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Fight, flight, or fall: Autonomic nervous system reactivity during skydiving

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ABSTRACT

Sensation seeking (SS) traits may drive individuals toward high-intensity environments because of a desire for novelty and risk; however, research has not identified the psychophysiological mechanisms underlying SS behavioral expression or disentangled the relative contribution of novelty-seeking for physiological arousal. We used an ambulatory device to measure autonomic nervous system (ANS) activity before, during, and after skydiving in 44 jumpers. To identify the contribution of novelty, we compared novice jumpers to experienced jumpers. Hierarchical linear modeling revealed (1) whether there was physiological activation for each individual and (2) whether there were differences in responsivity between novice and experienced jumpers. All jumpers displayed increases in HR during the jump, indicating that repeated exposure to an unwavering risk did not habituate the response. Group differences in baseline functioning suggest that novelty may initially motivate propensities toward SS behaviors. Interestingly, coactivation of the SNS and PNS emerged during the jump and fall, suggesting that both components of the ANS are necessary to facilitate coping with intense challenges.

1. Introduction

The psychophysiological mechanisms driving individuals to partake in high-risk activities is understudied and not well understood. What is known is that novelty and risk may motivate the decision to participate in high-risk activities in individuals with a broad range of sensation seeking (SS) trait expression (Zuckerman, 1994). This investigation intended to identify the pattern of autonomic nervous system (ANS) activity that instantiates novelty and risk in the progression of SS into behavioral expression. In this study, skydiving was used as a window into the SS trait as it is a socially-sanctioned, intense, yet risky behavior. ANS activation was quantified *while* participants were skydiving, which permitted us to directly assess the proposed physiological mechanisms underlying SS propensities in an ecologically-valid setting.

1.1. The sensation seeking trait

In 1969, Marvin Zuckerman introduced sensation seeking as a measurable construct with wide individual differences in trait expression. As research involving SS expanded over the next decade, an emphasis was placed on the SSrelated behavioral outcomes. Individuals with the SS trait are more likely to participate in high-risk sports, jobs, and sexual behaviors (Freixant, 1991; Musolino & Hershenson, 1977; Thornquist, Zuckerman, & Exline, 1991), yet it is still not entirely clear what biological processes motivate or sustain these behaviors. SS is defined as "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). Based on this definition, novelty and risk emerge as important factors influencing the process by which individuals are motivated to engage in SS behaviors. Research involving animal (Piazza et al., 1993) and human (Zuckerman, 1996) models of sensation seeking implicate the stress response systems and the reward pathway as central to novelty- and risk-seeking, respectively. One theory postulates that high sensation seekers have increased stress resistance and threshold for aversive situations (Netter, Hennig, & Roed, 1996); sensation seeking scores have been associated with gonadal and endocrine hormone levels (Gerra et al., 1999). However, the direct influence of sensation seeking activities on acute physiological functioning remains understudied. Disentangling the role of novelty and risk may be most feasible during a high-risk activity, because physiological processes are most likely to be activated *during* an SS activity.

1.2. Physiological arousal

The present investigation focuses on the ANS because, in addition to being the forerunner of the stress response, the neural circuitry

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implicated in SS behaviors communicates directly with the ANS (Joseph, Liu, Jiang, Lynam, & Kelly, 2008). High levels of parasympathetic (PNS) control suggest a more controlled and less aroused state, as well as adaptive orientation and self-regulation in response to attention demanding situations (Porges, 2003). Conversely, decreased PNS control suggests diminished socioemotional flexibility (Kennedy, Rubin, Hastings, & Maisel, 2004), and increased risk for arrhythmic death in coronary heart disease (Kleiger et al., 1991). We evaluated the root mean square successive difference (RMSSD) as an index of HRV and, thus, indirectly captured PNS influence (Berntson, Lozano, & Chen, 2005) during tonic functioning and in response to the extreme challenge of skydiving.

HR has also been used extensively in previous research quantifying the sympathetic nervous system (SNS; Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004). Increases in HR facilitate acute psychological and physical changes that provide the individual with the ability to fight or flee. Increased HR in response to a challenge is considered an adaptive coping strategy; in fact, decreases in HR in response to a challenge can indicate behavioral dysregulation, including aggression (Gottman et al., 1995) and antisocial behavior (Ortiz & Raine, 2004).

The classical conception of the ANS involves an increase in SNS control and decrease in PNS control in response to demanding situations (Cacioppo, 1994), but the autonomic space theory offers that stimuli can evoke a range of autonomic patterns of input to bodily systems (Berntson, Cacioppo, & Quigley, 1991). The theory suggests that the SNS and PNS have a dynamic relationship in which coactivation and coinhibition are possible, complimenting research suggesting that a variety of symmetrical and asymmetrical patterns of activation between and across physiological systems is necessary for coping with an environment that simultaneously requires active engagement and relaxation (Hastings et al., 2011).

1.3. Behavioral expression of the SS trait

The context of skydiving is an ecologically valid setting in which evaluating the real-world physiological valence of risk-taking behaviors is possible. The context of skydiving is anticipated to elicit ANS activation, as the body attempts to adaptively regulate functioning in the face of environmental change; we expected that skydiving would elicit ANS reactivity. At a behavioral level, the activation of these systems may be perceived as rewarding in individuals with higher SS tendencies, motivating them toward engaging further in risky behaviors. The particular pattern of psychophysiological activation during a specific high-risk challenge may provide insight into how the brain and body communicate levels of risk, reward, and novelty during that preferred high-risk activity. Including individuals with differences in previous exposure to the activity (novice versus experienced jumpers) may identify the contributions of novelty and risk in motivating behavioral expression. We expected group differences in ANS reactivity as a function of previous exposure, such that experienced jumpers would exhibit blunted reactivity in comparison to first time jumpers. Novelty is expected to wear off over time and this phenomenon may motivate the SS individual to engage in varied SS-behaviors, though the risk is unwavering. The process whereby novelty wears off is of utmost importance in regard to possible wear-and-tear on the physiological systems because different physiological systems are anticipated to reduce activity to novel stimuli at varying rates. Last, we expected that levels of SS would influence patterns of ANS reactivity, as previous research suggests an association between SS scores and other physiological systems (Gerra et al., 1999).

2. Methods

2.1. Participants

Forty-four participants (aged 18–49; $M = 24$, SD = 4.6), including 29 novice jumpers (18 males) and 15 experienced jumpers (14 males), were recruited from Goldcoast Skydivers Company. Novice jumpers were required to be skydiving for the first time, and experienced jumpers completed at least 10 previous jumps. Eighty-eight percent of the sample was Caucasian ($N = 39$). Individuals were only considered if they expressed a pre-existing desire to skydive, were between 18 and 50 years of age, and had no obvious or reported health complications. Individuals unwilling to complete the training provided by the skydiving company were excluded from participation. This research protocol was approved by the Institutional Review Board at the University of New Orleans.

2.2. Measures

2.2.1. Autonomic measures

The Actiheart device (Cambridge Neurotechnology, Ltd.) records physical activity by means of an accelerometer, as well as continuous monitoring of beat by beat HR. Reliability and validity of the Actiheart have been documented (Brage, Brage, Franks, Ekelund, & Wareham, 2005). This device allows for individual calibration of the standard set point by use of the individual's height, weight, and fitness level. The device is ambulatory, compact (7 mm thick, 33 mm diameter, 10 g weight), and does not have long wires; thus, it is able to be applied in an ecologically valid research setting. The Actiheart processing software automatically discards any recording greater than 37.5% of the average (Zakeri, Adolph, Puyau, Vohra, & Butte, 2008), so as to ensure validity in the reported data (reporting few, if any, artifacts). Data were also visually inspected for outliers prior to analysis. Previous research demonstrated that HR measurements indicated by the Actiheart matched an ECG simulator (Dale Technology, Thornwood, NY). Pilot testing confirmed that the Actiheart acquires data at 14,000 ft.

2.2.2. Questionnaire

The Sensation Seeking Scale version five (SSS-V) includes four subscales and a total score that is assumed to be reflective of SS traits (Zuckerman, 1994). Reliability estimates for the SSS-V range from .83 to .86 (Zuckerman, 1994). In this study, Cronbach's alpha estimates revealed reliability of .73. Both males ($t = 3.01$, $p < .0001$) and females ($t = 5.69$, $p < .0001$) in this study were higher than reported means of a normal sample on the total SSS-V scores (Zuckerman, Kuhlman, Thornquist, & Kiers, 1991). While elevated within individuals willing to skydive, it is important to note that there was a wide range of SSS scores, indicating individual differences in sensation seeking desires and experiences (Table 1).

2.3. Procedure

Potential participants were presented the recruitment flyer and, if recruited, provided informed consent. After preparing skin on the chest area with nuPrep abrasive skin prep gel (D.O. Weaver & Company) to remove dead skin, a researcher applied the Actiheart device. The battery powered electrodes were placed horizontally on the left chest, approximately 3 in. away from each other and 2 in. from the arm crevice. The novice participants then completed 10 min of instruction provided by the skydiving company and dressed in the proper attire. Participants boarded the plane, ascended to 14,000 ft and jumped (M_{time} = 2:12 pm); the free-fall period was, on average, 90 s and the parachute gliding was, on average, 4.5 min. After landing, Actiheart devices were removed