

12-17-2010

Sensation Seeking and a Real World Stressor: Endocrine and Physiological Effects

Amber Allison
University of New Orleans

Follow this and additional works at: <https://scholarworks.uno.edu/td>

Recommended Citation

Allison, Amber, "Sensation Seeking and a Real World Stressor: Endocrine and Physiological Effects" (2010). *University of New Orleans Theses and Dissertations*. 1275.
<https://scholarworks.uno.edu/td/1275>

This Thesis is protected by copyright and/or related rights. It has been brought to you by ScholarWorks@UNO with permission from the rights-holder(s). You are free to use this Thesis in any way that is permitted by the copyright and related rights legislation that applies to your use. For other uses you need to obtain permission from the rights-holder(s) directly, unless additional rights are indicated by a Creative Commons license in the record and/or on the work itself.

This Thesis has been accepted for inclusion in University of New Orleans Theses and Dissertations by an authorized administrator of ScholarWorks@UNO. For more information, please contact scholarworks@uno.edu.

Sensation Seeking and a Real World Stressor: Endocrine and Autonomic Effects

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
In partial fulfillment of the
Requirements for the degree of

Master of Science
In
Psychology

By

Amber Allison

B.S. Louisiana State University

December, 2010

© 2010, Amber Allison

Table of Contents

List of Tables and Figures	v
Abstract.....	vi
Introduction	1
<i>Sensation Seeking Trait</i>	1
<i>Neurobiology of the SS Trait</i>	4
<i>Physiological Arousal: Stress Responsive Systems</i>	5
<i>Mechanisms of the Stress Response System.</i>	7
<i>SAM System.</i>	8
<i>HPA Axis.</i>	9
<i>Integration of SAM and HPA.</i>	11
<i>Behavioral Expression of SS Trait</i>	12
<i>Disentangling Novelty from Risky Behavior: Group Comparison</i>	14
Statement of Problem.....	15
Hypotheses.....	16
Method.....	16
<i>Participants</i>	16
<i>Measures</i>	17
<i>Procedure</i>	18
<i>Data Preparation and Analysis</i>	22
Results.....	28
<i>Do the individuals in this study qualify as high sensation seekers?</i>	28
<i>Did the participants experience an increase in cortisol in response to skydiving?</i>	29
<i>Did the novices have a more robust increase in cortisol than the experienced jumpers?</i>	30
<i>Were there other between-individual variables that predicted cortisol values?</i>	30
<i>Did the participants experience an increase in heart rate in response to skydiving?</i>	31
<i>Did the novices have a more robust increase in heart rate than the experienced jumpers?</i>	32
<i>Were there other between-individual variables that predicted heart rate?</i>	32
Discussion.....	33
<i>Do the individuals in this study qualify as high sensation seekers?</i>	34

<i>Did the participants experience an increase in cortisol in response to skydiving?</i>	36
<i>Did the novices have a more robust increase in cortisol than the experienced jumpers?</i>	37
<i>Did the participants experience an increase in heart rate in response to skydiving?</i>	38
<i>Did novices experience more robust increase in heart rate during the jump?</i>	39
<i>Broader Implications</i>	41
<i>Limitations</i>	43
<i>Future Directions</i>	43
References.....	46
Appendix	53
IRB approval form.	57
VITA.....	58

List of Tables and Figures

Figure 1. Theoretical pathway relating the SS trait to behavioral expression.....	page 1.
Figure 2. Procedure within the theoretical framework.....	page 19.
Figure 3. Cortisol levels on skydiving and basal days	page 55.
Figure 4. Cortisol levels on skydiving and basal days for experienced and novice jumpers.....	page 55.
Figure 5. Heart rate on skydiving day for experienced and novice jumpers.....	page 56.
Figure 6. Heart rate on jump day for novice and experienced jumpers.....	page 56.
Table 1. Skydiving day procedure.....	page 53.
Table 2. Single sample t-tests for males and females on the SSS-V.....	page 54.
Table 3. Single sample t-tests for males and females on the SSS-VI.....	page 54.

Abstract

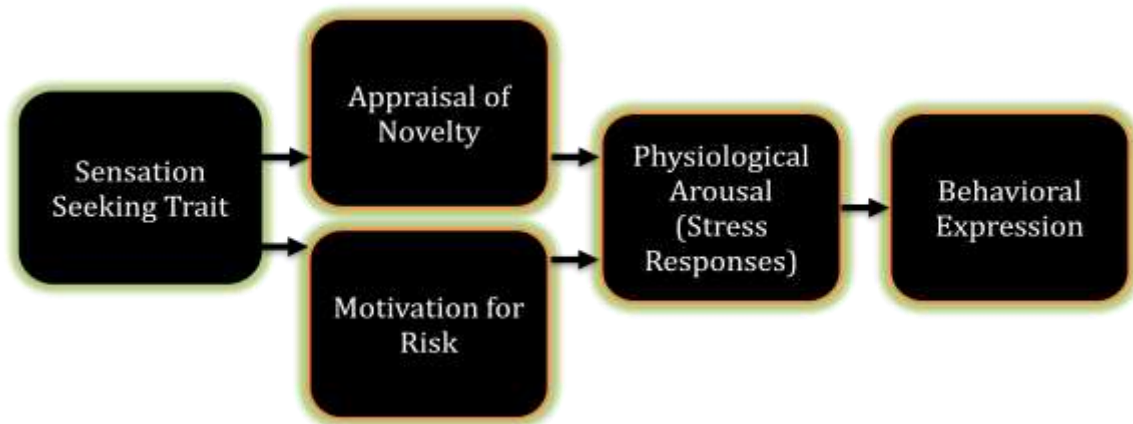
We attempted to identify the psychobiological mechanisms that mediate the process by which the sensation seeking trait culminates in behavior. We used the Sensation Seeking Scales to assess the SS trait in individuals who expressed a desire to skydive. We obtained measures of autonomic (heart rate) and endocrine (salivary cortisol) activity before, during and after skydiving. To distinguish the contribution of novelty, we compared novices (N=29) to experienced jumpers (N=15). All jumpers exhibited HPA-axis activation; novices exhibited a prolonged response and more extreme peak in cortisol compared to experienced jumpers, suggesting that novelty contributes to an intense pattern of stress responding. Both groups displayed increases in heart rate; there were no significant differences between the groups, indicating that repeated exposure to the stressor did not habituate this system. We provided evidence that the stress response systems instantiate novelty and risk to motivate and reward behavioral expressions of the SS trait.

Keywords: *sensation seeking; novelty; risk-taking; cortisol; heart rate; skydivin*

Introduction

The trait of sensation seeking manifests itself differently depending on the context and the individual; however, high sensation seeking individuals typically participate in high-risk activities more often than low sensation seeking individuals (Zuckerman, 1994). As such, sensation seeking emerges as an important psychological construct, and the goal of the present study was to identify the motivational components and physiological underpinnings of the sensation seeking (SS) trait in order to understand how this trait manifests in behavior. Figure one shows a theoretical framework for how the sensation seeking trait may culminate in behavioral expression.

Figure 1. Theoretical pathway relating the SS trait to behavioral expression.



Sensation Seeking Trait

In 1969, Marvin Zuckerman introduced sensation seeking as a measurable construct to the field of psychology. Ten years later, he compiled the theoretical and empirical research regarding sensation seeking in a book entitled, “Sensation Seeking: Beyond the Optimal Level of Arousal” (Zuckerman, 1979). In this book Zuckerman proposed a psychobiological model of sensation seeking by expanding on Hebb’s

“optimal level of stimulation” theory. This theory states that increases in stimulation are rewarding to some individuals because of subsequent cortical activation (Hebb, 1949; Zuckerman, 1979). As research involving sensation seeking expanded over the next decade, an emphasis was placed on the behavioral outcomes associated with understudied biological mechanisms of physiological arousal. Current definitions of sensation seeking involve two inter-related behavioral components: “the tendency to seek novel, varied, complex, and intense sensations and experiences *and* the willingness to take risks for the sake of such experience” (Zuckerman, 1994). The current project explored both novelty-seeking and risk-taking components of the sensation-seeking trait by examining a high risk behavior (i.e. skydiving) performed by two different groups of sensation-seeking individuals.

Upon observation of the vast individual differences in optimal levels of self-reported arousal, Zuckerman (1979) theorized an underlying trait involving sensation seeking and impulsivity. The “impulsive sensation-seeking trait” (SS trait) facilitates and sustains motivation and competition in obtaining goals (Zuckerman, 1994). Research indicates that individuals with the SS trait are more likely to participate in high-risk sports (i.e. mountain climbing, parachuting, karate), jobs (i.e. pilot, police, fire-fighter), and sexual behaviors (i.e. multiple partners, unprotected sex) (Freixant, 1991; Musolino & Hershenson, 1977; Thornquist, Zuckerman & Exline, 1991). According to Zuckerman, these risky sensation-seeking behaviors can be seen as an outcome of the interaction between the SS trait, the appraisal of novelty, and motivation for risk (Zuckerman, 1994). Zuckerman attempts to place the sensation seeking trait in an evolutionary framework. As a core personality trait, Zuckerman emphasizes that the trait may have evolved to help

individuals engage in hunting, explore new environments and participate in other high risk behaviors. This same trait continues to be expressed, though not through the same behaviors or contexts; rather than being implicated when fighting a mammoth, the trait may underlie fast driving, or drug and alcohol misuse. By extension, developmental evolutionary models emphasize that, depending on the individual's context, the sensation seeking trait may be maintained in modern society (despite some cultural suppression of the behaviors) because the sensation seeking behaviors can result in greater access to resources (e.g., financial rewards from financial trading, gambling or other novel trading decisions) or sexual partners (e.g., enhanced sex appeal).

In order to quantitatively describe levels of sensation seeking in individuals, Zuckerman (1979) created the sensation seeking scale (SSS), which assesses experiences and inclinations toward novelty and risk. The SSS-V uses a forced-choice format to produce scales that evaluate thrill and adventure seeking (TAS), experience seeking (ES), disinhibition (Dis), boredom susceptibility (BS), and a total score (Zuckerman, 1994). The ES and BS scales tend to appraise levels novelty seeking in both sensations and experiences; conversely, Zuckerman also focused on motivation for riskiness, and the TAS and Dis scales evaluate propensities toward risk-taking (Zuckerman, 1994). A more recent modification of the SSS (VI) selects specifically for sensation seeking traits rather than just the behavioral expression of sensation seeking activities. This scale quantifies the desire to engage in future sensation-seeking activities as well as the preference for sensation-seeking activities already experienced (Zuckerman, 1994). **Our first hypothesis was that individuals who volunteer to skydive for this study would score higher than reported means on the Sensation Seeking Scales and would, thus,**

qualify as high-sensation seeking individuals. Specifically, we expected that scores on the subscales of the SSS-V may help disentangle the motivation toward high-risk activities in our participants.

Neurobiology of the SS Trait

It may seem self-evident that individuals who express the trait of sensation seeking often engage in sensation seeking behaviors; however, there are mediating factors that influence whether the trait of sensation seeking will culminate in a specific behavior. One such mediating factor is degree of novelty. Joseph et al., (2008) found that high and low sensation seekers showed different profiles of brain activation in response to novel stimuli. High-sensation seekers had pronounced activity in the insula, an area of the brain where visceral signals are received and interpreted for valence. Activation of the insula indicates that these individuals interpreted the novel stimuli as highly emotional and arousing. Low-sensation seekers, on the other hand, had increased activity in the anterior cingulate cortex (ACC), an area associated with conflict monitoring or the ability to determine when a physiological and behavioral response is necessary (Eisenberger, Lieberman, & Williams, 2003). This suggests that low SS individuals interpret novelty as dissonant input requiring changes in the information processing centers and subsequent activation of the prefrontal cortex (PFC) in order to determine the extent of the conflict and the appropriate response (van Veen & Carter, 2002). Low and high sensation seekers may use different brain regions to perceive and respond to novel stimuli. Patterns of activation in important emotion-related neural circuitry may underlie the disparity in novelty-seeking behavior in these two groups.

Motivation for risk-taking constitutes another factor mediating the relationship between the sensation-seeking trait and behavioral expression. It has been theorized that high-sensation seeking individuals have high motivation for risk-taking due to a diminished fear response to potentially dangerous activities, and that risk-taking may activate the reward pathway in the brain in high-sensation seeking individuals. The amygdala and nucleus accumbens (NAcc) are especially important to this theory, since these structures are involved in fear-processing and appetitive behavior. In fact, research confirms that these areas are activated in situations involving risk (Abler et al., 2006; Ernst et al., 2005; Kuhnen et al., 2005), and that this activation may be rewarding in individuals who are less harm-avoidant (Matthews et al., 2004). In an attempt to understand why sensation-seeking individuals prefer high-risk activity, Zuckerman (1994) implicated several mediating physiological systems, including those involved in arousal, stress responsiveness, and reward. He postulates that high SS individuals do not have higher tonic levels of cortical arousal, but rather heightened arousability to high-risk stimuli, including heart rate increases and stress hormone responsivity (Zuckerman, 1994). However, research directly relating risk-taking with these physiological systems is limited (see below). In this study, we propose that unveiling the direct physiological repercussions of sensation-seeking behaviors will offer insight into why individuals who possess the sensation-seeking trait require varied stimulation and feel restless when forced to endure predictable stimulation.

Physiological Arousal: Stress Responsive Systems

It is well known that environmental conditions can alter biology, especially within the context of environmental stress effects on physiological functioning. Theoretical models and empirical verification of this are found throughout the psychobiological stress

literature (Boyce & Ellis, 2005; Ellis, Essex & Boyce, 2005). Stress responsive systems represent a possible psychobiological model of the basis of sensation seeking. As evidence of this, the neural circuitry reviewed above connects directly with peripheral stress physiology (Critchley, 2005; Critchley et al., 2000), both by sending and receiving input from HPA axis and autonomic nervous system. Oppenheimer et al. (1991) found that activation in the right insula is associated with increased heart rate (i.e. increased SAM activity), indicating a direct association between this brain structure and the autonomic nervous system. Additionally, the insula projects to the nucleus of the hypothalamus, which controls activation of the endocrine system (Risold, Thompson, & Swanson, 1997). Wang et al. (2005) found that a laboratory stressor induced both cortisol release and activity in the insula. Similarly, a positive association between the ACC and the endocrine system has been identified, but the direction of the effect is not yet understood. Some studies show that ACC activation produces an increase in cortisol levels (Eisenberger, Taylor, Gable, Hilmert, & Lieberman, 2007), while others indicate that cortisol precedes activation of the ACC (Stark, et al., 2006). These empirical findings suggest that stress response systems may influence how the brain perceives environmental input, and then determine how that neural activation culminates in behavior. As such, the stress response systems emerge as a physiological mediator of the association between the sensation seeking trait and behavioral expression of the trait.

A limited body of research addresses a possible association between sensation seeking and stress response systems. Smith, Johnson, and Sarason (1978) suggest that high sensation seekers report less “distress” in response to negative events when compared to low sensation seekers, indicating that the SS trait may influence an

individual's perception of negative events. High SS individuals may be more physiologically conservative with regard to activation of the stress response systems that are necessary when coping with a perceived negative event. Previous research highlights the importance of identifying the hormonal stress-response changes specific to individuals who are considered sensation seekers (Kalichman et al, 1996; Levenson, 1990; Rosenblitt et al., 2001). In this study, we empirically tested whether stress responsive systems were related to sensation seeking behavior. We viewed the desire to participate in high-risk activities (i.e. skydiving) as an indication of the sensation seeking trait, consistent with Zuckerman's emphasis on risky behavior as an expression of SS traits (Hymbaugh and Garrett, 1974; Zuckerman, 1979). Further, by selecting individuals who engaged in this behavior for the first time, we targeted the sensation-seeking trait via Zuckerman's emphasis on novelty-seeking. In order to understand sensation seeking as a trait and subsequent behavior, we explored the underlying physiological mechanisms contributing to and resulting from sensation seeking.

Mechanisms of the Stress Response System.

When an individual perceives a stressful event, several physiological changes occur in order to help the body manage and regulate appropriately. Theorists have coined the term "allostasis" to refer to an organism's ability to adapt to change and challenge (McEwen & Wingfield, 2003). In contrast to homeostasis, which is the stability of physiological systems necessary to sustain life, allostasis lends the ability to respond appropriately to environmental stress and is an adaptive phenomenon essential for maintaining optimal homeostatic balance in a particular social context (Lupien et al., 2006). An example of allostasis in the cardiovascular system is the role that catecholamines play in adjusting heart rate and blood pressure to various environmental

conditions, such as sleeping and physical exercise. In this case, the organism must modify its physiology to match environmental demands to facilitate optimal functioning (Lupien et al., 2006; Sterling & Eyer, 1988). The optimal set-point of catecholamines when the organism sleeps would not be optimal when the organism exercises (and vice versa). Allostasis is relevant to the present proposal because skydiving is an activity in which activation of a stress response would be considered adaptive and context-appropriate, such that a response helps the individual react appropriately to a demanding situation. The theory of allostasis demonstrates that environments have the ability to “get under the skin,” and that these effects are quantifiable via psychobiological measures.

SAM System.

When sensory information is appraised as stressful, the sympathetic-adrenomedullary (SAM) system is activated, leading to immediate release of epinephrine and norepinephrine and subsequent increases in vigilance and arousal (Sapolsky, 1998). From an evolutionary perspective, this system is vital for surviving in the face of acute danger. Increases in blood pressure, heart rate, and breathing rate facilitate the appropriate behavioral responses necessary for survival. Activation of SAM can be indirectly measured by charting cardiovascular changes and rhythms (Pomeranz et al., 1985; Gunnar & Quevedo, 2007). We used small ambulatory devices (Actiheart devices, Metrisense, Bend, OR) to capture autonomic activity measures of sympathetic and parasympathetic nervous system activity. Increases in heart rate facilitate acute psychological (vigilance and arousal) and physical (dilation of pupils, blood to peripheral muscles) changes that provide the individual with the ability to “fight or flight;” meaning the individual prepares to face an extraordinary challenge or gains the resources necessary to get away from that challenge. Heart rate is primarily controlled by the

sympathetic nervous system, thereby indexing the immediate perceived stress. Vagal tone, as an index of parasympathetic nervous system activity, has been proposed as a physiological indicator of stress vulnerability because it represents an individual's ability to control his/her physiological arousal in order to remain relaxed and calm in the face of a challenge (Porges, 2003). **We hypothesized that skydivers would show a substantial increase in heart rate as a response to skydiving.**

HPA Axis.

Another vital physiological component of the stress response is the hypothalamic-pituitary-adrenal (HPA) axis. Sensory information is assessed as threatening (i.e. stressful) via central interactions in the prefrontal cortex and limbic system. This appraisal may activate the hypothalamic secretion of corticotropin releasing hormone (CRH), which promotes the anterior pituitary to secrete adrenocorticotropin releasing hormone (ACTH), in turn causing the adrenal release of cortisol into the bloodstream (Dickerson & Kemeny, 2004). Once in the bloodstream, most of the cortisol binds to serum proteins, such as corticosteroid-binding globulin (CBG) and albumin; the small amount of cortisol that remains free (10-15%) is considered biologically active (Robin et al., 1977). Non-protein-bound cortisol enters saliva intracellularly; thus, salivary cortisol provides a good estimate of biologically active cortisol (Vining et al., 1983). Previous research indicates that measuring salivary cortisol is an opportune and viable way to characterize HPA axis activity (Laudet et al., 1988). In normal individuals, HPA activation results in elevated levels of cortisol in saliva, though typically there is a fifteen minute delay between stress-induced activation of the HPA axis and cortisol levels in saliva (Dickerson & Kemeny, 2004).

In 1968, Mason described three psychological determinants that predict induction of the HPA stress response system: novelty, unpredictability, and lack of control. Though this stress response system is highly variable, the effect does depend on the type and intensity of the stressor. In fact, we now know that not all stressors that elicit a stress response are inherently negative (Berk et al., 1989). A differentiation has been made between stress and eustress; stress indicates negative situations that are stressful while eustress indicates positively-valenced situations capable of inducing a stress response. The stress response system may respond to these potentially rewarding situations, like sports competition (Bateup et al., 2002; Gonzales-Bono et al., 1999; Kivlighan et al., 2005) and laughter (Berk et al., 2001).

Regardless as to whether a stressor is positively or negatively valenced, cortisol release exerts long-lasting effects by directly changing gene expression over the course of minutes, hours, days and years. *Cortisol reactivity* refers to the acute release of cortisol in response to an environmental stressor, and is considered one powerful allostatic mediator the body employs in an attempt to return to homeostatic equilibrium. Cortisol reactivity in response to a high-risk activity may indicate that the experience was characterized as novel, unpredictable and/or uncontrollable (Mason, 1968), and was salient enough to ‘get under the skin’ and alter levels of physiological activation. Acute cortisol surges facilitate functional repercussions that help the body maintain resources necessary to respond to challenge, such as inhibition of reproductive physiology, decreased appetite and sharpened cognition (Sapolsky, Romero, & Munck, 2000).

The intensity of cortisol reactivity can reveal information about an individual’s physiological arousal in the face of a stressor, but it may be difficult to discern reactivity

without having a non-stress comparison measure of HPA functioning. Collecting measures on a ‘basal’ day provides a benchmark from which to determine cortisol reactivity, yet basal cortisol levels are also an important independent component of HPA axis functioning. *Basal cortisol* refers to the relatively stable levels of cortisol present naturally throughout the day. Daily cortisol follows a distinct pattern, with high levels expected in the morning, a peak within 30 minutes of awakening, and then steady declines throughout the day. This rhythm provides the necessary resources to cope with moment-to-moment changes in the environment. **We hypothesized that, compared to time-matched basal levels, skydivers would show an increase in salivary cortisol during the activity of skydiving.**

Integration of SAM and HPA.

The co-regulation of SAM and HPA stress response systems constitutes another example of an allostatic response, as this co-regulation helps the organism adaptively manage the environment. The SAM is a fast-acting peripheral system, while the HPA targets the central nervous system and has slower but longer lasting effects (Cannon, 1929; Bohus et al., 1982; de Kloet, 1991). Despite their functional differences, the effects of these two systems are modulated by limbic system activity, where input is appraised for potential stressors. These systems remain somewhat integrated in the hypothalamus, and continue to be so in the anterior pituitary, where pro-opiomelanocortin (POMC) is stored and subsequently cleaved into various hormones, including ACTH and endorphin (epinephrine) (Gunnar & Quevedo, 2007; Raffin-Sanson et al., 2003). Especially relevant to the current investigation is how the previously mentioned brain structures associated with the SS trait may alter peripheral physiological

states (Oppenheimer et al., 1991; Risold et al., 1997; Stark et al., 2006; Eisenberger et al., 2007), helping to instantiate peripheral SAM and HPA signals in the brain.

Behavioral Expression of SS Trait

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 largest increases in cortisol as well as the longest recovery times. On the other hand, Shiffman and Stone (1998) state that, “laboratory studies afford unparalleled control, but lack real-world realism or ecological validity.” Ecologically valid settings hold the advantage of having unique practical applications to individuals who engage in those behaviors, while also potentially allowing empirical investigations of situations that might otherwise not be possible to conduct in a laboratory. The current study aims to provide insight into biological mechanisms associated with the sensation-seeking trait, and in order to increase the ecological validity of the study, we will evaluate those mechanisms while individuals actually participate in the prototypical sensation-seeking behavior of skydiving.

Skydiving is an example of an extreme sport that is eagerly sought out by millions of people each year. According to the United States Parachuting Association (USPA), there were 3,500,000 skydives made in the United States in 2007. This statistic attests to the fact that not only are a significant proportion of people willing to endure this form of acute but intense stress (or eustress), but they actually seek out such forms of stimulation. As such, we expected that the willingness to skydive is indicative of the presence of the

sensation-seeking trait, as the desire to skydiving is included on the SSS-V and SSS-VI (Zuckerman, 1994), and previous research suggests that individuals who opt to skydive score higher on the SSS than those individuals not willing to skydiving (Hymbaugh & Garrett, 1974). Thus, our first hypothesis sought to evaluate whether scores on the sensation seeking scales predict the desire to skydive as a behavioral manifestation of the SS trait. Further, we expected that participants would experience some subsequent physiological arousal as the activity activated the stress response systems through the mechanism of novelty and motivation for risky behavior.

Skydiving in novice populations has been investigated previously as a stressor capable of triggering a hormonal response (Chatterton et al., 1997). This study revealed that salivary cortisol levels greatly increased in first-time jumpers as a response to getting in the airplane, and peak levels occurred about 15 minutes after landing. This study gives merit to the idea that skydiving is an effective biological stressor and the current study hoped to provide further insight into the biological mechanisms associated with positive, inherently rewarding stressful situations. We compared the relative contributions of both basal and reactive cortisol profiles of first time and experienced jumpers. We expected that basal levels of cortisol would provide insight about the motivating factors for the behavior as well as the cortisol levels characteristic of the sensation-seeking trait. We expected cortisol reactivity within the context of skydiving to provide insight into the mechanism of risk-taking behavioral expression of the trait. We also charted changes in heart rate in order to evaluate the association between sensation seeking behaviors and the fast-acting SAM system, specifically whether skydiving elicited a “fight or flight” response. Though we do not obtain standard basal measures of heart rate, we

conceptualize a baseline measure of heart rate due to the quick responding and recovery of the SAM system to stressors (Sapolsky, 1998).

High sensation seeking individuals may participate in high-risk behaviors due to the desire for novelty and risk. In turn, these behaviors may activate both the acute (heart rate) and longer-lasting (cortisol) stress response systems, and this physiological arousal might reward the behavioral expression of the trait. The context of skydiving is an ecological situation in which we can evaluate the real-world physiological valence of risk-taking behaviors. Following the idea of allostasis, this context is expected to elicit activation of the stress response systems, as the body attempts to adaptively regulate functioning in the face of environmental stress. At a behavioral level, the instigation of the stress response may be perceived as rewarding to individuals who possess the sensation-seeking trait. Thus, the particular physiological systems activated during a specific high-risk stressor may provide insight into how the brain and body communicate levels of risk, reward and novelty during that preferred high-risk activity.

Disentangling Novelty from Risky Behavior: Group Comparison

There are behavioral ramifications associated with sensation seeking traits, one of which may be a desire to go skydiving. In novice jumpers, this activity may be a behavioral expression of the trait because it is novel and/or because it is risky. Both of these desires have been associated with psychobiological stress responses, though the long-term consequences of novelty versus risky behavior are drastically different (Sapolsky, 1998). Novelty is expected to wear off over time and lend the sensation-seeking individual to engage in other and varied activities/behaviors. The process whereby novelty wears off is of utmost importance for understanding the development of

stress responsivity and allostasis (Koob & LeMoal, 2000). At a psychobiological level, we would anticipate that repeatedly engaging in a behavior may no longer trigger a stress response because the context would no longer be appraised as stressful (Deinzer et al., 1997). However, if the mechanism for activating a stress response to sensation seeking behaviors were due to the excitement stemming from taking a risk, then it would not be adaptive to diminish the stress response over time because risk remains elevated with each subsequent jump, as there might be expected or perceived reward that continues to outweigh the knowledge of potential harm.

In this study, we were interested in the important mediating factors (i.e. novelty and risk) and the psychobiological mechanisms that may instantiate the sensation seeking trait. We suspected that both mechanisms may be operating within each individual to different degrees. In order to explore this, we compared individuals experiencing the stressor for the first time (novice group) and individuals familiar with the physiological repercussions of the activity (experienced group). **Our last hypothesis was that there would be significant group differences in biological stress responsiveness between novices and experienced jumpers; while both groups may experience some stress responsivity, the lack of novelty associated with the stressor would attenuate biological stress responsiveness in the experienced group, compared to the novice group.**

Statement of Problem

The main goal of the present study was to gain an understanding of the psychobiological mechanisms underlying the sensation-seeking trait originally described by Zuckerman (1979, 1994). In doing this, we attempted to distinguish the roles of

novelty and risk in the association between the trait and subsequent sensation-seeking behaviors. We examined a group of high sensation seeking individuals as they engaged in a socially acceptable risky behavior. Further, we disentangled the contributions of novelty and risk by assessing the physiological responses in two groups: one in which the stressor is both novel and risky, and the other in which we expect the novelty to have worn off while the relative risk remains constant. This study has four main hypotheses:

Hypotheses

- A. Individuals who volunteer to skydive represent a population of sensation seekers, as indicated by scores significantly greater than the mean on forms five and six of the Sensation Seeking Scale (Zuckerman, 1979);
- B. Compared to time-matched basal levels, the novice jumpers will experience a substantial increase in salivary cortisol as a response to skydiving;
- C. Compared to time-matched basal levels, the experienced jumpers will show a mild hormonal response to skydiving;
- D. Compared to the experienced group, the novices will experience a much larger increase in cortisol and HR in response to skydiving, respectively.

Method

Participants

A total of 44 participants were recruited from Goldcoast Skydivers Company in Lumberton, Mississippi. The final sample consisted of 29 novice jumpers (18 males) and 15 experienced jumpers (14 males). Individuals were only considered for participation if they expressed a pre-existing desire to skydive, were between 18 and 50 years of age, and

had no obvious/reported health complications. We banned any individual unwilling, for any reason, to complete the training provided by skydiving company from participation. All aspects of this research protocol were approved by the Institutional Review Board at the University of New Orleans before any participants were recruited or data collected (see appendix).

Measures

Saliva Collection. Water was provided five minutes prior to saliva collections to ensure participants did not have dry throats. All saliva collection times were capped at ten minutes to minimize participant burden. Saliva was sent on dry-ice to Madison Biagnostics (Madison, WI) for assay. Cortisol was assayed using a commercially available enzymeimmunoassay (www.salimetrics.com), which involves a microtitre plate that is coated in cortisol antibodies. Cortisol from the saliva samples competes with an enzyme solution for antibody binding sites. After binding, the excess cortisol and enzyme solution are washed away, leaving only the bound antibodies. Since binding changes the color of the antibodies, the amount of cortisol bound can be measured by optical density; thus, the amount of cortisol present in the sample is inversely proportional to the amount of cortisol present. Raw cortisol values were transformed into the natural log (ln_{cort}) in order to satisfy normality assumptions of linear multilevel models. Then a constant (5) was added to the log transformed cortisol values in order to avoid negative numbers.

Daily Diary: At the time of each saliva collection, a “Daily Diary” was administered which asks about exercise, eating and sleep habits, and mood/emotion at the time of each sample. This diary has been used previously in psychobiological research (Granger et al.,

2003).

Autonomic Measures: Noninvasive ambulatory measures of activity, heart rate, and interbeat interval were used to assess autonomic nervous system activity continuously during the jump. The Actiheart monitoring device records physical activity by means of an accelerometer (Cambridge Neurotechnology, LTD). Heart rate, activity, and interbeat interval are reliable measures of autonomic activity. The Actiheart was chosen because it is lightweight and can easily and non-invasively be attached to the participants' chest using two standard ECG pads. Pilot testing confirmed that the Actiheart acquires data at 14,000 feet.

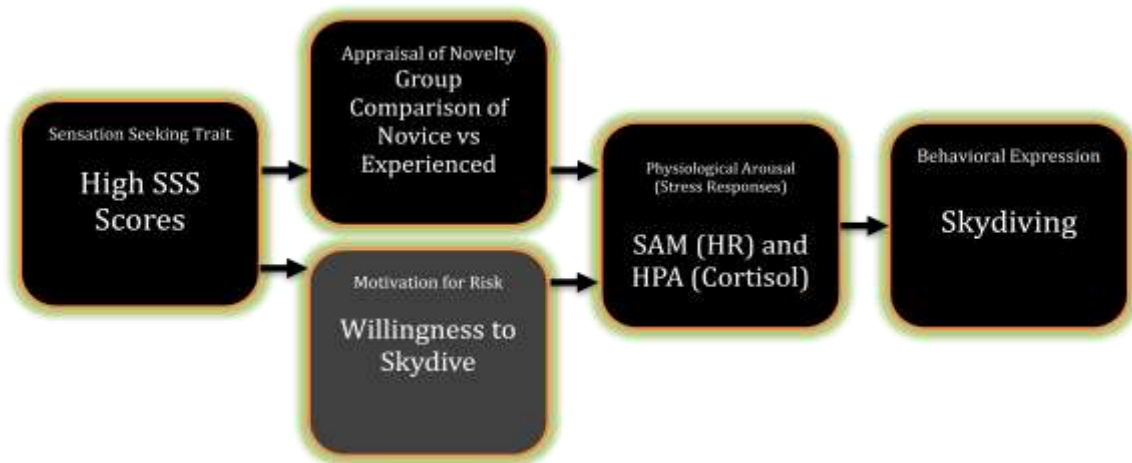
Questionnaire: The Sensation Seeking Scale version five (SSS-V) includes four subscales (TAS-thrill and adventure seeking, ES-experience seeking, DIS-disinhibition, and BS-boredom susceptibility) as well as a total score that is assumed to be reflective of sensation seeking traits (Zuckerman, 1979). Reliability estimates for the SSS-V range from .83-.86, with individual scale estimates as follows: TAS, .77-.82; ES, .61-.67; DIS, .74-.78; and BS, .56-.65 (Zuckerman, 1994). The Sensation Seeking Scale version six (SSS-VI) was also given to participants as it assesses both experience and future intentions related to sensation seeking behaviors, beliefs and attitudes (Zuckerman, 1979). Reliability estimates for the SSS-VI intention scales range from .83-.94, while the experience scales are slightly lower, ranging from .62-.66 (Zuckerman, 1994).

Procedure

Individuals recruited for this research study were asked to participate for a total of two days of data collection. The first day of involvement was the skydiving day (jump day); the second day of involvement was a comparison day (basal day). Figure 2 shows how

the procedural events fit within the previously introduced theoretical framework.

Figure 2. Procedure within the theoretical framework.



Skydiving day. Researchers were present at the skydiving site at an average time of 12:26pm (range 11:44am to 1:41pm); afternoon jump times were selected to diminish impact of the drastic drop in cortisol levels in the morning due to the circadian rhythm. Both novice and experienced jumpers were presented the recruitment flyer and given detailed information regarding the expectations of participation upon their arrival at the skydiving site and, if recruited, provided informed consent. Participants then filled out the first daily diary entry and the first saliva sample was immediately collected, at an average time of 12:32pm (range 11:51am to 1:51pm). This first sample may index ‘baseline cortisol levels’, but it may also be impacted by the anticipation of study involvement (Hastings et al., in review; Gunnar et al., 2009).

After cleaning and preparing the skin of the chest area, a researcher applied the Actiheart device, at an average time of 12:38pm (range 12:18pm to 1:43pm). The novice participants then completed ten minutes of instructing provided by the skydiving

company and dressed in the proper attire. Before boarding the airplane, at an average time of 1:46pm (range 12:52pm to 2:59pm), a second salivary sample was collected and the corresponding daily diary entry completed. This second sample was more likely than the first to index the anticipation of the impending jump which will occur in less than (an average of) 15 minutes. Participants then boarded the plane, ascended to 14,000ft and jumped (M= 2:12, range 12:40pm to 3:37pm). Immediately after landing, at an average time of 2:17pm (range 12:43pm to 3:46pm), a third saliva sample was collected and the corresponding daily diary entry completed. Given the slow response timing of the HPA stress response, this sample indexes the initial burst of the stress response systems as a consequence of having the plane takeoff and to the initial challenge of the jump. Participants then removed the jumpsuits. Fifteen minutes after landing, at an average time of 2:35pm (range 1:08pm to 3:59pm), a fourth salivary sample was collected and the corresponding daily diary was completed. This sample was designed to index the peak of the stress response associated with the jump.

Actiheart devices were removed from participants at an average time of 2:43pm (range 1:23pm to 4:03pm). A researcher then measured participants' digits using a caliper instrument, in addition to recording the participants' height and weight. Protocol for the basal day was explained to each participant by a researcher, a date for the basal saliva collection was determined, and the materials (including written instructions for saliva collection, a daily diary packet, and pre-labeled saliva tubes) were given to each participant. Participants were then asked to complete the Sensation Seeking Scale versions five and six. At one-hour post landing, at an average time of 3:25pm (range 2:20pm to 4:45pm) the fifth and final saliva sample was collected and the corresponding

daily diary was completed. This sample indexes the participant's ability to adaptively recover from the stress response. Table 1 (see appendix) shows the protocol for skydiving days with the average times.

Due to mechanical or technological problems (e.g., device falling off) some individuals did not have valid heart rate data ($N = 8$). These individuals did not differ significantly from the participants with heart rate data in age ($t(42) = -1.12, p = .268$), sex ($\chi^2(1) = .025, p = .873$), BMI ($t(42) = -1.33, p = .191$), or race ($\chi^2(1) = 1.254, p = .263$). Basal Day. On a non-stressful day following the skydiving day, participants were asked to provide five saliva samples at times corresponding to the spit times on the skydiving day. On this scheduled basal day, a researcher contacted the participant at each spit time in order to remind the participant to provide the sample and to answer any questions regarding the process. Participants were also given a questionnaire packet to fill out at their convenience. After the basal collection day, the materials (saliva and questionnaire) were retrieved from the participants by a researcher.

Most participants had multiple hormone samples across both the skydiving and the basal days; however, experienced jumpers were less likely than novice jumpers to complete and return basal samples ($\chi^2(1) = 18.08, p < .0001$). This resulted in a subset of participants having hormone data only for the skydiving day ($N=14$, including 3 novices, 11 experienced jumpers). The individuals who did not return their basal boxes did not differ significantly from the individuals who did in age ($t(42) = -0.64, p = .522$), BMI ($t(42) = -0.63, p = .511$), race ($\chi^2(1) = .363, p = .547$), or skydiving hormone levels ($t(182) = -1.02, p = .307$).

Data Preparation and Analysis

To test whether the participants in this study are high sensation seekers, single sample t-tests were employed to compare the Sensation Seeking Scale (V and VI) mean scores for our sample and reported means on these measures (Zuckerman et al., 1991; Zuckerman, 1994). Results were reported separately by sex because males tend to score higher on all sensation seeking subscales (Zuckerman, 1994).

To address whether the participants in this study experienced a significant stress response as a result of skydiving, and to ascertain group differences between the novice and experienced jumpers, an analytic strategy that separates within-individual from between-individual variability was necessary. In this study, heart rate and cortisol were gathered in a repeated measures fashion (i.e. multiple times per day), and this study was primarily interested in time-varying aspects of these physiological variables as opposed to simply looking at whether the levels were the same across data points. Additionally, since we expected that the heart rate and cortisol levels within an individual would be more similar than heart rate and cortisol levels between individuals, the basic assumption of independence in the data was violated. Finally, we had missing data (i.e. some participants did not provide basal samples), but were wary to delete these individuals entirely because it would drastically reduce our sample size and limit generalizability of the study to only the most compliant participants; thus, we selected a statistical method that would not force list-wise or case-wise deletion. To facilitate these needs, data was analyzed in a two-level multilevel linear model using HLM (Bryk & Raudenbush, 1992).

The first level of the cortisol model ($N = 335$) and the first level of the heart rate model ($N = 12,145$) included the time varying data and captures the within-individual

changes in cortisol and heart rate, respectively. The second level of the cortisol analysis (N = 44) and the heart rate analysis (N = 36) included between-individual variables that may influence cortisol and heart rate, respectively.

Cortisol HLM Model. The hierarchical model for cortisol analysis was carried out in steps in order to address each separate but interrelated part of the research questions. First, we explored what portion of the variance seen in cortisol levels was due to differences between individuals, and, conversely, what portion of the variance was due to differences within individuals. This was done using a null model with only the outcome variable (Incort) and no predictors. The null model showed that there was significant between-individual variability in basal cortisol levels, $\chi^2(43) = 168.75$, $p < .0001$ and that 28% of the variability seen in cortisol levels was attributable to differences between individuals (i.e., the intra-class correlation), while 72% was attributable to differences within individuals. This is highly consistent with previous research (Adam, 2006; Kirschbaum & Hellhammer, 1990). Additionally, the high intra-class correlation indicated that there was significant dependency in the data, further justifying the utility of an analytic strategy that does not require independent data.

Second, we built a model to assess whether within-individual variables significantly predicted cortisol levels throughout the jump and basal days. Saliva tubes 1-5 were dummy coded so that each could be evaluated separately. The tube-1 variable captured cortisol levels at the time of the first sample provided on the skydiving day (arrival or baseline). Tube-2 captured cortisol levels immediately before boarding the plane. Tube-3 captured cortisol levels immediately after landing, which was typically ten to fifteen minutes after jumping. Tube-4 captured cortisol levels fifteen minutes after

landing, typically twenty-five to thirty minutes after jumping. Tube-5 captured cortisol levels at 1-hour post landing (recovery). Figure three shows a scatter plot of these variables. Additionally, a variable representing the time since jump (TSJ) was created in order to control for varying jump times across participants. This variable assigned negative numbers to spit times before the jump and positive numbers to spit times after the jump. Due to the presence of outliers on either end of the time range and to avoid extrapolation, this variable was winsorized at -2.45 hours and 1.9 hours. The inclusion of Tube variables changed the interpretation of the beta-weight of TSJ because beta-weights in HLM, like GLM models, are independent of one another. The TSJ effect largely indexed the diurnal rhythm of the basal day and, to a smaller extent, the impact of the diurnal rhythm on the jump day. Within individual residual or error variability (ϵ) thereafter reflected moment-to-moment variability in cortisol levels after controlling for these time-varying factors.

The next step was to include the novice/professional (np) variable in order to test for cross-level interactions or group differences. Cross-level interactions refer to the ability of a second-level variable to predict cortisol levels beyond that accounted for by a first-level variable. Specifically, this step in the analysis tests for (1) whether novice jumpers exhibited a substantial increase in salivary cortisol as a response to skydiving, (2) whether experienced jumpers exhibited a substantial increase in salivary cortisol as a response to skydiving, and (3) whether there was a significant group difference in the responsiveness, such that novices experienced a more robust cortisol increase. Due to time constraints, experienced jumpers could only provide tube-1 (baseline), tube-3 (initial reactivity), and tube-4 (peak reactivity); differences between novices and experienced

jumpers are not examined for tube 2 or 5. The group variable Novice/Professional was centered on novice group members, so that this factor represents the additional change in HPA functioning in experienced jumpers compared to novice jumpers.

Finally, additional between-individual factors were tested to see if group differences in cortisol persisted after controlling for these demographic factors. Age has been empirically associated with increases in basal cortisol levels (Yen & Laughlin, 1998) but decreases in reactivity (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004). We centered age on the mean ($M = 29$ years) when including age (in years) as a control variable. We also included race, white ($N = 39$) or nonwhite ($N = 5$), since there is some evidence that race may influence cortisol (Bennett, Merritt, & Wolin, 2004). Body mass index (BMI) was included due to research indicating that BMI is positively associated with cortisol, such that individuals with higher body mass index also have higher cortisol (Rask et al., 2001). BMI was centered on the upper end of the normal range (29) in order to aid in interpretation of the results. Gender differences in HPA functioning are well documented in the literature (Kivlighan, Granger, & Booth, 2005; Rosenblitt, Soler, Johnson, & Quadagno, 2001), so we controlled for gender as well (0=male, 1=female). Between individual residual variance in cortisol levels (U_0) thereafter reflected the error component of the slope, or the deviation of the individual slopes from the overall slope.

A graph of the final cortisol model is shown in figure four and the regression equations for this model are described below.

[Level 1: within individual]

$$\text{Cortisol} = \beta_0 + \beta_1 * (\text{tube1}) + \beta_2 * (\text{tube2}) + \beta_3 * (\text{tube3}) + \beta_4 * (\text{tube4}) + \beta_5 * (\text{tube5}) + \beta_6 * (\text{TSJ}) + \varepsilon$$

[Level 2: between individual]

$$\beta_0 = \lambda_{00} + \lambda_{01} * (\text{np}) + \lambda_{02} * (\text{BMI}) + U_0$$

$$\beta_1 = \lambda_{10} + \lambda_{11} * (\text{np}) + \lambda_{12} * (\text{BMI})$$

$$\beta_2 = \lambda_{20} + \lambda_{21} * (\text{sex})$$

$$\beta_3 = \lambda_{30} + \lambda_{31} * (\text{np})$$

$$\beta_4 = \lambda_{40} + \lambda_{41} * (\text{np}) + U_4$$

$$\beta_5 = \lambda_{50} + U_5$$

$$\beta_6 = \lambda_{60} + \lambda_{61} * (\text{np}) + U_6$$

Heart Rate HLM Model. Similar to the cortisol analyses, the hierarchical model for heart rate analysis was carried out in steps in order to address each separate but interrelated part of the research question. First, we explored what portion of the variance seen in heart rate was due to differences between individuals, and, conversely, what portion of the variance was due to differences within individuals. This was done using a null model with only the outcome variable (HR) and no predictors. The null model showed that there was significant between individual variability in heart rate, $\chi^2(35) = 9254.44$, $p < .0001$ and that 42.5% of the variability in heart rate was attributable to differences between individuals (i.e., the intra-class correlation), while 57.5% was attributable to differences within individuals.

Second, we added within-individual variables to assess whether heart rate was significantly predicted by these variables. We identified three time intervals: (1) an interval indexing anticipatory responsivity (1 hour pre-jump until jump: TBJ1); (2) a jump interval (3 minutes prior to the average jump time to 12 minutes post average jump time: jump); and (3) a recovery interval (time after the jump interval: TAJ). Due to the non-linear nature of these time intervals, we included quadratic and cubic TBJ variables (TBJ1sq and TBJ1cub) and a quadratic TAJ variable (TAJsq). ActiHearts were applied to

participants at an average of 1 hour and 34 minutes before the jump, but our TBJ variable only captures 1 hour before the jump in order to index any rising anticipation associated with the impending stressor. We conceptualize that heart rate during the time before our anticipation interval indexes a baseline heart rate for the individual, consequently giving us a comparison for the intervals that index heart rate reactivity. The ability to identify a baseline on the jump day negated the need to obtain heart rate measures on the basal day. Figure five shows a scatterplot of the data with these variables. Within individual residual or error variability (ϵ) thereafter reflected moment-to-moment variability in heart rate after controlling for these time-varying factors.

Next, we included the novice/professional (np) variable in order to test for cross-level interactions or group differences. In this model, cross-level interactions refer to the ability of a second-level variable to predict heart rate beyond that accounted for by time intervals previously described. Specifically, this step in the analysis tested for whether there was a significant group difference in heart rate responsivity, such that novices experience a greater peak in heart rate during the jump. The group variable Novice/Professional was centered on novice group members, so that this factor represents the additional change in SAM activity in experienced jumpers compared to novice jumpers.

Finally, additional between-individual factors were tested to see if group differences in heart rate persisted after controlling for these demographic factors. Sex, race, and age have been empirically associated with heart rate (Jensen-Urstad et al., 1997; Liao et al., 1995). Thus, sex (0 = male, 1 = female), race (0 = white, 1 = nonwhite) and age are included in the model. We centered age on the mean ($M = 29$ years) when

including age as a control variable. Body mass index (BMI) was also included based on research suggesting a possible relationship between obesity and heart rate (Byrne et al., 1996; Antelmi et al., 2004). BMI was centered on the upper end of the normal range (29) in order to aid in interpretation of the results. Between individual residual variance in heart rate (U0) thereafter reflected the error component of the slope, or the deviation of the individual slopes from the overall slope.

A graph of the final heart rate model is shown in figure six and the regression equations for this model are described below.

[Level 1: within individual]

$$\text{HR} = \beta_0 + \beta_1*(\text{TBJ1}) + \beta_2*(\text{TBJ1sq}) + \beta_3*(\text{TBJ1cub}) + \beta_4*(\text{jump}) + \beta_5*(\text{T AJ}) + \beta_6*(\text{T AJsq}) + \varepsilon$$

[Level 2: between individual]

$$\begin{aligned} \beta_0 &= \lambda_{00} + \lambda_{01}*(\text{sex}) + \lambda_{02}*(\text{np}) + U_0 \\ \beta_1 &= \lambda_{10} + \lambda_{11}*(\text{age}) + U_1 \\ \beta_2 &= \lambda_{20} + \lambda_{21}*(\text{age}) + U_2 \\ \beta_3 &= \lambda_{30} + \lambda_{31}*(\text{age}) + U_3 \\ \beta_4 &= \lambda_{40} + \lambda_{41}*(\text{BMI}) + U_4 \\ \beta_5 &= \lambda_{50} + U_5 \\ \beta_6 &= \lambda_{60} + \lambda_{61}*(\text{age}) + U_6 \end{aligned}$$

Results

Do the individuals in this study qualify as high sensation seekers?

A series of one-sample t-tests were used to determine whether the participants in this study qualify as high sensation seekers. As shown in table 2, the means for each SSS-V subtest (TAS, ES, Dis, BS), as well as the total scores, were tested as compared to sex-specific means of an American sample reported by Zuckerman et al. (1991). Both males and females in this study scored significantly higher than the means on the TAS

and ES subscales, as well as on the total SSS-V scores, but not on the Dis and BS subtests. As shown in table 3, the means for each SSS-VI subscale (E-TAS, E-Dis, I-TAS, I-Dis) were compared to the sex-specific means reported by Zuckerman (1994). Males in this study scored significantly higher than the reported means on the thrill and adventure seeking subscales (E-TAS and I-TAS) but not on the disinhibition scales (E-Dis and I-Dis). Females, on the other hand, scored significantly higher on all SSS-VI subscales except the I-Dis. Additionally, independent-samples t-test revealed that novices and experienced jumpers in this sample did not significantly differ from each other on any of the SSSV or SSSVI subscales.

Did the participants experience an increase in cortisol in response to skydiving?

The level-1 model revealed significant within-individual variability in basal levels of cortisol, $\chi^2(28) = 206.90, p < .0001$. We conceptualized that this represents basal levels when TSJ=0, at an average time of 2:17pm (range 12:43pm-3:46pm). Our jump-day baseline variable (tube-1) did not significantly predict cortisol beyond basal levels, $\beta = 0.04, t = 0.28, p = .782$. This supports our conceptualization of this variable as a baseline value taken long enough before the jump (1 hour 40 minutes) that participants were not yet anticipating skydiving. By 26 minutes before the jump (tube-2), however, cortisol levels were significantly increased above time-matched basal levels, $\beta = 0.26, t = 1.96, p = .05$, indicating that participants were beginning to activate stress response systems due to anticipation of the jump. Immediately after landing (tube-3), cortisol increased sharply, $\beta = 1.11, t = 8.71, p < .0001$, and then continued to increase through 15-min after landing (tube-4), $\beta = 1.40, t = 8.84, p < .0001$. One hour after landing (tube-5), cortisol levels were still significantly greater than basal levels, $\beta = 0.93, t = 5.48, p < .0001$, but a decline from the peak at tube-4 was evident. Additionally, there were

significant between-individual differences at the time of tube-5, $\chi^2(28) = 44.21$, $p < .026$, signifying that rate of recovery from a stress response differed between individuals.

Finally, cortisol levels evinced a diurnal rhythm, such that cortisol levels on the basal day declined across the duration of the experiment on a basal, non-stress day (2 hours 57 minutes), $\beta = -0.22$, $t = -3.67$, $p < .0001$. There was also significant between-individual variability in the decrease in cortisol over the basal day, $\chi^2(28) = 46.34$, $p < .016$, which is consistent with previous research suggesting that the diurnal slope is different from one individual to another (Shirtcliff & Essex, 2008).

Did the novices have a more robust increase in cortisol than the experienced jumpers?

After the level-2 novice/professional variable was entered into the model, it was possible to establish group differences in cortisol levels and change over the basal day, as well as cortisol reactivity during the skydiving day. There were no group differences in cortisol levels at tube-1, $\beta = -0.21$, $t = -0.86$, $p = .39$ indicating that both novices and experienced jumpers may have approached the jump in relatively similar hormonal states. Immediately after landing (tube-3), however, cortisol levels were significantly different between the groups $\beta = -0.49$, $t = -2.36$, $p = .019$; experienced skydivers did not respond as intensely as the novice jumpers. By 15-min after landing (tube-4), group differences were even larger, $\beta = -.094$, $t = -3.98$, $p < .0001$; while novices continued to increase in cortisol levels, experienced skydivers began their recovery. Experienced skydivers had higher basal cortisol levels than novice skydivers, $\beta = 0.55$, $t = 2.77$, $p = .009$, as well as a steeper decline in cortisol throughout the basal day, $\beta = -0.33$, $t = -3.06$, $p = .004$.

Were there other between-individual variables that predicted cortisol values?

Individuals with higher BMI had significantly lower basal cortisol levels, $\beta = -0.05$, $t = -2.14$, $p = .038$, and an anticipatory rise in cortisol sooner on the jump-day (tube

1) than those with BMI within the normal range, $\beta = .08$, $t = 3.45$, $p < .0001$.

Nevertheless, group differences between novices and experienced jumpers in basal cortisol levels and tube 1 persisted after controlling for BMI. Sex differences in cortisol were evident fifteen minutes prior to the jump (tube 2), $\beta = -0.51$, $t = -2.75$, $p = .007$, indicating that females experienced less physiological anticipation before the jump. Again, differences between novices and experienced jumpers persisted after controlling for sex. Sensation seeking scale scores were also added as level-2 variables as exploratory analyses into the association between the trait, as indexed by the SSS, and cortisol levels. The total SSS-V score significantly predicted basal levels of cortisol, $\beta = -0.05$, $t = -2.49$, $p = .017$, and baseline levels of cortisol on the jump day (tube 1), $\beta = 0.065$, $t = 2.30$, $p = .022$. These results indicate that, for our sample, higher total SSS scores were associated with lower basal levels of cortisol but increased anticipation of the stressor on jump day. Race and age did not significantly predict cortisol levels.

Did the participants experience an increase in heart rate in response to skydiving?

The level-1 model revealed significant within-individual variability in baseline heart rate, $\chi^2(25) = 2083.64$, $p < .0001$. The interval representing the rising anticipation before the jump (TBJ1) significantly predicted heart rate levels, $\beta = -73.34$, $t = -4.80$, $p < .0001$, such that heart rate during this time was actually less than our conceptualized baseline. The quadratic ($\beta = -208.80$, $t = -5.78$, $p < .0001$) and cubic ($\beta = -140.16$, $t = -5.81$, $p < .0001$) transformations of this variable also predicted heart rate, suggesting that heart rate during this time did not follow a linear trend. Heart rate during the jump interval was significantly greater than heart rate at baseline, $\beta = 25.96$, $t = 8.97$, $p < .0001$, and there was significant within-individual variability during this interval, $\chi^2(25) = 872.29$, $p < .0001$, suggesting that the peak in heart rate differed for participants in the

sample. The recovery interval (TAJ) significantly predicted heart rate, $\beta = 90.42$, $t = 3.68$, $p < .0001$, such that heart rate was still elevated from baseline heart rate during this time. The quadratic transformation of this variable (TAJs²) also predicted heart rate, $\beta = -179.82$, $t = -3.95$, $p < .0001$, indicating that the recovery from peak heart rate did not follow a linear trend.

Did the novices have a more robust increase in heart rate than the experienced jumpers?

Contrary to our hypothesis, heart rate did not differ significantly between novices and experienced jumpers at any time interval on the jump day. There was a significant group difference, however, for baseline levels of heart rate, $\beta = 11.49$, $t = 2.61$, $p = .014$. While this difference might reflect a consequence of repeated skydiving on basal physiological functioning, we were cautious to interpret this difference as such due to the possibility that our baseline measure for experienced jumpers reflected their recovery from a previous jump that same day.

Were there other between-individual variables that predicted heart rate?

Sex was a significant predictor of baseline heart rate, $\beta = 15.15$, $t = 2.80$, $p = .009$, such that females had higher baseline heart rate. Individuals with higher BMI showed a greater increase in heart rate during the jump than those individuals within the normal BMI range, $\beta = 0.90$, $t = 2.89$, $p = .007$. Age significantly predicted the anticipatory heart rate increases, $\beta = 3.83$, $t = 2.11$, $p = .042$; older individuals evidenced more anticipation. Sensation seeking scale scores were also added as level-2 variables as exploratory analyses into the association between the trait, as indexed by the SSS, and heart rate throughout jump day. The findings were similar to those for cortisol levels, such that higher total SSS-V scores significantly predicted elevated baseline heart rate, $\beta = 1.37$, $t = 2.89$, $p = .007$, but there was not an association between SSS scores and heart rate

during anticipation, jumping, or recovery. Race was not a significant predictor of heart rate.

Discussion

The primary purpose of the present study was to gain an understanding of the sensation-seeking trait and the psychobiological mechanisms by which the trait becomes behaviorally expressed. We measured the stress response (both autonomic and hormonal) of individuals hypothesized to be high sensation seekers as they participated in a high-risk activity (skydiving). This first hypothesis, that individuals willing to skydive would score high on the sensation seeking scales, was largely supported. Furthermore, despite the fact that the activity was voluntarily sought-out by individuals in this study, we supported the second hypothesis that skydiving was an effective stressor that required activation of both the SAM system and the HPA-axis. Additionally, we utilized group differences in exposure to a specific sensation-seeking behavior in order to disentangle the relative contributions of novelty and risk in facilitating and maintaining the sensation seeking behavioral outcomes commonly associated with the trait. Though both experienced and novice jumpers exhibited stress responsivity, we found that the two groups elicited different timing and strength of cortisol release. Moreover, there were no significant differences between novice and experienced jumpers in autonomic stress responsivity, as indexed by heart rate changes. These findings have important implications for the role of novelty and risk in shaping stress responsivity across stress responsive systems.

Do the individuals in this study qualify as high sensation seekers?

Consistent with our first hypothesis, both males and females in this study scored significantly higher than the general population on total sensation seeking (version V). Upon closer examination, however, this hypothesis was not unequivocally supported across all subscales of the Sensation Seeking Scale. The individuals who opted to skydive for this investigation seek thrill, adventure and new experiences, but they can inhibit themselves from such experiences if necessary. Despite the fact that they are engaging in a quintessential sensation-seeking behavior, participants did not endorse an extreme need to seek new and risky sensations. This pattern of SS subscale scores is common in individuals who tend to express the SS trait via high-risk sports (Hymbaugh & Garrett, 1974) and vocations (Musolino & Hershenson, 1977), while higher scores on the Dis subscale are associated with delinquent expression of the SS trait (Newcomb & McGee, 1991). In order to support the notion that our participants do not represent a highly delinquent group, exploratory analyses compared our participants' self-reported delinquency scores with means from a normative sample and found no significant difference between the groups.¹

Zuckerman (1994) distinguishes between two forms of sensation seeking individuals: impulsive, unsocialized sensation seekers (ImpUSS) and non-impulsive, socialized sensation seekers. Subsequent research suggested the ImpUSS form of sensation seeking is captured by the Dis, BS, and ES subscales of the SSS-V, while the non-impulsive, socialized form of sensation seeking is captured by TAS subscale scores (Glicksohn and Abulafia, 1998). Further, high scores on the Dis and BS subscales are

¹ Normative sample general delinquency means reported by Heinrichs (2003). A single sample t-test revealed no significant difference between our participants and the normative sample, $t(28) = 1.08$, $p = .289$, 95% CI = $-.08$ to $.26$.

associated with a nonconforming and nonconventional personality type (Glicksohn and Abulafia, 1998). That individuals in this study scored consistently highest on the TAS subscales, resulting in elevated overall SS scores, suggests that our sample represents non-impulsive, socialized sensation seekers. As such, our sample may represent a population of individuals with a general tendency toward sensation seeking beliefs, ideas, attitudes and behaviors, but also a complementary ability to inhibit the SS trait or cope with boredom when necessary. Importantly, this may provide additional evidence for our overarching conceptual model which emphasizes mitigating or mediating factors between the trait and the expression of that trait.

Our participants exhibit context-appropriate SS trait expression, which is an important factor in how the SS trait may be evolutionarily adaptive. In contrast to Zuckerman's view on the lack of utility of the trait in current society (1994), more modern evolutionary theories can also explain why this trait may be advantageous. Evolutionary life history perspective offers that a trait is neither good nor bad independently; rather, the valence and usefulness of the trait depends on the life history of the individual and the environment in which the trait is expressed (Ellis, 2004; Ellis & Brumbach, 2009). The individual's life history and social context influence the underlying expression of a trait, rather than being enslaved to its ultimate expression. Evolutionary approaches emphasize that if the time, energy and resources invested in an activity lead to an increase in reproductive or survival probability, then the activity may be beneficial to the individual (Belsky et al., 1991). In some situations, even potentially dangerous behavioral expression of the trait (i.e. fast diving; drug dealing) may increase an individual's chances of reproducing by enhancing his or her appeal to the opposite

sex; thus, the benefit of the behavior may offset the small potential risk of decreased survival probability inherent in those activities.

Applying this evolutionary perspective to the present study, we speculate that individuals who possess the sensation seeking trait may appear interesting and exciting to potential mates, and the behavioral expression of the trait (i.e. witnessing someone participate in a high-risk activity) may intensify this perception. Our participants, however, did not score high on all components of SS scales; rather, they exhibited a pattern of responding suggesting motivation toward adventure and novelty, but only in context-appropriate situations. The ability to inhibit sensation seeking tendencies in situations that may not benefit the individual in terms of survival or reproduction may be an example of a resource-allocation strategy (Ellis & Brumbach, 2009), such that an individual expresses the SS trait only when there is an evident advantage to the behavior and not when expression may be extremely dangerous or futile.

Did the participants experience an increase in cortisol in response to skydiving?

Consistent with previous research, both novice and experienced jumpers evidenced increases in cortisol in response to the stressor (Piazza et al., 1993; Chatterton et al., 1997). Given the presumed timing of HPA stress responsivity (Dickerson & Kemeny, 2004), we supported our expectation that cortisol reactivity would peak after fifteen minutes. The samples collected upon landing and at fifteen minutes post-landing (tubes three and four, respectively) indicated a robust stress response for both groups of participants, suggesting that this positively-valenced, sought-out activity was an effective psychobiological stressor. The perception of skydiving as a stressor necessitated a psychobiological response in order to aid the individual in coping with the extreme

demands of the environment. Cortisol release is one allostatic mediator the body employs in order to optimize physical and mental conditions until the environment is rendered safe enough to return to homeostatic functioning (Lupien et al., 2006).

Did the novices have a more robust increase in cortisol than the experienced jumpers?

Novice jumpers demonstrated a peak in cortisol levels at the fifteen minute post-landing sample; based on the timing of the HPA stress response system, this indicates that novice individuals interpreted the actual jump from the plane as the most stressful experience. Experienced jumpers, on the other hand, evidenced a peak cortisol response immediately upon landing, indicating that experienced individuals had already begun their physiological recovery during the actual jump. This might be explained by the experienced jumpers' perception of control over the situation (Breier et al., 1987) or because repeated exposure to the same stressor facilitated a quick and efficient return to homeostatic functioning (Schommer et al., 2003). Previous research by Kudielka et al. (2006) suggests that habituation of cortisol release in response to a repeated, acute stressor is evidence of regulated and adaptive HPA-axis functioning.

Conversely, these findings demonstrate that, compared to individuals who have repeated exposure to the stressor, the presence of novelty prolongs the stress response and delays recovery. As previously described, high sensation seekers show activation in the insula whenever a novel stimulus is encountered, which indicates that novelty is emotionally arousing to these individuals. Emotional arousal is associated with cortisol release, possibly to facilitate memory storage of the emotional stimuli (Wittling & Pflüger, 1990; Buchanan & Lavallo, 2001); thus, the emotional arousal induced by the

perception of novelty may be one mechanism leading to the release of cortisol during this sought-out form of eustress.

As previously stated, the HPA-axis is activated to manage novel, unpredictable and/or uncontrollable situations (Mason, 1968). Our results showed no group difference in cortisol during baseline samples but a significant group difference in cortisol levels (i.e. robustness of response) during and after the jump. This suggests that individuals in both groups started from similar physiological states, but that the interpretation of novelty, uncontrollability, and/or unpredictability differed between the groups and led to differences in reactivity to the stressor. Since this was the first jump for novice jumpers, novelty is an obvious factor contributing to the difference in the allostatic response. Uncontrollability could provide an additional explanation, since our novice participants were required to jump in tandem and, therefore, had no control over the status of the jump. On the other hand, that the experienced jumpers initiated an allostatic response at all implies that the motivation for risk alone is sufficient to produce a physiological change. The stress response exhibited by the experienced jumpers also indicates that these individuals have not completely physiologically habituated to the stressor, despite repeated exposure, which lends evidence that the physiological repercussions of the sensation seeking behavior may be inherently rewarding (Piazza et al., 1993).

Did the participants experience an increase in heart rate in response to skydiving?

As would be expected based on previous literature describing the acute stress effects on the SAM system (Sapolsky, 1998; Al'Absi et al., 1997), participants experienced an increase in heart rate in response to skydiving. Since our participants wore the Actiheart devices for an average of 2 hours and 5 minutes, we identified an

anticipation interval that occurs in the hour before the jump interval in order to assess changes in heart rate caused by the anticipation of the stressor. Consistent with previous research, we found that heart rate decreased during the anticipation interval, possibly in preparation of allocating resources for the expected stressful event (Molen et al., 1989; Jennings et al., 1990). During the jump interval, however, participants evidenced a robust increase in heart rate, suggesting activation of the SAM system in order to elicit a fight or flight response. Zuckerman (1990) suggested that the heart rate response of high sensation seekers to an activity is dependent on the intensity and interest; our findings suggest that both groups perceived the stressor to be of sufficient intensity and of great enough interest to elicit such a response. In addition to the anticipatory and jump intervals, we also identified a recovery interval, which captures changes in heart rate over the (average of) 26 minutes the Actiheart devices were worn after landing. During this interval, most participants began to recover from the peak heart rate during the jump. However, consistent with previous research suggesting that individual differences drive heart rate recovery (Roger & Jamieson, 1987), there was not a linear trend to the recovery interval and there was substantial variability in the patterns of recovery.

Did novices experience more robust increase in heart rate during the jump?

There were no significant differences in heart rate between novice participants and experienced participants before, during, or after the jump. In fact, the raw data illustrates that experienced jumpers, if anything, sustained higher heart rates throughout the skydiving day, including during the jump interval. This is contrary to our original hypothesis, which stated that experienced jumpers would experience an attenuated heart rate response. However, we concede that this may be one mechanism underlying the motivation to repeatedly participate in the same high-risk activity. For example,

activation of the SAM system leads to rapid increases in heart rate and release of epinephrine, which would typically aid an individual to fight or run from a threat (Kemeny, 2003). However, if the individual does not perceive the stressor eliciting this response as threatening, activation of the SAM system may be interpreted as a physiological “rush,” as the release of epinephrine and norepinephrine associated with SAM activation may modulate the reward system in the brain (Poschel & Ninteman, 1963; German & Bowden, 1974). Thus, it is possible that this rush is subjectively pleasant and is, therefore, assigned a positive valence and may be inherently rewarding to the individual, motivating them to engage in the behavior again in order to achieve activation of the SAM system.

Furthermore, evidence for habituation in one physiological system and not another is a powerful demonstration that the components of the stress response are not identical, but are coordinated in an intricate balance. Several empirical paradigms have demonstrated differential habituation patterns in the SAM system and the HPA axis (Frankenhaeuser et al., 1980; McCann et al., 1993; Schommer et al., 2003). In regard to reactivity, the SAM system responds in an emergency and facilitates immediate vigilance, arousal, activation and mobilization; this system does not habituate because no matter how many times the emergency is encountered, a response is still necessary and adaptive (Sapolsky, 1998). The HPA-axis, however, responds mostly to novel and unpredictable stressors and habituates because both of these factors are weakened with repeated exposure (Wust et al., 2005). These apparently divergent findings regarding habituation of the stress response systems fit with the theory of allostasis in that activation of the HPA-axis seems to “cost” the body more immediately and in regard to

long-term consequences (Lupien et al., 2006). Over-activation of the HPA-axis may lead to inefficient functioning of this stress response system, and may also contribute to increased vulnerability to disease (McEwen, 1998). Thus, fast-acting and fast-recovering SAM system may be the optimal coping mechanism with an acute stressor, especially after repeated exposure.

Broader Implications

By investigating the biology associated with skydiving, we hoped to unveil a better understanding of why some individuals (namely, those with the sensation seeking trait) choose to participate in behaviors that are risky. From an applied perspective, this information could be useful for the long-term health of these individuals. In the extreme form, expression of sensation seeking behaviors may be maladaptive for the individual's mental and physical health. It is notable, however, that our participants likely do not reflect the most extreme sensation seekers, but rather achieve a balance of context-appropriate trait expression. Although it is relatively safe to jump out of an airplane, other sensation seeking behaviors or more extreme trait expression may pose health risks. For example, high sensation seeking has been associated with excessive gambling (Kuley & Jacobs, 1988), risky sex (Donohew et al., 2000), drug abuse (Wagner, 2001), and reckless driving (Clement & Jonah, 1984). These modern expressions of the trait pose a health risk for these individuals, such that they are putting themselves at jeopardy for unnecessary illness or death. By understanding the physiological underpinnings associated with these behaviors, there is potential to help these individuals resist the urge to participate in these dangerous activities or consider ways of improving their safety standards in order to subsequently avoid unnecessary health problems.

In addition to the previously described behavioral expressions, there is potential for understanding antisocial behavioral expressions, since some components of the underlying physiological mechanisms may be shared. Two individuals who possess the sensation-seeking trait may behaviorally express it differently. For example, one individual chooses skydiving and the other chooses shoplifting as a means to achieve the same physiological response. Research suggests that the Dis scale of the SSS-V is highly correlated with delinquent behavior (Newcomb & McGee, 1991), and White et al., (1985) used scores on the Dis scale to predict future delinquency in adolescents. Interestingly, Goma et al., (1988) compared firefighters and prisoners and found that, while total SSS scores were not significantly different between the two groups, subscale differences were found such that prisoners were higher on Dis and BS and firefighters were higher on TAS and ES. Based on these findings, it seems possible that criminal behavior is one profile of the sensation seeking trait, while non-criminal sensation seeking behavior is another profile. It has been suggested that socio-economic status (SES) is one of the determining factors for which type of risk-taking activities an individual will engage in (Farley, 1973; 1981). According to this theory, high SES affords an individual socially acceptable or context-appropriate means of behavioral expression, such as cars, travels and sports. On the other hand, individuals from low SES backgrounds may pursue criminal means of expression because of the physiological and financial rewards. Unfortunately, these same behaviors may be considered context-appropriate for the environment in which these individuals live, and so the SS trait may be adaptive for the individual at the same time that may be considered maladaptive for society as a whole. By identifying the biological mechanisms leading to and resulting from these behavioral expressions in individuals

who participate in socially sanctioned outlets, there is potential for extending our understanding the antisocial manifestation of sensation seeking as well.

Limitations

The sample size of the experienced group leaves something to be desired. This group of individuals was unexpectedly difficult to recruit, and even more difficult to retain through collection of basal samples. Though we believe our data conveys meaningful information, we concede that having more individuals representing the experienced jumpers would boost confidence in the findings. Additionally, though our procedure has ecological validity, the non-laboratory design forced us to adapt the protocol to the time-constraints of a typical day for the experienced jumpers. This left us with fewer saliva samples and less heart rate data for the experienced group as compared to the novice group. Nonetheless, the data that was collected maintained the same rigorous data collection protocol treatment as the other group, so the reliability of the data across groups should be parallel.

Future Directions

Our findings represent the psychobiological mediators of the sensation seeking trait only in individuals who qualify as high sensation seekers; thus, adding a low sensation seeking control group is a viable future direction in order to identify the role of the stress response systems across all manifestations of the sensation seeking trait. Our results indicate that the Sensation Seeking Scales might be a useful way of classifying individuals along the continuum of the sensation seeking. Since basal cortisol levels help the body maintain physiological functioning by regulating how open the individual is to information about their environment (Boyce & Ellis, 2005), we might expect basal cortisol from low sensation seeking individuals to elucidate whether the sensation

seeking trait is associated with basal hormone levels. In other words, we could address whether high SS individuals have lower basal cortisol due to their repeated activation of the stress response system and subsequent altering of the homeostatic set point of the HPA axis. In line with the optimal level of arousal theory, low basal cortisol levels may be associated with a propensity for high-risk events because individuals with low cortisol may seek physiologically stimulating activities in order to experience physiological arousal at normal levels (Lovallo, 1997; van Goozen et al., 2007).

Additionally, by adding a control group of low sensation seekers, HPA and SAM reactivity could be assessed by simulating a skydiving event via auditory and visual input (i.e. watching a video from the perspective of a skydiver with the appropriate sounds accompanying the video). This would allow the opportunity to expand our theoretical model to include low SS individuals as they experience a risk-taking activity; thus, the novelty component would be present, but the motivation for risk would be diminished. We would expect that these individuals would experience a more robust stress response than either the novice or experienced jumpers, such that a gradient of stress reactivity would emerge.

This investigation highlighted the factors that mediate the process by which the sensation seeking trait culminates in behavioral expression. We solidified novelty and risk as key components in the expression of the trait, but we also provided evidence that the stress response systems are essentially involved in motivating and rewarding high-risk activities, such as skydiving. Specifically, the HPA-axis may underlie the motivation toward participating in high-risk activities for the first time, as activation of this system is dependent upon novelty and unpredictability (Mason, 1968) and is necessary for

motivation toward acquisition of a desired stimulus (Goeders, 2002; Marinelli & Pizza, 2002). The SAM system, on the other hand, may underlie the motivation toward repeated participation in a high-risk activity, as this psychobiological system shows resistance to habituation (Schommer et al., 2003) and can be perceived as inherently rewarding (German & Bowden, 1974). The findings of this study provide preliminary insight into the psychobiological mechanisms underlying sensation seeking behaviors. Understanding these mechanisms is imperative to identifying individuals who may put themselves or others at risk, whether through socially-sanctioned or delinquent expression, and who may continue to seek these behaviors over time.

References

- Abler, B., Walter, H., Erk, S., Kammerer, H., & Spitzer, M. (2006). Prediction error as a linear function of reward probability is coded in human nucleus accumbens. *Neuroimage*, 31(2), 790-795.
- Adam, E. (2006). Transactions among adolescent trait and state emotion and diurnal and momentary cortisol activity in naturalistic settings. *Psychoneuroendocrinology*, 31(5), 664-679.
- Al'Absi, M., Bongard, S., et al. (1997). Cardiovascular and neuroendocrine adjustment to public speaking and mental arithmetic stressors. *Psychophysiology*, 34(3): 266-275.
- Antelmi, I., De Paula, R., Shinzato, A., et al. (2004). Influence of age, gender, body mass index, and functional capacity on heart rate variability in a cohort of subjects without heart disease. *Am J Cardiol.*, 93: 381–385.
- Bateup, H., Booth, A., Shirtcliff, E., & Granger, D. (2002). Testosterone, cortisol, and women's competition. *Evolution and Human Behavior*, 23(3), 181-192.
- Belsky, J., Steinberg, L., & Draper, P. (1991). Childhood experience, interpersonal development, and reproductive strategy: An evolutionary theory of socialization. *Child Development*, 62, 647-670.
- Bennett, G., Merritt, M., & Wolin, K. (2004). Ethnicity, education, and the cortisol response to awakening: a preliminary investigation. *Ethn Health*, 9(4), 337-347.
- Berk, L., Tan, S., Fry, W., Napier, B., Lee, J., Hubbard, R., Lewis, J., & Eby, W. (1989). Neuroendocrine and stress hormone changes during mirthful laughter. *American Journal of Medical Sciences*, 298(6).
- Berk, L., Felten, D., Tan, S., Bittman, B., & Westengard, J. (2001). Modulation of neuroimmune parameters during the eustress of humor-associated mirthful laughter. *Alternative Therapies in Health and Medicine*, 7(2), 62–76.
- Bohus, B., de Kloet, E., Veldhuis, H. (1982). Adrenal steroids and behavioral adaptation: relationship to brain corticoid receptors. In D Granten & D Pfaff (Eds.), *Current Topics in Neuroendocrinology* (pp. 107–48). Berlin: Springer-Verlag.
- Boyce, T. & Ellis B. (2005). Biological sensitivity to context: I. An evolutionary-developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology*, 17, 271-301.
- Breier, A., Albus, M., Pickar, D., Zahn, T., Wolkowitz, O., & Paul, S. (1987). Controllable and uncontrollable stress in humans: alterations in mood and neuroendocrine and psychophysiological function. *Am J Psychiatry*, 144: 1419-1425
- Buchanan T., & Lovallo W. (2001). Enhanced memory for emotional material following stress-level cortisol treatment in humans. *Psychoneuroendocrinology*, 26(3), 307-317.
- Byrne, E., Fleg, J., Vaitkevicius, P., Wright, J., & S. W. Porges. (1996). Role of aerobic capacity and body mass index in the age-associated decline in heart rate variability. *J. Appl. Physiol.* 81: 743-750.
- Cannon, W. (1929). *Bodily Changes in Pain, Hunger, Fear, and Rage*. Boston: Branford

- Chatterton, R., Vogelsong, K., Lu, Y., & Hudgens, G. (1997). Hormonal Responses to Psychological Stress in Men Preparing for Skydiving. *Journal of Clinical Endocrinology and Metabolism*, 82(8), 2503-2509.
- Critchley, H. (2005). Neural mechanisms of autonomic, affective, and cognitive integration. *J Comp Neurol*, 493(1), 154-166.
- Critchley, H., Corfield, D., Chandler, M., Mathias, C., & Dolan, R. (2000). Cerebral correlates of autonomic cardiovascular arousal: a functional neuroimaging investigation in humans. *J Physiol*, 523 Pt 1, 259-270.
- de Kloet E. (1991). Brain corticosteroid receptor balance and homeostatic control. *Front. Neuroendocrinology*, 12, 95-164.
- Deinzer, R., Kirschbaum, C., Gresele, C., & Hellhammer, D. (1997). Adrenocortical Responses to Repeated Parachute Jumping and Subsequent h-CRH Challenge in Inexperienced Healthy Subjects. *Physiology & Behavior*, 61(4), 507-511.
- Dickerson, S., & Kemeny, M. (2004) Acute Stressors and Cortisol Responses: A Theoretical Integration and Synthesis of Laboratory Research. *Psychological Bulletin*, 130(3), 355-391.
- Ellis, B. (2004). Timing of pubertal maturation in girls: an integrated life history approach. *Psychol Bull*, 130(6): 920-958.
- Ellis, B., Essex, M. & Boyce, T. (2005). Biological sensitivity to context: II. Empirical explorations of an evolutionary-developmental theory. *Development and Psychopathology*, 17, 303-328.
- Ellis, B. & Brumbach, B. (2009). Fundamental dimensions of environmental risk: the impact of harsh versus unpredictable environments on the evolution and development of life history strategies. *Human Nature*, 20, 204-268.
- Eisenberger, N., Lieberman, M., & Williams, K. (2003). Does rejection hurt? An FMRI study of social exclusion. *Science*, 302(5643), 290-292.
- Eisenberger, N., Taylor, S., Gable, S., Hilmert, C., & Lieberman, M. (2007). Neural pathways link social support to attenuated neuroendocrine stress responses. *Neuroimage*, 35(4), 1601-1612.
- Ernst, M., Nelson, E., et al. (2005). Amygdala and nucleus accumbens in responses to receipt and omission of gains in adults and adolescents. *Neuroimage* 25(4): 1279-1291.
- Farley, F. (1973). *Implications for a theory of delinquency*. Paper presented at *The sensation seeking motive*, a symposium at the meeting of the American Psychological Association, Montreal, Canada. August.
- Farley, F. (1981). Basic process individual differences: A biologically based theory of individualization for cognitive, affective, and creative outcomes. In FH Farley & NJ Gordon (Eds.), *Psychology and education: the state of the union*. Berkeley, CA: McCutcheon Publishing.
- Frankenhaeuser, M., Lundberg, U., & Forsman, L. (1980). Dissociation between sympathetic-adrenal and pituitary-adrenal responses to an achievement situation characterized by high controllability: comparison between type A and type B males and females. *Biol Psychol*, 10:79-91.
- Frexiant, M. (1991). Personality profile of subjects engaged in high physical risk sports. *Personality and Individual Differences*, 12, 1087-1093.

- German, D. & Bowden, D. (1974). Catecholamine systems as the neural substrate for intracranial self-stimulation: a hypothesis. *Brain Research* 73(3): 381-419.
- Goeders, N. (2002). The HPA axis and cocaine reinforcement. *Psychoneuroendocrinology*, 27, 13-33.
- Goma, M., Perez, J., & Torrubia, R. (1988). Personality variables in antisocial and prosocial disinhibitory behavior. In T.E. Moffitt & S.A. Mednick (Eds.), *Biological contributions to crime causation* (pp. 211-222). Dordrecht, the Netherlands: Martinus Nijhoff.
- Gonzalez-Bono, E., Salvador, A., Serrano, M. A., & Ricarte, J. (1999). Testosterone, cortisol, and mood in a sports team competition. *Horm Behav*, 35(1), 55-62.
- Granger, D., Shirtcliff, E., Zahn-Waxler, C., Usher, B., Klimes-Dougan, B., & Hastings, P. (2003). Salivary testosterone diurnal variation and psychopathology in adolescent males and females: individual differences and developmental effects. *Dev Psychopathol*, 15(2), 431-449.
- Gunnar, M., & Quevedo, K. (2007). The Neurobiology of Stress and Development. *The Annual Review of Psychology*. 58, 145-173.
- Gunnar, M., Talge, N., & Herrera, A., (2009). Stressor paradigms in developmental studies: what does and does not work to produce mean increases in salivary cortisol, *Psychoneuroendocrinology*, 34, 953-967.
- Hastings, P., Ruttle, P., Serbin, L., Mills, R., Stack, D., & Schwartzman, A. (In review). Adrenocortical Responses to Strangers in Preschoolers: Relations with Parenting, Temperament, and Psychopathology. *Developmental Psychobiology*.
- Hebb, D. (1949). *The organization of behavior*. New York: Wiley.
- Heinrichs, B. (2003). Self-Reported Delinquency (Fast Track Project Technical Report). Available from the Fast Track Project website: <http://www.fasttrackproject.org>
- Hymbaugh, K., & Garrett, J. (1974). Sensation seeking among skydivers. *Perceptual and Motor Skills*, 38, 118.
- Jennings, J., Molen, M., Somsen, R., & Terezis, C. (1990). On the Shift from Anticipatory Heart Rate Deceleration to Acceleratory Recovery: Revisiting the Role of Response Factors. *Psychophysiology*, 27(4), 385-395.
- Jensen-Urstad K, Storck N, Bouvier F, Ericson M, Lindblad LE & Jensen-Urstad M (1997). Heart rate variability in healthy subjects is related to age and gender. *Acta Physiologica Scandinavica*, 160: 235-241.
- Joseph, J., Liu, X., Jiang, Y., Lynam, D., & Kelly, T. (2008). Neural correlates of emotional reactivity in sensation seeking. *Psychological Science* 20(2), 215-223.
- Kalichman, S., Heckman, T., & Kelly, J. (1996). Sensation Seeking as an explanation for the association between substance use and HIV-related risky sexual behavior. *Archives of Sexual Behavior*, 25(2), 141-154.
- Kemeny, M.E. (2003). The psychobiology of stress. *Current Directions in Psychological Science*, 12, 124-129.
- Kirschbaum, C., & Hellhammer, D. (1990). Methodological aspects of salivary cortisol measurement. In C. Kirschbaum, G. F. Read & D. Hellhammer (Eds.), *Assessment of hormones and drugs in saliva in biobehavioral research*. Gottingen, Germany: Hogrefe & Huber Publishers.
- Kivlighan, K., Granger, D., & Booth, A. (2005). Gender differences in testosterone and cortisol response to competition. *Psychoneuroendocrinology*, 30(1), 58-71.

- Koob, G., & DeMoal, M. (2000). Drug addiction, Dysregulation of Reward, and Allostasis. *Neuropsychopharmacology*, 24(2), 97-129.
- Kudielka, B., von Kanel, R., et al. (2006). Exhaustion is associated with reduced habituation of free cortisol responses to repeated acute psychosocial stress. *Biol Psychol*, 72(2): 147-153.
- Kudielka, B., Buske-Kirschbaum, A., Hellhammer, D., & Kirschbaum, C. (2004). HPA axis responses to laboratory psychosocial stress in healthy elderly adults, younger adults, and children: impact of age and gender. *Psychoneuroendocrinology*, 29(1), 83-98.
- Kuhnen, C., & Knutson, B. (2005). The neural basis of financial risk-taking. *Neuron*, 47:763–770.
- Kuley, N., & Jacobs, D. (1988). The relationship between dissociative-like experiences and sensation seeking among social and problem gamblers. *Journal of Gambling Studies*, 4(3), 197-207.
- Laudet, M., Cerdas, S., Fournier, C., Guiban, D., Guilhaume, B., & Luton, J. (1988). Salivary cortisol measurement: a practical approach to assess pituitary-adrenal function. *Journal of Clinical Endocrinology and Metabolism*, 66, 343-348.
- Lovallo, W. (1997). *Stress and health: Biological and psychological interactions*. Vol. 1. Sage publications; Thousand Oaks.
- Levenson, M. (1990). Risk Taking and Personality. *Journal of Personality and Social Psychology*, 58(6), 1073-1080.
- Liao, D., Barnes, R., Chambless, L., et al. (1995). Age, race, and sex differences in autonomic cardiac function measured by spectral analysis of heart rate variability-The ARIC study. *Am J Cardiol*, 76: 906–12.
- Lupien, S., Ouellet-Morin, I., Hupbach, A., Tu, M., Buss, C., Walker, D., Pruessner, J. & McEwen, B. (2006). Beyond the stress concept: Allostatic load- A developmental Biological and Cognitive perspective. In: D Cicchetti (Ed.), *Handbook series on developmental psychopathology* (pp. 784-809). Wisconsin.
- Marinelli, M., & Piazza, P.. (2002). Interaction between glucocorticoid hormones, stress and psychostimulant drugs. *Eur. J. Neurosci.* 16:387–94
- Mason, J. (1968). A review of psychoendocrine research on the sympathetic-adrenal medullary system. *Psychosomatic Medicine*, 30(Suppl. 5), 631–653.
- Matthews, S., Simmons, A., Lane, S., & Paulus, M. (2004). Selective activation of the nucleus accumbens during risk-taking decision-making. *NeuroReport*, 15:2123–2127.
- McCann, B., Carter, J., Vaughan, M., Raskind, M., Wilkinson, C., Veith, R. (1993). Cardiovascular and neuroendocrine responses to extended laboratory challenge. *Psychosom Med*, 55:497–504.
- McEwen, B. (1998) Protective and damaging effects of stress mediators. *N Engl J Med*, 338:171–9.
- McEwen, B. & Wingfield, J. (2003). The concept of allostasis in biology and biomedicine. *Hormones and Behavior*, 43, 2-15.
- McRae A., Saladin, M., Brady, K., Upadhyaya, H., Back, S., & Timmerman, M. (2006). Stress Reactivity: biological and subjective responses to the cold pressor and Trier Social stressors. *Human Psychopharmacology*, 21, 377-385.

- Molen, M., Boomsma, D., Jennings, J., & Nieuwboer, R. (1989). Does the Heart Know What the Eye Sees? A Cardiac/Pupillometric Analysis of Motor Preparation and Response Execution. *Psychophysiology*, 26, 70-80.
- Musolino, R., & Hershenson, D. (1977). Avocational sensation seeking in high and low risk taking occupations. *Journal of Vocational Behavior*, 10, 358-365.
- Newcomb, M., & McGee, L. (1991). The influence of sensation seeking on general and specific problem behaviors from adolescence to young adulthood. *Journal of Personality and Social Psychology*, 61, 614-628.
- Oppenheimer, S., Wilson, J., Guiraudon, C., & Cechetto, D. (1991). Insular cortex stimulation produces lethal cardiac arrhythmias: a mechanism of sudden death. *Brain Res* 550:115–121.
- Piazza, P., Deroche, V., Deminie`re, J., Maccari, S., Le Moal, M., & Simon, H. (1993). Corticosterone in the range of stress-induced levels possesses reinforcing properties: implications for sensation-seeking behaviors. *Proc Natl Acad Sci USA* 90:11738–11742.
- Pomeranz, B., Macaulay, R., Caudill, M., Kutz, I., Adam, D., Gordon, D., Kilborn, K., Barger, A., Shannon, D., & Cohen, R. (1985). Assessment of Autonomic Function in humans by heart rate spectral analysis. *Heart and Circulatory Physiology*, 248(1), 151-153.
- Porges, S. (2003). The polyvagal theory: phylogenetic contributions to social behavior. *Physiol Behav*, 79:503–13.
- Poschel, B., & Ninteman, F. (1963). Norepinephrine: A possible excitatory neurohormone of the reward system. *Life Sciences* 2(10): 782-788.
- Raffin-Sanson ML, de Keyzer Y, & Bertagna X (2003). Proopiomelanocortin, a polypeptide precursor with multiple functions: from physiology to pathological conditions. *Eur. J. Endocrinology*, 149(2), 79–90.
- Rask, E., Olsson, T., Soderberg, S., Andrew, R., Livingstone, D., Johnson, O., & Walter, B. (2001). Tissue-specific dysregulation of cortisol metabolism in human obesity. *J Clin Endocrinol Metab*, 86(3), 1418-1421.
- Risold, P., Thompson, R., & Swanson, L. (1997). The structural organization of connections between hypothalamus and cerebral cortex. *Brain Res Brain Res Rev*, 24(2-3), 197-254.
- Robin P, Predine J, & Milgrom E. (1977) Assay of unbound cortisol in plasma. *Journal of Clinical Endocrinology and Metabolism*, 46, 277-283.
- Roger, D. & Jamieson, J. (1987). Individual differences in delayed heart-rate recovery following stress: The role of extraversion, neuroticism and emotional control. *Journal of Personality and Individual Differences*, 9(4), 721-726.
- Rosenblitt, J. C., Soler, H., Johnson, S. E., & Quadagno, D. M. (2001). Sensation seeking and hormones in men and women: exploring the link. *Horm Behav*, 40(3), 396-402.
- Sapolsky, R. (1998). *Why zebras don't get ulcers: A guide to stress, stress-related diseases, and coping*. New York: Freeman.
- Sapolsky, R., Romero, M., Munck, A. (2000). How Do Glucocorticoids Influence Stress Responses? Integrating Permissive, Suppressive, Stimulatory and Preparative Actions. *Endocrine Reviews*, 21(1), 55-89.
- Shiffman, S. & Stone, A. (1998). Ecological Momentary Assessment: A new tool for

- behavioral medicine research. In DS Kantz and A Baum (Eds.), *Technology and Methods in Behavioral Medicine* (pp. 117-131). Mahwah, NJ: Erlbaum.
- Shirtcliff, E. A., & Essex, M. J. (2008). Concurrent and longitudinal associations of basal and diurnal cortisol with mental health symptoms in early adolescence. *Dev Psychobiol*, 50(7), 691-703.
- Smith, R., Johnson, J., & Sarason I. (1978). Life change, the sensation seeking motive, and psychological distress. *Journal of Consulting and Clinical Psychology*, 46, 348-349.
- Stark, R., Wolf, O. T., Tabbert, K., Kagerer, S., Zimmermann, M., Kirsch, P., et al. (2006). Influence of the stress hormone cortisol on fear conditioning in humans: evidence for sex differences in the response of the prefrontal cortex. *Neuroimage*, 32(3), 1290-1298.
- Sterling, P., & Eyer, J. (1988). In S Fisher & J Reason (Eds.), *Handbook of life stress, cognition and health* (pp. 629-649). Oxford, England: John Wiley and Sons.
- Thornquist, M., Zuckerman, M., & Exline, R. (1991). Loving, liking, looking and sensation seeking in unmarried college couples. *Personality and Individual Differences*, 12, 1283-1292.
- van Goozen, S., Fairchild, G., Snoek, H., & Harold, G. (2007) The evidence for a neurobiological model of childhood antisocial behavior. *Psychological Bulletin*, 133(1), 149–182.
- van Veen, V. & Carter, C. (2002). The timing of action-monitoring processes in the anterior cingulate cortex. *Journal of Cognitive Neuroscience*, 14(4), 593-602.
- Vining R, McGinley R, & Symons R. (1983). Hormones in saliva: mode of entry and consequent implications for clinical interpretation. *Clinical Chemistry*, 29, 1752-1756.
- Wang, J., Rao, H., Wetmore, G., Furlan, P., Korczykowski, M., Dinges, D., et al. (2005). Perfusion functional MRI reveals cerebral blood flow pattern under psychological stress. *Proc Natl Acad Sci U S A*, 102(49), 17804-17809.
- White, H., LaBouvie, E., & Bates, M. (1985). The relationship between sensation seeking and delinquency: A longitudinal analysis. *Journal of Research in Crime and Delinquency*, 22, 197-211.
- Wagner, M. (2001). Behavioral characteristics related to substance abuse and risk-taking, sensation-seeking, anxiety sensitivity, and self reinforcement. *Addictive Behaviors*, 26(1), 115-120.
- Wittling, W., & Pfluger, M. (1990). Neuroendocrine hemisphere asymmetries: Salivary cortisol secretion during lateralized viewing of emotion-related and neutral films. *Brain and Cognition*, 14, 243–265.
- Wüst, S., & Federenko, S., et al. (2005). Habituation of cortisol responses to repeated psychosocial stress--further characterization and impact of genetic factors. *Psychoneuroendocrinology*, 30(2): 199-211.
- Yen, S., & Laughlin, G. (1998). Aging and the adrenal cortex. *Exp Gerontol*, 33(7-8), 897-910.
- Zuckerman, M. (1979). *Sensation Seeking: Beyond the Optimal Level of Arousal*. Erlbaum, Hillsdale, NJ.
- Zuckerman, M. (1990). The Psychophysiology of Sensation Seeking. *Journal of Personality*, 58(1), 313-345.

Zuckerman, M., Kuhlman, D., Thornquist, M., & Kiers, H. (1991). Five (or three) robust questionnaire scale factors of personality without culture. *Personality and Individual Differences*, 12, 929-941.

Zuckerman, M. (1994). *Behavioral Expressions and Biosocial Bases of Sensation Seeking*. Cambridge University Press: New York.

Appendix

Table 1. Skydiving day procedure.

Average Time	Activity
12:26pm	Informed Consent Obtained
12:32pm	First Saliva sample w/ Daily Dairy
12:38pm	Actiheart placed on participant
12:45pm	Novice Training for jump
12:55pm	Dressing in jumpsuits
1:46pm	Second Saliva sample w/ Daily Dairy
1:58pm	Board plane
2:00pm	Take-off
2:12pm	Jump
2:17pm	Third Saliva Sample w/Daily Dairy
2:25pm	Undressing from jumpsuit
2:35pm	Fourth Saliva Sample w/Daily Dairy
2:43pm	Actiheart removed
2:45pm	Finger lengths measured
2:50pm	Basal day scheduled and explained; Sensation seeking scales completed
3:25pm	Fifth Saliva Sample w/ Daily Dairy

Table 2. Single sample t-tests for males and females on the SSS-V.

	Mean	SD	t	p	95% C.I.		Normal Sample ¹	
					Lower	Upper	Mean	SD
Males								
Total	26.76	5.15	3.01	.000**	1.12	6.41	23.0	5.6
TAS	8.71	1.49	2.78	.013*	.24	1.77	7.7	2.2
ES	7.17	1.33	6.12	.000**	1.29	2.66	5.2	2.4
Dis	6.71	2.64	.332	.752	-1.15	1.56	6.5	2.6
BS	4.17	2.07	1.15	.267	-.49	1.64	3.6	2.1
Females								
Total	24.3	2.95	5.69	.000**	3.19	7.41	19.0	5.7
TAS	8.20	1.48	3.86	.004**	.74	2.86	6.4	2.7
ES	6.70	1.16	5.19	.001**	1.07	2.73	4.8	2.1
Dis	6.00	1.76	1.61	.141	-3.16	2.16	5.1	2.3
BS	3.40	2.01	1.26	.24	-.64	2.24	2.6	2.0

¹Data from: Zuckerman, M., Kuhlman, D., Thornquist, M., & Kiers, H. (1991). Five (or three) robust questionnaire scale factors of personality without culture. *Personality and Individual Differences*, 12, 929-941.

Table 3. Single sample t-tests for males and females on the SSS-VI.

	Mean	SD	t	p	95% C.I.		Normal Sample ¹	
					Lower	Upper	Mean	SD
Males								
E-TAS	28.83	4.73	5.72	.000**	4.03	8.74	22.45	4.77
E-Dis	97.06	12.26	1.20	.247	-2.63	9.56	93.59	16.77
I-TAS	52.00	7.02	4.01	.001**	3.29	10.27	45.22	9.32
I-Dis	90.67	12.15	-2.38	.029*	-13.93	-.84	98.05	18.76
Females								
E-TAS	25.10	3.67	4.12	.003**	2.16	7.40	20.32	3.74
E-Dis	90.90	5.84	3.91	.004**	3.04	11.40	83.68	14.0
I-TAS	46.60	5.64	2.97	.016*	1.26	9.34	41.30	8.87
I-Dis	77.50	11.82	-2.80	.021*	-18.91	-2.01	87.96	16.23

¹Data from: Zuckerman, M. (1994). *Behavioral Expressions and Biosocial Bases of Sensation Seeking*. Cambridge University Press: New York.

Figure 3. Cortisol levels on skydiving and basal days.

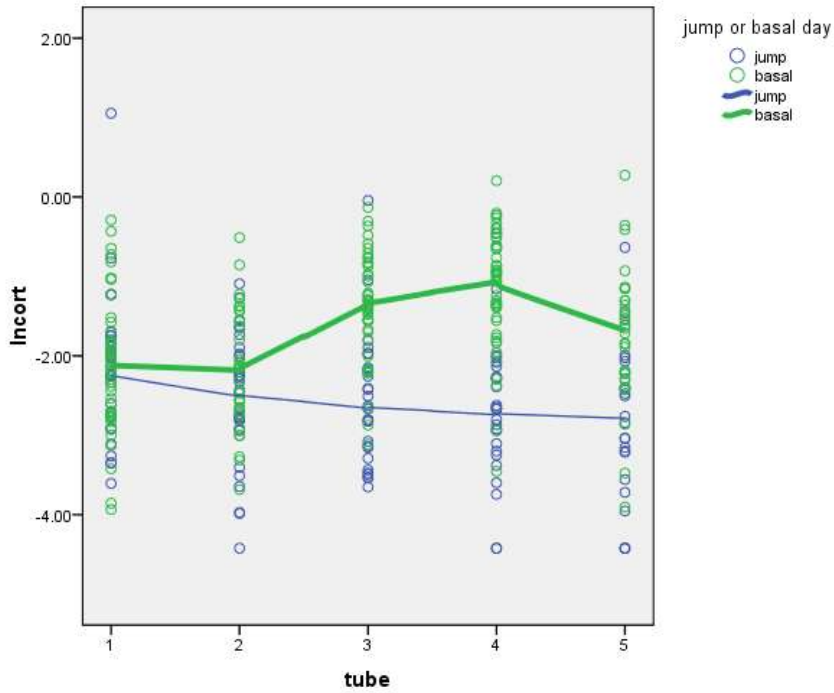


Figure 4. Cortisol levels on skydiving and basal days for experienced and novice jumpers.

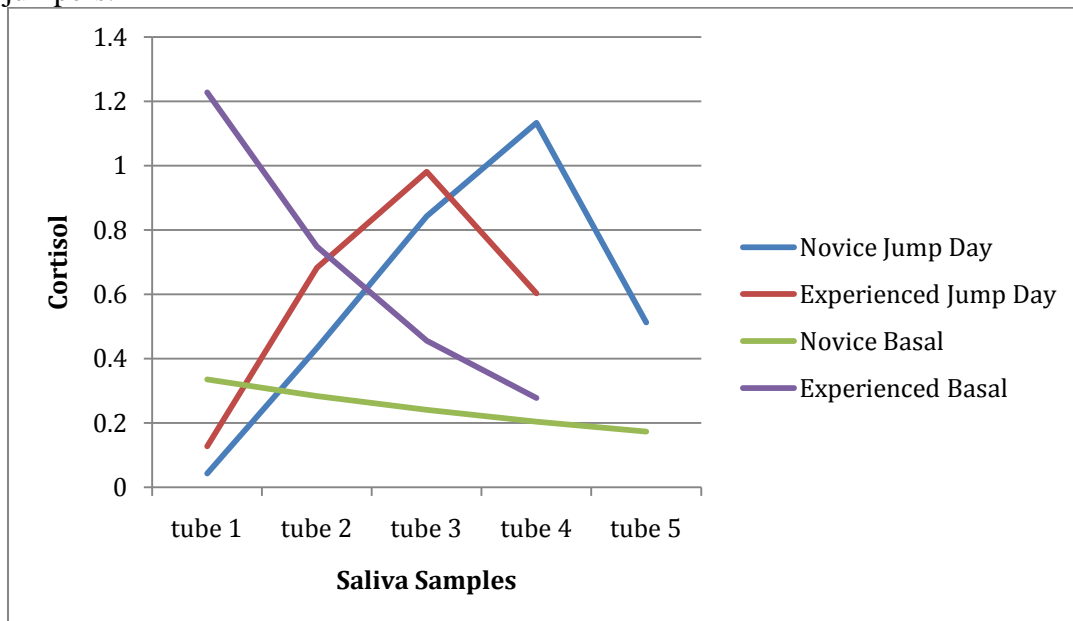


Figure 5. Heart rate on skydiving day for experienced and novice jumpers.

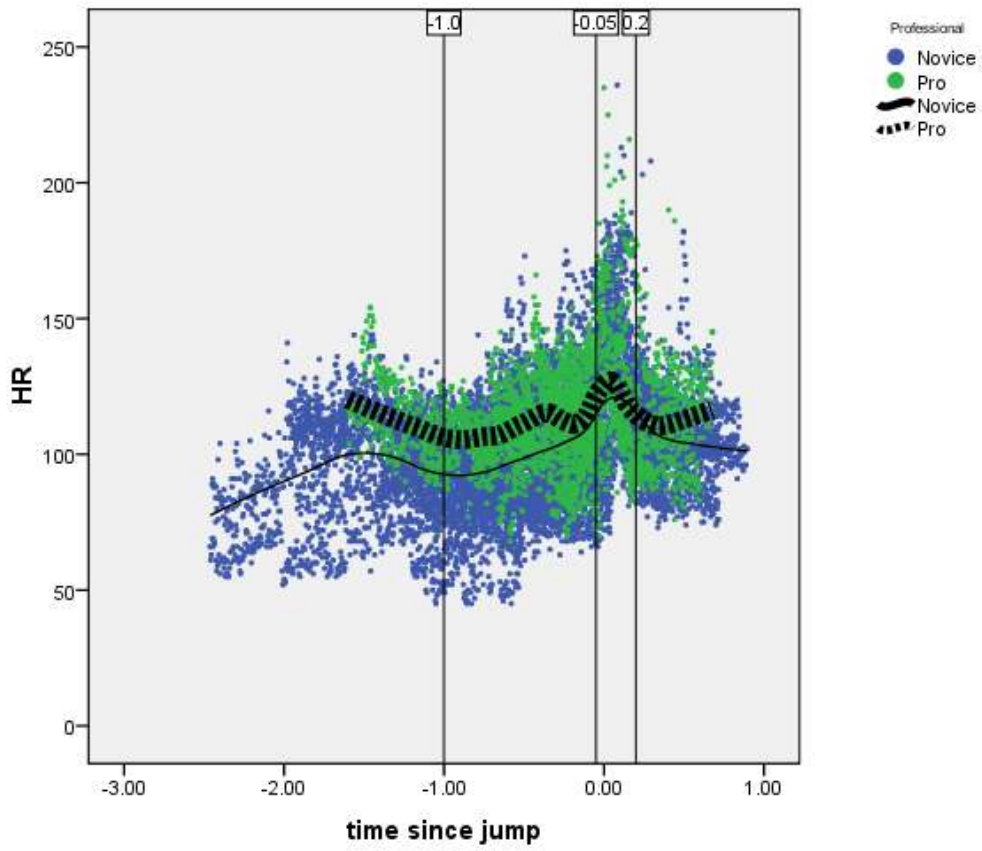
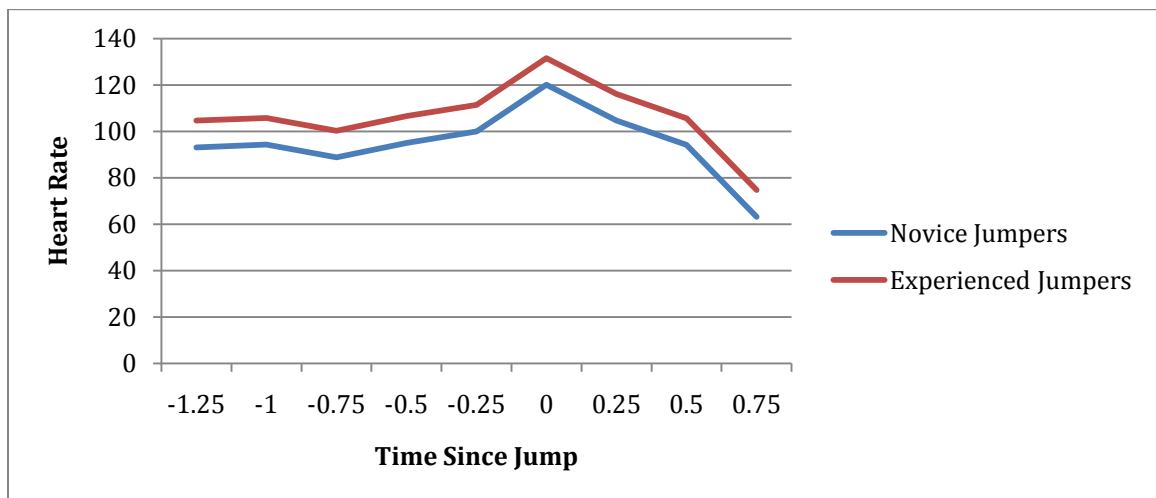


Figure 6. Heart rate on jump day for novice and experienced jumpers.



IRB approval form.

***University Committee for the Protection
of Human Subjects in Research
University of New Orleans***

Campus Correspondence

Principal Investigator: Elizabeth Shirtcliff
Co-Investigator: Amber Allison
Date: April 6, 2009
Protocol Title: "Sensation Seeking and A Real World Stressor:
Hormonal and Autonomic Effects"
IRB#: 05March09

The IRB has deemed that the research and procedures are compliant with the University of New Orleans and federal guidelines. The above referenced human subjects protocol has been reviewed and approved using expedited procedures (under 45 CFR 46.116(a) category 7).

Approval is only valid for one year from the approval date. Any changes to the procedures or protocols must be reviewed and approved by the IRB prior to implementation. Use the IRB number listed on this letter in all future correspondence regarding this proposal.

If an adverse, unforeseen event occurs (e.g., physical, social, or emotional harm), you are required to inform the IRB as soon as possible after the event.

Best wishes on your project!

Sincerely,

Robert D. Laird, Chair
UNO Committee for the Protection of Human Subjects in Research

VITA

The author was born in Baton Rouge, Louisiana. She received her Bachelor's degree in Psychology in May of 2008 and began graduate school at the University of New Orleans in August of 2008. She works under the direction of Dr. Elizabeth Shirtcliff in the Stress Physiology in Teens (SPIT) lab in the biopsychology program.