Autonomic Neuroscience: Basic and Clinical 205 (2017) 72–76

Contents lists available at ScienceDirect

Autonomic Neuroscience: Basic and Clinical

journal homepage: www.elsevier.com/locate/autneu

The effect of anxiety sensitivity on psychological and biological variables during the cold pressor test

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ARTICLE INFO

Keywords:
Autonomic nervous system responses
Anxiety sensitivity
Fear
Pain
Cold pressor test

ABSTRACT

We examined the relationship between anxiety sensitivity (AS) and autonomic nervous system responses (ANS) during the cold pressor test (CPT). Seventy-four university students participated and were divided into low-AS (M = 9.06, SD = 3.97) and high-AS groups (M = 28.68, SD = 6.63) based on AS Index scores (n's = 36 and 38, respectively). The study included three phases: Rest, CPT, and Recovery. We measured the psychological variables (fear of pain and subjective pain) at pre- and post-CPT. ANS response data were collected during each phase. Fear of pain was experienced more strongly in the high-AS group (M = 4.74, SD = 3.25) relative to the low-AS group (M = 2.72, SD = 2.31), and subjective pain was also stronger in the high-AS group (M = 3.08, SD = 1.91) relative to the low-AS group (M = 2.47, SD = 1.00) in post-CPT. While parasympathetic nervous system (PNS) responses did not differ between the two groups during the CPT, the high AS-group demonstrated lower PNS activity during the Recovery phase. The high-AS group reported significantly more anticipatory fear and pain prior to the CPT, which appeared to aggravate subjective pain experiences. Furthermore, for individuals with anxiety sensitivity, ANS reactivity may be the mechanism underlying the relationship between negative affect and subjective pain.

1. Introduction

Anxiety sensitivity (AS) is among the most important concepts for understanding subjective pain (Keogh and Birkby, 1999) and is defined as the belief that anxiety-related sensations have negative consequences (Reiss, 1987; Taylor, 1995). Regarding the relationship between AS and pain, most research has examined chronic pain (Asmundson, 1999); however, AS can also impact acute pain (Keogh and Birkby, 1999; Keogh and Cochrane, 2002; Keogh and Mansoor, 2001). One popular method for assessing acute pain is the cold pressor test (CPT). The CPT involves participants submerging a body part (i.e., a hand or foot) in cold water, generating a controlled acute pain experience within an experimental setting. Here, participants are unable to control the stressful situation and, thus, must cope with the pain in a passive manner (Obrist, 1981). Previous studies have observed that high-AS individuals experience greater subjective pain than low-AS individuals (Keogh and Birkby, 1999; Keogh and Cochrane, 2002; Keogh and Mansoor, 2001); however, this relationship is not always straightforward. For instance, Imai et al. (2007) revealed that fear of pain did not differ between high- and low-AS groups after a CPT protocol, whereas Dodo and Hashimoto (2015) observed that fear of pain post-CPT was greater among high-AS individuals compared to those low in AS.

Psychological responses are known to be associated with biological responses. For example, when we feel fear or anxiety (psychological response), the biological responses we experience include shortness of breath, compression of the chest, palpitations, sweating, dizziness, tremor, and other autonomic symptoms. Here, variability in heart rate is influenced by the autonomic nervous system (ANS). However, the results concerning the biological aspects (heart rate variability: HRV) in studies using CPT were inconsistent (Hallman et al., 2011; Huang et al., 2011; Moses et al., 2007; Wirch et al., 2006). The reason for this is that spectral analyses are widely used to assess HRV. HRV is greatly influenced by respiratory sinus arrhythmia (RSA) Parati et al. (1995). To avoid the influence of RSA, the necessity of paced breathing was pointed out (Sawada, 2001). Sawada (1995), on the other hand, pointed out that ANS response induced by CPT is affected when paced breathing is performed. Accordingly, Lorenz plot analyses do not require controlling for breathing at a non-constant rate and depth. Additionally, Lorenz plot analyses allow parasympathetic (PNS) and sympathetic nervous system (SNS) activity to be measured separately

Abbreviations: AS, anxiety sensitivity; ANS, autonomic nervous system responses; CPT, cold pressor test; PNS, parasympathetic nervous system; HRV, heart rate variability; SNS, sympathetic nervous system

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http://dx.doi.org/10.1016/j.autneu.2017.05.006
Received 1 December 2016; Received in revised form 6 March 2017; Accepted 9 May 2017
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(Toichi et al., 1997). A pilot study for the present investigation (Dodo and Hashimoto, 2015) addressed this issue and reported on the role of AS on ANS responses both during and following the CPT. The pilot study used a small sample of 24 individuals, limiting generalizability. Therefore, the purpose of the present study was to assess the links between AS and ANS within a larger sample.

2. Method

2.1. Participants

Initially, 358 undergraduate and graduate students completed the Japanese version of the Anxiety Sensitivity Index (ASI) (Muranaka et al., 2001). Participants indicated their degree of concern about the possible negative consequences of anxiety symptoms using a five-point scale (0 = very little, 4 = very much) (Muranaka et al., 2001). Muranaka and Sakano (2002) reported the Japanese normative data as follows: the mean score for 9603 participants (5068 men and 4535 women) was 17.1, with a standard deviation of 10.5. Based on this mean score, we assigned participants who scored below 16 to the low-AS group and those who scored 19 or above to the high-AS group (Dodo and Hashimoto, 2015). As a result, there were 116 individuals in the low-AS and 222 individuals in the high-AS group. One hundred and twenty-six of them applied to participate in the experiment (79 in low-AS and 47 in high-AS). A total of 95 participants without smoking and drinking habits were eligible to complete the CPT. Two participants with ASI scores ≥ 30 were excluded from the final analyses as they were unable to submerge their hand for the full 3 min. A further 19 participants were excluded due to electrocardiogram (ECG) artifacts or because they were taking medication. Thus, a final sample of 74 participants was included in the final analyses (Table 1).

The Welch test was used to analyze ASI scores due to homoscedasticity issues. As intended, ASI scores were significantly higher in the high- relative to low-ASI group ($t = 15.55$, $p < 0.05$; $d = 3.57$). However, the high- and low-AS groups did not differ in terms of age ($t = 1.34$, *n.s.*) or gender ratio ($\chi^2 = 0.03$, *n.s.*).

This study received institutional ethical review board approval; all participants voluntarily provided written informed consent before participation.

2.2. Procedure

The study included three phases: Rest, CPT, and Recovery. Each phase lasted for 3 min, during which the participants focused on a fixation point. Participants were seated and this posture was maintained throughout the experiments. During the Rest phase, participants relaxed. During the CPT phase, participants submerged their non-dominant hand in cold water, held at a constant temperature of 10 °C in a water bath (TMi-150, AS ONE Co., Ltd., Osaka, Japan). During the Recovery phase, participants removed their hand from the water and relaxed. We confirmed that participants' pain had completely subsided before the experiment was considered complete. All participants evaluated their subjective pain, and fear of pain, twice (pre-CPT: before the Rest phase; post-CPT: upon completion of the Recovery phase). Participants arrived at the laboratory (room temperature: 24.63 ± 1.30 °C; relative humidity: 37.68 ± 5.93%) without having consumed any food or drink, other than water, for at least 2 h.

Table 1
Demographic characteristics of the participants.

n	Low-AS 36	High-AS 38
Age (years)	20.67 (2.35)	21.61 (3.51)
ASI score	9.06 (3.97)	28.68 (6.63)
Range	2–16	19–47

Note: Values for age and anxiety sensitivity index scores are expressed as mean (SDs).

2.3. Measures

2.3.1. Psychological estimation

Participants rated their fear of pain and subjective pain before the Rest phase (pre-CPT) and upon completion of the Recovery phase (post-CPT), respectively.

2.3.2. Fear of pain

We used affective pain descriptors from the Japanese version of the short form McGill Pain Questionnaire (Yokota et al., 2005). Participants rated the following affective pain descriptors: tiring-exhausting, sickening, fearful, and punishing-cruel. Each descriptor was scored from 0 (*none*) to 3 (*severe*).

2.3.3. Subjective pain

The Wong-Baker FACES Pain Rating Scale (Garra et al., 2010) was used to measure sensory pain perception. Participants rated their pain experience on a scale from 0 (no pain) to 5 (the worst pain imaginable or unbearable pain).

2.3.4. ANS responses

ANS response data were collected during all three phases. An electrocardiogram (ECG) with three Ag–AgCl disposable electrodes (PSC-SC43m, Senstec Co., Ltd., Tokyo, Japan), arranged in a manner similar to that of a lead II configuration (i.e., two on the breastbone and one on the left lower abdomen), was administered to assess HRV. ECG data were digitized using a 12-bit A/D converter at a sampling rate of 1 kHz (MaP222A, NIHONSANTEKU Co., Ltd., Osaka, Japan) and collected via a notebook computer (T60, IBM Japan, Ltd., Tokyo, Japan).

HRV was evaluated using the Lorenz plot analysis (MaP1060, NIHONSANTEKU Co., Ltd., Osaka, Japan). Fluctuations observed in the interbeat interval (IBI) were transformed into an ellipsoid distribution using the Lorenz plot. Following Toichi et al. (1997), a program (MaP1060) calculated the length of the longitudinal (L) and transverse (T) axes within the ellipsoid distribution. The Cardiac Vagal Index (CVI) was calculated as a log 10 (L × T) transformation, and the Cardiac Sympathetic Index (CSI) was calculated as L/T (Toichi et al., 1997).

The lower frequency region in the heart rate spectrum is regarded as an indicator of SNS activity. However, Parati et al. (1995) pointed out that the lower frequency region may also depend on the PNS and other mechanisms. Therefore, Sawada and Tanaka (1997) pointed out that spectral analysis is unsuitable to analyze cardiac SNS activity. Toichi et al. (1997) confirmed that CVI is not affected by propranolol (Adrenergic β Receptor Blocker) but is decreased by atropine (PNS blocking agents). CSI is not affected by atropine but is decreased by propranolol: Lorenz plot analysis can evaluate parasympathetic (CVI) and sympathetic (CSI) functions simultaneously and independently. Therefore, we preferred Lorenz plot analysis to Spectral analyses (Dodo and Hashimoto, 2015).

2.4. Statistical analyses

Data were analyzed using SPSS v.19.0. A two-way repeated measures analysis of variance (ANOVA) was performed with AS group and phase (psychological estimation: pre-CPT and post-CPT; HRV assessment period: Rest, CPT, and Recovery) as factors. The Greenhouse-Geisser corrections for sphericity violations were used as necessary. Post-hoc analyses were performed with Bonferroni corrections.

Spearman's correlation analysis was performed to examine the relationships among CVI, CSI, and AS. Additionally, Spearman's correlation analysis was performed to examine the relationships between

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