutionarily speaking, females
may be more evolved and specialized in accessing the needed social skills that come from this coping mechanism because such skills likely came from their female ancestors who had to excel at such or die. This may also lead to further interesting implications as to what this could mean for women’s skills toward “tending-and-befriending” and perhaps better navigating and coping with the world and its social challenges. Despite all this, no matter what the conditions, apparently survival knows no gender.

Shiffman and Stone (1998) state that, “laboratory studies afford unparalleled control, but lack real-world realism or ecological validity;” therefore, limitations of this study include the non-naturalistic setting from which the results and conclusions were drawn. However, this may also be seen as a strength for determining causation, given that the study’s highly controlled nature allows for elimination for practically any extraneous factors. Another limitation of the present study may be the loose usage of the terms “reward” and ”punishment,” which may imply that operant conditioning or learning occurred; however, because the nature of this study was that of a single trial, there was not enough time to allow for learning or conditioning. The terms “reward” and ”punishment” were simply used here for concision and convience. An additional limitation may include the overall small sample size, and the relatively small sample size of the modification groups compared to the no modification group, though statistically, all of the results were significant.
Nonetheless, the current literature does not provide a clear understanding of the relation between cardiovascular reactivity and disease risk in males versus females. Therefore, investigating alterations in ANS reactivity (i.e., HR and RSA responses) during stress is imperative due to the link between increased heart reactivity and various coronary diseases. It may also offer a window into the mechanism underlying various differing heart diseases in males and females. Furthermore, establishing the specific situations that may render negative perception of evaluation is also vitally important considering that repeated and/or chronic activation of the stress response physiology system can have such detrimental effects on overall physical, as well as mental, health.

Showing differential modification responsivity in the ANS to the TSST and other stressors is important due to the innumerable positive and negative mental and physical health implications. Investigating this would do a lot for the possible institution of prevention measures or reductions of stressors that could possibly benefit human health. Future directions include replicating the present study with a larger sample size to validate the present study’s results, and further research into effective coping and preventive measures to reduce the impact of the ANS on mental and physical health, such as the ongoing studies of the innumerable positive benefits of relaxation and meditation therapies. The findings of the present study may also establish requisite data to support further examination of differential environmental stimuli and social support or physiological attunement during stressors like the TSST, and may actually lay very solid groundwork for future inquiries into investigating inter-individual gender differences in physiologically
attunement in couples that experience the TSST together as a participant/supporter dyad. Because of the present study's noted gender differences in responsivity and their possible implications, future goals also include examining whether there is a difference in attunement (more/less matched ANS responsivity) in hetero- and homosexual couples who experience the TSST together.
References:


Psychopathology. *Developmental Psychobiology*.


APPROVAL SHEET

This is to certify that Brittany Elizabeth Verret has successfully completed her Senior Honors Thesis, entitled:

Gender Differences in Autonomic Nervous System Reactivity to Stress

Elizabeth A. Shawcliff  
Director of Thesis

D'Lane R. Compton  
for the Department

Carl D. Malmgren  
for the University Honors Program

May 4, 2012  
Date