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Development of the Sensory Hypersensitivity Scale (SHS): a self-report tool for assessing sensitivity to sensory stimuli

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Abstract

Sensory hypersensitivity is one manifestation of the central sensitization that may underlie conditions such as fibromyalgia and chronic fatigue syndrome. We conducted five studies designed to develop and validate the Sensory Hypersensitive Scale (SHS); a 25-item self-report measure of sensory hypersensitivity. The SHS assesses both general sensitivity and modality-specific sensitivity (e.g. touch, taste, and hearing). 1202 participants (157 individuals with chronic pain) completed the SHS, which demonstrated an adequate overall internal reliability (Cronbach's α) of 0.81, suggesting the tool can be used as a cross-modality assessment of sensitivity. SHS scores demonstrated only modest correlations (Pearson's r) with depressive symptoms (0.19) and anxiety (0.28), suggesting a low level of overlap with psychiatric complaints. Overall SHS scores showed significant but relatively modest correlations (Pearson's r) with three measures of sensory testing: cold pain tolerance (-0.34); heat pain tolerance (-0.285); heat pain threshold (-0.271). Women reported significantly higher scores on the SHS than did men, although gender-based differences were small. In a chronic pain sample, individuals with fibromyalgia syndrome demonstrated significantly higher SHS scores than did individuals with osteoarthritis or back pain. The SHS appears suitable as a screening measure for sensory hypersensitivity, though additional research is warranted to determine its suitability as a proxy for central sensitization.

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Compliance with ethical standards

Conflict of interest Eric A. Dixon, Grant Benham, John A. Sturgeon, Sean Mackey, Kevin A. Johnson, and Jarred Younger declare that they have no conflict of interest.

Human and animal rights and Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of the 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

Keywords

Sensory hypersensitivity; Scale development; Central sensitivity; Validity; Reliability; Quantitative sensory testing

Introduction

Central sensitization is an amplified state of neural signaling in the central nervous system (CNS) that is implicated in the pathogenesis of several chronic conditions that primarily involve pain (Kaya et al., 2013; Lluch et al., 2014; Wang et al., 2014) and complex, multisymptom illnesses (Batheja et al., 2013). When in the sensitized state, the CNS amplifies the sensory processing of the peripheral inputs so that the experience of the individual no longer accurately reflects the information provided by peripheral inputs (Woolf, 2011). This state has been described as an increase in signal gain in which low-level sensory inputs are amplified into stronger signals, or as a decrease in signal inhibition processes, or both (Woolf, 2011). Experimental pain protocols can induce transient, but robust, central sensitization in healthy individuals (Shenker et al., 2008). In these cases, central sensitization manifests as a lower threshold at which a stimulus is interpreted as noxious, such as hyperalgesia and allodynia (Latremoliere & Woolf, 2009). Pain is the sensory modality most often studied experimentally in the context of central sensitization, though any sensory experience (e.g. light, sound, temperature) may conceivably be affected by central sensitization (Woolf, 2011).

Researchers have typically performed human central sensitization experiments on healthy individuals; however, the concept of central sensitization has become particularly interesting to researchers characterizing chronic pain conditions and complex, multi-symptom illnesses. Many chronic pain conditions that are currently poorly understood may share a common feature of central sensitization (Yunus, 2007). These conditions, such as fibromyalgia syndrome, temporomandibular disorder, and irritable bowel syndrome, have been referred to as central sensitivity syndromes (Yunus, 2008). In these cases of chronic central sensitization, an amplification of sensory inputs may be manifested as allodynia, hyperalgesia, sleep disturbances, and cognitive disruption (Aaron et al., 2000). Furthermore, individuals with a central sensitivity syndrome may find normally innocuous stimuli (e.g. touch, heat, cold, sight, sound, smell) to be noxious.

Direct assessment of central sensitization would require invasive and time-consuming procedures. However, it may be possible to study central sensitivity indirectly by examining sensory sensitivity. Several psychophysiological tests involving heat, cold, pressure, and auditory modalities have identified sensory sensitivity in different patient populations, such as those with irritable bowel syndrome (Piché et al., 2010; Rodrigues et al., 2005), fibromyalgia syndrome (Blumenstiel et al., 2011; Smith et al., 2008; Geisser et al., 2008), and temporomandibular disorder (Fernández-de-las-Peñas et al., 2010). Although tests of sensory hypersensitivity are in the early stages of development, the literature suggests that they may provide a measurable proxy for central sensitization. However, not all researchers and clinicians have access to the resources required to conduct these tests. In such cases, a

self-report tool can fill an important need in scientific research. A self-report measure of sensory hypersensitivity may be useful for studying and screening large numbers of individuals, as well as potentially characterizing important subgroups. Several questionnaires have been developed that measure different aspects of sensitivity, but none to our knowledge focus on widespread physical sensory sensitivity. Some tools focus on only one sensory modality, such as pain (Ruscheweyh et al., 2009, 2012). Other tools, such as the Highly Sensitive Persons Scale (Aron & Aron, 1997a), comparatively place a larger emphasis on emotionality and introversion. The tool most similar to the SHS has been published is the Sensory Perception Quotient (SPQ) (Tavassoli et al., 2014). The SPQ was intended primarily for the study of individuals with autism spectrum conditions, but also contains several items related to sensory sensitivity. However, the majority of the sensory sensitivity items in that questionnaire address the stimulus perception threshold, such as distinguishing different people by their smell, or differentiating milk and dark chocolate by their taste. Even though the stimulus perception threshold is an important concept, it is conceptually distinct from the increased noxiousness that is exhibited by individuals with putative central sensitivity syndromes. In the latter case, sensory sensitivity is manifested as lower stimulus intensity needed to exhibit a noxious or overwhelmed response from the participant. In short, while several currently-available self-report tools measure aspects of sensory hypersensitivity, none specifically address the need for a multi-modality proxy measurement of central sensitization.

We aimed to develop a tool that was focused on the sensory aspects of hypersensitivity and was also largely independent from psychological constructs of depression and anxiety. We determined that an optimal instrument for this construct would assess a range of sensory modalities, and would be easy to complete by both healthy and clinical samples. We describe five studies involved in the development and testing of a scale of sensory hypersensitivity. We separately present methods and results for each of the five studies, followed by a common discussion. Study 1 was an initial psychometric examination of an 88-item pool used to create the final item set; Study 2 was an assessment of the scale's internal reliability; Study 3 re-examined internal reliability, and assessed divergent validity with symptoms of depression and anxiety; Study 4 examined internal validity in patient populations, and preliminary construct validity by distinguishing conditions hypothesized to involve central sensitization (fibromyalgia syndrome) from conditions not suspected to primarily involve central sensitization (osteoarthritis); and Study 5 examined the scale's convergent validity with both individuals with chronic low back pain and healthy participants' heat pain threshold, heat pain tolerance, and cold pain tolerance.

Study 1

In this study, we reduced an initial pool of 88 items to a final item set, using a factor analysis approach and iterative removal of items based on subscale internal reliability based on the general guidelines as described by Clark and Watson (1995).

Methods

Item content was developed by two of the authors (G. B. and J. Y.) after an extensive literature review of questionnaires such as the Highly Sensitive Person scale (Aron & Aron, 1997b). Each original item consisted of a first-person statement describing an experience related to one of the following sensory modalities: touch, taste, smell, hearing, light, pain, medications, allergies, and temperature. Participants were asked to rate how much they agreed with each statement using the Likert-scale, which contained the following response options: 1 = “Strongly Disagree.” 2 = “Disagree.” 3 = “Neutral/Not Sure.” 4 = “Agree.” to 5 = “Strongly Agree.” The item pool can be seen in Supplemental Table 1.

Data were collected from 373 undergraduate students (85 male, 262 female, 26 not reported; mean age = 21.17, SD = 2.88) from the University of Tennessee, Knoxville. Of the 373 participants 316 self-identified as Caucasian, 17 as African American, 10 as neither, and 30 declined to report this information. All participants provided written informed consent in accordance with the university’s Institutional Review Board (IRB).

In studies 1–5, analyses involving internal consistency, parametric correlation, and analysis of variance (ANOVA) were conducted using SPSS 21 (IBM, New York). An initial exploratory factor analysis was performed using the maximum likelihood extraction method, with a promax rotation method. Items were chosen for retention that loaded clearly on one subscale. In cases where a subscale had more than three highly-loading items, a recursive removal process was used in which the item with the poorest item-total correlation was removed. The goal was to obtain an internal reliability (coefficient alpha) of at least 0.80 for each subscale (Clark & Watson, 1995). In order to keep the tool as brief as possible, items were deleted with the goal of having no more than three items for each subscale. As a post hoc test, mean SHS scores were contrasted between male and female participants using an independent-samples *t* test.

In order to determine the adequacy of model fit in Study 1, additional exploratory factor analyses were conducted using structural equation modeling approaches in Mplus (Muthén & Muthén, 2007) using a geomin (oblique) rotation. Each item was classified as categorical. Mplus software provides several indices of model fit for exploratory factor analysis. In the current study, adequacy of model fit was determined using the Chi-square test of model fit, comparative fit index (CFI), Tucker Lewis Index (TLI), the root mean square error of approximation (RMSEA), and the standardized root-mean-square residual (SRMR). Scores of 0.90 or higher on the CFI and TLI and scores under 0.05 for RMSEA and SRMR parameters were used as benchmarks to determine good model fit (Hu & Bentler, 1999).

Results

The factor analysis of the original 88-item pool revealed eight factors with eigenvalues greater than one. The final items and their psychometric properties as found using the maximum likelihood extraction method with promax rotation, including factor loadings, communalities, variance explained, and eigenvalues are all listed in Table 1. Similarly, the final items and their psychometric properties as found using the structural equation modeling approaches using goemin rotation can be found in Table 2. Remaining factors were clearly

delineated by sensory modality and included touch, taste, smell, hearing, light, pain, allergies, heat, and cold.

After the weakest-loading items were removed from the factors using the iterative approach, 25 items remained in the measure. Although the initial factor analysis suggested retention of 8 factors based on the number of eigenvalues above 1, it was felt that the retained items more appropriately encompassed 9 distinct content domains. Consequently, we estimated the relative fit of the 8-factor and 9-factor models using the reduced 25-item pool. In general, both the 8-factor model (RMSEA = 0.061, CFI = 0.981, TLI = 0.955, SRMR = 0.026) and the 9-factor model (RMSEA = 0.036, CFI = 0.994, TLI = 0.984, SRMR = 0.017) demonstrated adequate model fit. However, the 9-factor model demonstrated superior fit according to all fit indices, and there was some indication of model misfit in the 8-factor model according to the RMSEA index. Notably, there was some indication of model misfit according to the Chi-square test of model fit in both models, [$\chi^2(128) = 304.06, p < 0.001$ for the 8-factor model; $\chi^2(111) = 164.42, p = 0.001$ for the 9-factor model]; however, as Chi-square values are susceptible to inflated values in large sample sizes (Anderson & Gerbing, 1988), we deemed the overall model fit to be adequate, based on the other model fit indices. Further, we compared the relative fit of these models using a Chi-square difference test, which suggested that the model fit of the 8-factor model was significantly worse than the 9-factor model [$\chi^2(17) = 113.03, p < 0.001$]. Additionally, the 8-factor model specified that the heat and cold sensitivity subscales be combined into a single subscale; however, this combined subscale showed poor internal consistency (Cronbach's $\alpha = 0.20$). As the 9-factor model appeared to perform at a superior level in all of these analyses, we opted to retain the 9-factor structure in the final scale.

All factors contained 3 items (1 item reverse-coded) each with the exception of heat and cold, which contained 2 items each (coded in the same direction). Preliminary internal reliability (Cronbach's alpha) for the entire measure was 0.76. Internal reliability for the subscales was: allergies (0.91), heat (0.60), cold (0.72), light (0.76), pain (0.82), smell (0.74), hearing (0.77), taste (0.84), and touch (0.79). Eigenvalues for the subscale factors ranged from 0.93 to 3.93 with total explained variance of 74.42 %; all subscale eigenvalues can be found at Table 1. Correlations between the subscales were small with the largest effect size being 0.27. The resulting 25-item questionnaire was called the Sensory Hypersensitivity Scale (SHS). Participants total SHS scores were normally distributed (skewness = -0.07; SE = 0.13; kurtosis = -0.18, SE = 0.25). A further description of the SHS subscale score distribution can be found on Table 3. Mean SHS scores were significantly higher for women (mean = 2.94, SD = 0.36) than men (mean = 2.76, SD = 0.33; $t(35) = 4.09, p < 0.001$).

Study 2

In this study, we re-assessed the internal reliability of the SHS scale and subscales in a new sample of participants. We also measured the relationship between the SHS and a popular measure of psychological sensitivity; the 27-item Highly Sensitive Persons scale (HSP). The Highly Sensitive Person scale (HSP; Aron & Aron, 1997a, b) is a Likert-type scale that measures *sensory processing sensitivity*: the extent to which sensory input is cognitively

processed, driven by heightened emotional reactivity (Aron et al., 2012). The measure includes a broad range of items related to sensitivity, including “Are you easily overwhelmed by strong sensory input?” and “Do you have a rich, complex inner life?” Response options range from (1) “Not at All” to (5) “Extremely”. The measure has been demonstrated to have discriminant and convergent validity and Cronbach’s alphas reported in previous studies range from 0.85 to 0.87 (HSP; Aron & Aron, 1997a, b). In the present study, Cronbach’s alpha was 0.84. The final score ranges from 1 to 5 and is calculated as the average of the 27 ratings. The scale’s authors propose the measure of sensory processing sensitivity is unidimensional and bimodal, with approximately 25 % of the population being categorized as “highly sensitive”. However, other researchers have proposed multiple factor models of the scale (e.g. Smolewska et al., 2006) and demonstrated normal distributions of scores (e.g. Benham, 2006).

Methods

Data were collected from 462 undergraduate students (217 male, 240 female, 5 not reported; mean age = 20.64, SD = 5.84) at Arizona State University. Of the 462 participants 314 participants self-identified as Caucasian, 43 as Hispanic, 12, as African American, 11 as Native American, 2 as Middle Eastern, 35 identified as biracial, 8 did not identify as any listed, and 2 declined to report this information. All participants provided written informed consent as approved by the university’s IRB.

The 25-item SHS (Table 1) was used in this study. Along with the SHS, participants were provided the HSP (19); a 27-item self-report tool that measures introversion, emotionality, and general sensory sensitivity.

Internal reliability of the SHS was examined using Cronbach’s alpha. Differences in the mean scores of males and females were measured using an independent samples t-test. A parametric (Pearson’s r) bivariate correlation analysis assessed the relationship between psychological sensory sensitivity and the SHS.

Results

Internal reliability for the entire 25-item scale was 0.82. Internal reliability for each of the factors was: allergies (0.87), heat (0.72), cold (0.80), light (0.88), pain (0.80), smell (0.75), hearing (0.81), taste (0.82), and touch (0.75). Participant’s total scores were normally distributed; skewness = -0.20 (SE = 0.11) and kurtosis = 0.82 (SE = 0.23). Women (mean = 2.98, SD = 0.48) scored significantly higher on the total SHS than did men (mean = 2.67, SD = 0.51); $t(455) = -6.51, p < 0.001$. Basic statistics (i.e. mean, SD, skewness, kurtosis) for all subscales can be found in Table 3. Participant age was not significantly correlated with total SHS scores ($r = 0.03, p = 0.55$). There were no significant group differences in regards to race/ethnicity. Total SHS scores were significantly correlated with the HSP scores but had small to moderate effect sizes ($r = 0.47; p < 0.001, 23\%$ shared variance). The HSP scores were also significantly correlated with all subscale domains; allergies ($r = 0.12; p < 0.012, 1.3\%$ shared variance), light ($r = 0.43; p < 0.001, 18\%$ shared variance), smell ($r = 0.21; p < 0.001, 4\%$ shared variance), sound ($r = 0.24; p < 0.001, 6\%$ shared variance), taste ($r = 0.09; p < 0.048, 0.8\%$ shared variance), touch ($r = 0.29; p < 0.001, 9\%$ shared

variance), pain ($r = 0.33$; $p < 0.001$, 11 % shared variance), heat ($r = 0.30$; $p < 0.001$, 9 % shared variance), cold ($r = 0.18$; $p < 0.001$, 3 % shared variance).

Study 3

In this study, we tested the internal reliability of the SHS scale and subscales a third time. In addition, we examined the relationship between SHS scores, depressive symptoms, and symptoms of anxiety. Depression was measured via the 21-item Beck Depression Inventory II (BDI-II; Beck et al., 1996). The BDI-II has been validated for use in under-graduate populations, shows high internal consistency, and demonstrates a latent 2-factor structure, encompassing vegetative and somatic symptoms as one factor and cognitive and affective symptoms as a second factor (Dozois et al., 1998). Anxiety was measured with the 20-item trait subscale of the State Trait Anxiety Index (STAI; Spielberger & Sydeman, 1994). The STAI has been validated for use in multiple populations, including high school and college students, demonstrates adequate internal consistency and reliability, and has been found to correlate with anxiety in both clinical and experimental settings (Okun et al., 1996; Spielberger, 1983). The relationships between SHS and BDI scores as well as SHS and STAI scores were tested to determine the statistical distinctiveness of sensory sensitivity from constructs of psychological distress.

Methods

Data were collected from 210 participants (122 male, 73 female, 15 not reported; mean age = 32.3, SD = 14.39). All participants were individuals recruited from the communities surrounding Stanford University, who provided written informed consent as approved by the Stanford University's IRB.

In addition to the SHS, participants were administered scales of state depressive symptoms and trait anxiety. Depression was measured via the 21-item Beck Depression Inventory II (Beck et al., 1996). Anxiety was measured with the 20-item trait subscale of the State Trait Anxiety Index (Spielberger & Sydeman, 1994).

Internal reliabilities were assessed using Cronbach's alpha. Relationships between the SHS, depressive symptoms, and trait anxiety were assessed using parametric (Pearson's r) bivariate correlations.

Results

Internal reliability for the entire scale was 0.84. Internal reliability for each factor was: allergies (0.88), heat (0.75), cold (0.83), light (0.88), pain (0.74), smell (0.79), hearing (0.80), taste (0.77), and touch (0.81).

The SHS was correlated with depression ($r = 0.19$, $p = 0.009$, 4 % shared variance) and anxiety ($r = 0.28$, $p < 0.001$, 8 % shared variance). Correlations between depressive symptoms, trait anxiety, and SHS subscales can be found in Table 4. Depressive symptoms were most highly correlated with cold sensitivity ($r = 0.26$, $p < 0.001$), whereas trait anxiety was most highly correlated with taste sensitivity ($r = 0.26$, $p < 0.001$). Participant depression scores (mean = 5.34, SD = 5.46) were skewed positively (skewness = 1.44, SE = 0.18) and

leptokurtic (kurtosis = 1.89, SE = 0.36). Participants' anxiety scores (mean = 33.58, SD = 8.90) were positively skewed (skewness = 0.83, SE = 0.19) but were not kurtotic (kurtosis = 0.73, SE = 0.38). The mean scores of women (mean = 2.74, SD = 0.52) were significantly higher than men (mean = 2.58, SD = 0.52); $t(193) = 2.19, p = 0.029$. There was no significant correlation between age and total SHS scores ($r = 0.09, p = 0.21$).

Study 4

This study was designed to assess the internal reliability of the SHS in individuals with chronic pain. We also examined differences in mean SHS scores and subscale scores in healthy female participants from Study 3, individuals with a suspected central sensitivity syndrome (fibromyalgia syndrome), and individuals with a chronic pain condition not thought to primarily involve central sensitivity (osteoarthritis).

Methods

Data were collected from Arizona State University and Stanford University, and were approved by the Institutional Review Boards of these institutions. The data from Arizona State University were collected as part of a prior observational study of individuals with fibromyalgia and osteoarthritis (Zautra et al., 2005). Participants from Arizona State University were included on the basis of a confirmed physician diagnosis of fibromyalgia syndrome, osteoarthritis, or osteoarthritis and fibromyalgia syndrome (Zautra et al., 2005), as well as meeting the 1990 American College of Rheumatology diagnostic criteria for fibromyalgia; as the prevalence of rates of fibromyalgia were significantly higher in women than men under these criteria, this study recruited only female participants (Nicolson et al., 2010). Each participant from Arizona State University provided written informed consent. Stanford University provided additional data collected from patients with self-reported diagnoses of fibromyalgia syndrome. Participants were recruited from Stanford's Pain Management Clinic and the surrounding communities. Stanford-area participants provided written informed consent as approved by the university's IRB. A total of 124 participants were included in the internal reliability analysis and were grouped as follows: fibromyalgia syndrome ($n = 44$, mean age = 44.14, SD = 11.33, all female, two participants recruited from Arizona State University); osteoarthritis ($n = 43$, mean age = 59.33, SD = 8.02, all female, all recruited from Arizona State University); and osteoarthritis and fibromyalgia syndrome ($n = 39$, mean age = 56.36, SD = 8.17, all female, all recruited from Arizona State University). A total of 190 participants were included in all other data analysis, which included the participants included the above stated groups, as well the healthy participants ($n = 66$, mean age = 35.39, SD = 13.24, all female) from Study 3. The healthy participants from Study 3 were excluded from the internal reliability analysis due to possible confounding effects.

Internal reliability was assessed using Cronbach's alpha. Groups differences in SHS total and subscale scores were analyzed using a univariate analysis of covariance (ANCOVA) with age modeled as a covariate. All significant main effects for the groups were followed by pairwise Bonferroni post hoc tests.

Results

Across all participants, internal reliability for the SHS was 0.86. The subscale reliabilities were allergies (0.85), heat (0.70), cold (0.78), light (0.82), pain (0.62), smell (0.80), hearing (0.83), taste (0.75), and touch (0.88).

The ANCOVA results showed a significant main effect of diagnosis on SHS total score while controlling for age [$F(3, 185) = 17.65, p < 0.001$] and age did not have a significant effect [$F(1, 185) = 0.06, p < 0.806$]. As seen in Table 5, post hoc tests revealed that participants with fibromyalgia syndrome showed greater sensory sensitivity than did participants with osteoarthritis (mean difference = 0.42, $p = 0.011$) and healthy controls (mean difference = 0.78, $p < 0.001$), but SHS scores for participants with fibromyalgia did not significantly differ from the scores of participants with both fibromyalgia and osteoarthritis. Similarly, the SHS total scores of the fibromyalgia with osteoarthritis group were significantly higher than those of the healthy control group (mean difference = 0.64, $p < 0.001$).

There were significant correlations between age and SHS total scores ($r = 0.20, p = 0.005$), SHS heat subscale scores ($r = 0.29, p < 0.001$), SHS light subscale scores ($r = 0.17, p < 0.18$), and SHS pain subscale scores ($r = 0.17, p < 0.022$).

Table 5 shows the results from the between-group ANCOVAs with age modeled as the covariate for all SHS subscales, including pairwise post hoc comparisons. Significant group differences were observed for: cold [$F(3, 185) = 6.24, p < 0.001$]; heat [$F(3, 185) = 9.51, p < 0.001$]; allergies [$F(3, 185) = 5.05, p < 0.002$]; smell [$F(3, 185) = 4.50, p < 0.005$]; pain [$F(3, 185) = 9.20, p < 0.001$]; taste [$F(3, 185) = 4.30, p < 0.006$]; light [$F(3, 185) = 7.58, p < 0.001$]; sound [$F(3, 184) = 2.74, p < 0.045$]; and touch [$F(3, 184) = 7.68, p < 0.001$]. Age did not have a significant effect in any of the above stated ANCOVA results.

Study 5

The purpose of this study was to assess the convergent validity of the SHS among a heterogeneous sample of healthy participants and patients with chronic lower back pain. Scores on the SHS were tested for correlation with quantitative sensory testing of heat pain threshold, heat pain tolerance, and cold pain tolerance. We predicted that higher SHS scores would be associated with greater sensitivity to heat and cold stimuli for both groups.

Methods

A total of 103 participants volunteered for this study; 44 healthy participants (female = 24, missing = 2; mean age = 40.26, SD = 11.6) and 59 patients with chronic low back pain (female = 27, missing = 4; mean age = 40.56, SD = 11.32). Participants reported to be mostly right handed (right handed $n = 91$; left handed = 4). A total of 54 participants reported to be Caucasian, 13 Asian, 9 African American, 1 Pacific Islander, 1 American Indian/Alaska Native, 17 other, and 8 declined to answer. Income levels were recorded and are as follows; 11 reported an income less than \$10,000, 8 between \$10,000–19,999, 8 between \$20,000–29,999, 12 between \$30,000–39,000, 17 between \$40,000–49,000, 14 between \$50,000–59,999, 10 between \$60,000–69,999, 6 between \$70,000–79,999, 11

reported \$80,000 or more and 6 declined to state. Patients were screened to assure that they were not currently (within 3 months) taking opioid medications and they did not have a history of extended (more than 30 days) opioid use. All participants were recruited from Stanford University's surrounding communities. Written informed consent was provided by each participant as approved by Stanford University's Institutional Review Board.

Measures of heat pain threshold and tolerance were obtained using a thermal stimulus delivery system (Pathway) designed for human quantitative sensory testing. A CHEPS thermode was attached to the participant's right hand. From the baseline non-noxious temperature of 30 °C, the temperature was increased at a rate of 0.3 °C per second. Using an analog scale with a manual sliding lever (Medoc COVAS), participants rated the pain they felt from the temperature on a scale from "no pain" to "worst pain". Heat pain threshold was defined as the temperature at which the participant moved the bar to 10/100 pain. Heat pain tolerance was the temperature at which the participants moved the bar to 100/100 pain and terminated the stimulus.

Cold pain tolerance was measured using the cold pressor test. The cold pressor test involved a cold water bath divided into two sections via a perforated plastic wall. One side of the bath contained ice and water while the other contained only water. The water was circulated until the water reached a stable 5 °C. Participants placed their left hand in 5 °C water until they could no longer tolerate the stimulus (maximum time allowed was 120 s). Pain ratings were also obtained at 30, 60, 90, and 120 s.

Differences in total SHS scores and quantitative sensory testing scores between healthy participants and patients with chronic back pain were examined. For both healthy controls and patients with chronic back pain, bivariate correlation analyses were also conducted between their quantitative sensory testing outcomes (heat pain threshold, heat pain tolerance, cold pain tolerance), and the total SHS scores, as well as the heat, cold, and pain SHS subscores.

Results

Healthy participants' (mean = 2.89, SD = 0.52) total SHS scores were not significantly different from those of participants with chronic back pain (mean = 2.83, SD = 0.46); [$t(82) = 0.55$, $p < 0.58$]. Differences in heat pain threshold between healthy participants (mean = 45.29, SD = 3.05) and patients with chronic back pain (mean = 44.8, SD = 2.79) were non-significant; [$t(65) = -0.73$, $p < 0.47$]. Heat pain tolerance levels between healthy participants (mean = 47.93, SD = 1.02) and participants with chronic back pain (mean = 47.47, SD = 2.4) were not significantly different; [$t(63) = -0.97$, $p < 0.34$]. Participants with chronic back pain (mean = 53, SD = 35.8) did not have significantly different cold pressor durations than healthy participants (mean = 56.3, SD = 39.8); [$t(66) = -0.36$, $p < 0.72$].

The total SHS scores of the participants with chronic back pain negatively correlated with heat pain threshold ($r = -0.40$, $p = 0.019$) and cold pressor duration ($r = -0.50$, $p = 0.002$) but did not significantly correlate with heat pain tolerance. Similar results were found for the SHS cold subscale scores in that the participants with chronic back pain correlated with both the heat pain threshold ($r = -0.40$, $p < 0.05$) and the cold pressor duration ($r = -0.55$, $p <$

0.001). These data demonstrate that participants with chronic back pain with higher SHS scores show higher initial sensitivity to heat and lower tolerance cold stimuli. The healthy SHS scores did not significantly correlate with any of the QST measures. Interestingly, healthy participants' SHS cold sensitivity subscale scores negatively correlated with their heat pain tolerance measure ($r = -0.59, p < 0.001$). SHS Heat sensitivity subscales did not significantly correlate with any of the quantitative sensory testing outcomes: cold pressor duration ($r = 0.07, p = 0.7$), heat pain threshold ($r = 0.25, p = 0.17$), heat pain tolerance ($r = 0.01, p = 0.96$). The complete bivariate correlation matrix for the healthy participants can be found in Table 6 and for the individuals with low back pain can be found in Table 7.

The mean SHS scores of women (mean = 2.99, SD = 0.47) were significantly higher than for those of men (mean = 2.71 SD = 0.48); [$t(82) = -2.64, p < 0.01$]. The duration of time spent in the cold pressor task was significantly shorter for female participants (mean = 42.97, SD = 31.06) than male participants (mean = 68.48, SD = 40.27); [$t(66) = -2.64, p < 0.01$]. Heat pain thresholds were not significantly different between women and men; [$t(65) = 1.15, p < 0.25$]. Tolerance levels for heat pain were also not significantly different between genders as well; [$t(63) = 1.75, p < 0.085$]. Age did not significantly correlate with total SHS scores ($r = 0.13, p = 0.234$).

Discussion

We developed the SHS to be a simple measure of sensory hypersensitivity in both healthy individuals and individuals with chronic conditions. It has sufficient internal reliability to be used as a unifactorial measure of sensory hypersensitivity; however, the subscales may provide additional information. SHS scores were correlated with two of the three temperature sensitivity outcomes examined with quantitative sensory testing for individuals with chronic back pain, suggesting that higher scores on the scale may reflect greater sensitivity to sensory stimuli under certain conditions.

We discovered a few interesting features of the SHS over the course of the five studies. First, women reported higher sensitivity than men. Women are reported to demonstrate lower sensory thresholds and tolerances than men to some painful stimuli, with the greatest differences seen with heat, cold, and pressure (Racine et al., 2012). The reason for the difference is unclear and many possible explanations have been investigated (Bartley & Fillingim, 2013), including factors such as sex hormones (Rhudy et al., 2013), gender roles (Alabas et al., 2012), attentional biases (Ohla & Lundström, 2013), and greater perceived stress (Benham, 2006).

It is perhaps not surprising that SHS scores were correlated with self-reported symptoms of depression and anxiety, because somatic discomfort is commonly associated with both depression and anxiety (Kroenke et al., 2010; Simms et al., 2012). We note that the correlations, while significant, were modest, with SHS scores having 4 % overlapping variance with depression and 8 % with anxiety. It should be understood that the participants in this group were largely healthy individuals with lower levels of self-reported depression and anxiety. Therefore, our results preliminarily suggest that sensory hypersensitivity is largely conceptually distinct from depression and anxiety within healthy individuals. Further

investigation among people with higher degrees of depression and anxiety should be conducted in order to confirm that these results generalize across a more diverse group. Likewise, future research with larger samples would need to be conducted in order to verify that SHS subscales are differentially associated with common psychological conditions.

We also observed that the SHS and HSP scores showed a moderate degree of overlap, sharing 22 % of their total variance. The correlation between these measures was unsurprising, as the sensory hypersensitivity and aversiveness assessed by the SHS would seem to share some conceptual overlap with the degree of broad interoceptive focus assessed by the HSP. However, the majority of variance in the SHS was not shared with the HSP, suggesting that sensory hypersensitivity is most appropriately defined as a distinct construct. It is notable that subscales of the SHS showed differing levels of correlation with measures of temperature sensitivity for healthy participants and participants with chronic low back pain. Considering that there were no significant differences in the mean SHS scores of the healthy participants and individuals with low back pain, it was interesting that healthy participants did not show the same significant relationship of perceived sensory hypersensitivity as the participants in the low back pain group. It is possible that this difference is due to an underlying difference attributable to the presence of chronic pain; more specifically, persistent chronic low back pain may induce a low level or mild state of central sensitization resulting in slightly different sensory profiles between healthy participants and individuals with chronic low back pain, which has been suggested by some recent studies (Corrêa et al., 2015). The relationship of back pain and central sensitization noted by Corrêa and colleagues was reportedly driven by stronger indications of this relationship in female participants. Though our sample was somewhat small to statistically test the sex-based differences in the relationship between SHS scores and objective temperature sensitivity testing, our results do appear to at least partially support this effect, as female participants tended to report higher levels of sensory hypersensitivity across studies. This phenomenon thus warrants additional attention in future studies.

Limitations

The SHS demonstrated good reliability and appears to be a promising measure for future research, but several limitations do exist. Mainly, as with most self-report instruments, the tool would ideally be validated against performance measures and other objective data. For example, flinching in reaction to auditory stimuli of varying decibels could be assessed in the laboratory. Most of the sensory modalities assessed with the SHS could be tested for associations with objectively-measured threshold and tolerance. We note that the low back pain group used in this study was a sample of convenience, and as such may not have been ideally suited to demonstrate differences in central sensitization. In order to clearly elucidate the relationships between self-reported hypersensitivity and objective measures of sensitivity, it may be beneficial to conduct a similar study in the future with a group of individuals with a condition suspected to involve central sensitization, such as fibromyalgia.

An additional limitation of this study concerns our use of 2-item subscales. Our analyses identified only 2 items to be retained for the heat and cold sensitivity subscales. Although evidence suggests that factors containing at least 3 indicators are superior in terms of

reliability and psychometric construction, models may be identified if they contain correlated factors containing only 2 indicators (Marsh et al., 1998). In the case of the current study, our 2-item subscales consistently demonstrated acceptable levels of reliability across several samples within our study. Furthermore, these subscales were included in the final scale, as they were felt to represent key aspects of sensory hypersensitivity; this conclusion was supported by the high degree of interdependence noted between these subscales and other subscales of the SHS. Nevertheless, these 2-item factors do not represent an ideal psychometric construction; consequently, it is recommended that these subscales be examined in future studies as part of an overall composite score, and their use as independent subscales should be understood with the prior limitations in mind.

It should also be noted that additional research is necessary to determine whether self-reported sensory hypersensitivity is a valid proxy for assessing central sensitization. More research is needed to determine the relationship between these two phenomena. Without measuring upstream and downstream messages, and delineating peripheral versus central contributions to the signal, we cannot be certain that self-reports of sensory hypersensitivity are directly related to central sensitivity. The SHS, therefore, should not be used to make unreserved inferences regarding the degree of central sensitivity in individuals before more studies are conducted. Similarly, our validation of this measure focused on one feature of sensitivity, pain, which has a clear manifestation in clinical populations, such as fibromyalgia. However, self-reported sensitivity in other domains on the SHS, such as auditory, visual, or olfactory sensitivity, was not correlated with objective tests in these same domains. The utility of this measure may therefore be enhanced by validating its use in other populations that show sensitivities to specific sensory modalities, such as chronic migraine, where there may be sensitivities in the visual, auditory, or olfactory domains.

It is also noteworthy that the data gleaned from fibromyalgia and osteoarthritis in Study 4 were drawn exclusively from women. Although this step was taken due to the fact that the prevalence of fibromyalgia was several magnitudes higher in women than men according to earlier versions of the American College of Rheumatology criteria for fibromyalgia, these results may be biased by the lack of male participants with these chronic pain disorders. Consequently, our findings regarding the validity of the SHS in fibromyalgia and osteoarthritis patients should be interpreted with this caution in mind, and it may be value to examine the utility of the SHS in both men and women with these pain disorders.

Our use of a relatively healthy, undergraduate, sample in the development of the tool may also be considered a limitation. It is possible that a different factor structure would have emerged, or different items selected, if individuals with chronic pain or other pain samples were included. However, we observed the tool to perform well in the clinical pain samples in Study 4, with subscale alphas similar to those seen in the healthy groups. Although future validation would be valuable in other clinical samples, our results suggest that the tool is suitable for use in both healthy and patient populations.

Future directions

The results of the current study suggest that the SHS may be a valuable tool to screen large groups of patients, broadly characterize clinical populations, and to identify potential patient subgroups. However, further study is needed to determine if SHS estimates remain stable across time. If follow-up validation studies replicate the temporal stability of the SHS, it may provide a valuable diagnostic tool that may help to predict the onset of central sensitization disorders like fibromyalgia syndrome, chronic fatigue syndrome, and temporomandibular disorders. Similarly, the scale may be useful in tracking the development of central sensitivity in acute injuries such as whiplash (Stone et al., 2013), spinal cord injury (Finnerup et al., 2003) and peripheral nerve injury (Taylor et al., 2010). As these groups were not included in the current study, the appropriateness of using of the SHS instrument in these populations remains to be demonstrated by future studies. Moreover, this scale may also demonstrate some utility for future research; Study 4 is evidence that it can be used to characterize perceived sensory differences between clinical populations (i.e. fibromyalgia, osteoarthritis, fibromyalgia with osteoarthritis, and healthy controls). Furthermore if indeed it proves stable over time this tool could be used to assess the effectiveness and mechanisms of various treatments, or measure the effects of an experimental design.

Sensory hypersensitivity is of great interest in the field of autism research, and those researchers have made greater progress in measuring sensitivities particular to that disorder (Robertson & Simmons, 2013). Tools such as the Sensory Profile questionnaire (Dunn, 1999), SensOR Assessment (Schoen et al., 2008), and SensOR Inventory (Schoen et al., 2008) use examiners and caregivers, rather than the affected individual, to observe behavioral responses to stimuli. Self-report tools, such as the Adult/ Adolescent Sensory Profile (AASP) (Brown & Dunn, 2002) also exist. Even though several tools have been developed to assess sensory integration problems in individuals with autism spectrum conditions, those tools address concepts that are not necessarily integral to the sensory sensitivity exhibited in central sensitization. For example, the Sensory Profile questionnaire examines basic perception and detection of stimuli, rather than tolerance. The AASP and SensOR items also include behavioral and affective responses. Although the sensory processing disorder exhibited by individuals with autism spectrum disorders may not be related to sensory hypersensitivity in chronic pain patients, some of the factors may overlap. Future research may examine the degree of correlation between the tools assessing varying aspects of sensory processing.

It should be noted that our samples predominately consisted of non-Hispanic white participants and that sensory hypersensitivity could be affected by race and cultural background. For example, several studies have observed cross-culture effects on quantitative sensory tests for individuals with temporomandibular disorder (Al-Harthy et al., 2015; Gazerani & Arendt-Nielsen, 2005) as well as knee osteoarthritis (Cruz-Almeida et al., 2014). An examination of cross-cultural differences in self-reported sensory hypersensitivity in clinical or non-clinical populations could be a possible avenue for future research.

Another consideration for future research concerns the potential implications of menopausal status on sensory hypersensitivity (e.g. hot flashes). Given that hormonal changes that underlie menopause may manifest in changes in both sensory and psychological domains (Farage et al., 2008), it is not unreasonable to assume that menopause may similarly have implications for the degree of sensory hypersensitivity of women. Consequently, we urge attention to this issue in future studies. As we did not record menopausal status in the current study, it may be worth-while to examine whether there are reliable differences in sensory hypersensitivity related to menopausal status.

Conclusion

We propose that the SHS can serve as a measure of sensory hypersensitivity that is appropriate for both healthy individuals and chronic disease patients. Notable differences in SHS scores were observed between healthy participants and individuals with pain disorders suspected to be secondary to central sensitization, such as fibromyalgia. This finding suggests that the SHS may demonstrate some utility in identifying a salient feature of some clinical groups. However, our paper demonstrates only a cross-sectional relationship between SHS and fibromyalgia, and requires validation in longitudinal studies to determine if it may serve as a useful screening tool for individuals susceptible to long-term development of central sensitivity. At this stage, it appears appropriate to state that the SHS may demonstrate value as a potential screening tool for central sensitization in large samples, and its value may be further enhanced by examining its utility in predicting later onset of clinical symptoms, such as pain.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

SHS	Sensory Hypersensitivity Scale
HSP	Highly Sensitive Person
CNS	Central nervous system
SPQ	Sensory perception quotient
AASP	Adult/Adolescent Sensory Profile

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Table 1

The final SHS item set

Items	Factors					Communalities				
	Allergies	Heat	Cold	Light	Pain	Smell	Hearing	Taste	Touch	Extraction
I suffer from allergies	0.892									0.459 0.584
I am allergy-free	0.889									0.566 0.672
I have a number of allergies	0.827									0.581 0.650
I often feel too hot in an environment where others don't seem to be bothered		0.563								0.505 0.602
I am easily disturbed by high temperatures		0.668								0.697 0.801
I often feel too cold in an environment where others don't seem to be bothered			0.839							0.274 0.365
I am easily disturbed by low temperatures			0.620							0.580 0.730
My eyes are sensitive to sunlight				0.805						0.508 0.610
I am sensitive to bright light				0.864						0.501 0.589
I am not really bothered by bright lights				0.531						0.295 0.469
I am quite sensitive to pain					0.752					0.577 0.828
I can tolerate a large amount of pain					0.853					0.536 0.775
Things that would ordinarily hurt others are not painful to me					0.746					0.627 0.847
I often react to odors that other do not initially notice						0.769				0.459 0.557
I seem to notice smells that other people do not						0.853				0.357 0.373
I rarely notice smells						0.525				0.555 0.726
When I read, it must be totally quiet							0.794			0.697 0.793
I cannot study or read if there is any conversation or noise around							0.897			0.301 0.263
I can work even in noisy circumstances							0.540			0.638 0.698
I tend to be a picky eater								0.851		0.483 0.561
There are many foods that taste bad to me								0.729		0.491 0.571
I can eat almost anything								0.818		0.399 0.696
I am generally unable to wear clothes made of rough material									0.780	0.554 0.671

Items	Factors					Communalities					
	Allergies	Heat	Cold	Light	Pain	Smell	Hearing	Taste	Touch	Initial	Extraction
I am sensitive to rough textures									0.717	0.394	0.470
I can wear almost any kind of fabric without it bothering me									0.777	0.241	0.289
Total variance explained											
Eigenvalue	3.928	0.925	1.504	1.745	2.351	1.682	1.932	2.700	1.837		
Percent of variance explained	15.712	3.702	6.017	6.979	9.402	6.728	7.727	10.802	7.350		
Cumulative % of variance explained	15.712	74.419	70.717	57.972	35.915	64.700	43.643	26.513	50.992		

Factor loadings, communalities, eigenvalues, and variance explained on the nine SHS subscales are provided

Table 2

SHS items and their psychometric properties

Items	Factors								
	Allergies	Heat	Cold	Light	Pain	Smell	Hearing	Taste	Touch
I suffer from allergies	0.922								
I am allergy-free	0.932								
I have a number of allergies	0.895								
I often feel too hot in an environment where others don't seem to be bothered		0.635							
I am easily disturbed by high temperatures		0.613							
I often feel too cold in an environment where others don't seem to be bothered			0.804						
I am easily disturbed by low temperatures			0.720						
My eyes are sensitive to sunlight				0.819					
I am sensitive to bright light				0.928					
I am not really bothered by bright lights				0.542					
I am quite sensitive to pain					0.792				
I can tolerate a large amount of pain					0.861				
Things that would ordinarily hurt others are not painful to me					0.801				
I often react to odors that other do not initially notice						0.797			
I seem to notice smells that other people do not						0.860			
I rarely notice smells						0.586			
When I read, it must be totally quiet							0.844		
I cannot study or read if there is any conversation or noise around							0.914		
I can work even in noisy circumstances							0.528		
I tend to be a picky eater								0.883	
There are many foods that taste bad to me								0.786	
I can eat almost anything								0.853	
I am generally unable to wear clothes made of rough material									0.812
I am sensitive to rough textures									0.713
I can wear almost any kind of fabric without it bothering me									0.793
<i>Variance explained</i>									
Eigenvalue	1.971	1.632	0.912	2.907	1.852	2.448	2.021	1.722	4.185

Factor loadings and eigenvalues on the nine SHS subscales are provided

Table 3

SHS total and subscale score distribution for Study 1 and Study 2

Study 1	Mean	SD	Skewness	SE	Kurtosis	SE
SHS total	3.025	0.434	−0.066	0.126	−0.179	0.252
Allergies	3.036	1.242	−0.61	0.126	−1.167	0.252
Heat	2.702	0.948	0.419	0.126	−0.577	0.252
Cold	2.807	1.013	0.309	0.126	−0.681	0.252
Light	3.421	0.856	−0.312	0.126	−0.578	0.252
Pain	2.974	0.926	0.165	0.126	−0.657	0.252
Smell	3.247	0.784	−0.038	0.126	−0.334	0.252
Hearing	3.101	0.983	0.066	0.126	−0.948	0.252
Touch	3.012	0.870	0.011	0.126	−0.837	0.252
Taste	2.744	1.082	0.298	0.126	−0.947	0.252
Study 2	Mean	SD	Skewness	SE	Kurtosis	SE
SHS total	2.829	0.519	−0.202	0.114	0.817	0.227
Allergies	2.583	1.248	0.339	0.114	−0.922	0.227
Heat	2.605	1.034	0.274	0.114	−0.457	0.227
Cold	2.8330	1.115	0.494	0.114	1.172	0.227
Light	2.989	1.043	0.074	0.114	−0.864	0.227
Pain	2.856	0.979	0.332	0.114	−0.255	0.227
Smell	3.014	0.845	0.076	0.114	−0.099	0.227
Hearing	3.093	1.066	0.017	0.114	−0.756	0.227
Touch	2.674	0.868	0.063	0.114	−0.383	0.227
Taste	2.728	1.109	0.254	0.114	−0.740	0.227

Table 4
Bivariate correlations between the SHS total scale and subscales, as well as self-reported depression and anxiety symptoms

	Depression	Anxiety	Allergies	Heat	Cold	Light	Pain	Smell	Hearing	Taste	Touch
SHS total	0.193**	0.278***	0.525***	0.540***	0.416***	0.688***	0.405***	0.445***	0.552***	0.544***	0.712***
Depression		0.669***	0.053	0.054	0.259***	0.188*	-.028	0.023	0.131	0.173*	0.084
Anxiety			0.100	0.202**	0.236**	0.153	0.101	0.069	0.108	0.264***	0.146
Allergies				0.222**	0.107	0.259***	0.140*	0.121	0.130	0.138*	0.221**
Heat					-0.128	0.375***	0.070	0.243***	0.356***	0.263***	0.332***
Cold						0.257***	0.165*	0.049	0.183**	0.161*	0.330***
Light							0.280***	0.217**	0.312***	0.230***	0.379***
Pain								0.009	0.178**	0.075	0.220**
Smell									0.081	0.166*	0.223**
Hearing										0.167*	0.303***
Taste											0.404***

* Significant at the 0.05 level (2-tailed)

** Significant at the 0.01 level (2-tailed)

*** Significant at the 0.001 level (2-tailed)

Table 5

ANCOVA of sensory sensitivity across different chronic pain groups

SHS scale	FM ^a	OA ^b	FM + OA ^c	HC ^d	F value	p value
Total score	3.5344 ^{b,d}	3.1262 ^a	3.4084 ^d	2.7513 ^{a, c}	17.645	0.000000
Cold	3.7500 ^d	3.0119	3.4872 ^d	2.9318 ^{a, c}	6.239	0.0004
Heat	3.3430 ^d	3.3333 ^d	3.7436 ^d	2.3333 ^{a, b, c, d}	9.506	0.000007
Allergies	3.5426 ^d	3.3175	3.7778 ^d	2.8586 ^{c,a}	5.047	0.002
Smell	3.9070 ^d	3.4365	3.7521	3.1717 ^a	4.496	0.005
Pain	3.6357 ^{b,d}	3.0635 ^a	3.3248	2.7652 ^a	9.201	0.00001
Touch	3.6357 ^d	3.0397	3.5789 ^d	2.6869 ^{a,c}	7.682	0.00007
Hearing	3.1905	2.8016	2.7521	2.6616	2.741	0.045
Light	4.0155 ^d	3.7659 ^d	3.9402 ^d	3.1187 ^{a, b, c, d}	7.580	0.00008
Taste	2.8372 ^d	2.3810	2.4701	2.1465 ^a	4.302	0.006

Separate ANOVA's are presented for the SHS total score, as well as each subscale

For example, for the "light" subscale, FM is significantly different than back pain

^a FM fibromyalgia,^b OA osteoarthritis,^c FM + OA fibromyalgia and osteoarthritis,^d HC healthy controls.^{a, b, c, d} Significant pairwise post hoc differences are indicated

Table 6

Healthy participants—bivariate correlations between the SHS total scale and subscales (i.e. pain, heat, cold), as well as QST measures of heat pain threshold, heat pain tolerance and cold pain tolerance

	SHS heat	SHS cold	SHS pain	Heat pain threshold	Heat pain tolerance	Cold pain tolerance
SHS total	0.249	0.408 *	0.607 **	−0.114	−0.226	−0.161
SHS heat		−0.046	0.213	0.247	0.010	0.070
SHS cold			0.295	−0.269	−0.590 **	−0.201
SHS pain				−0.272	−0.183	−0.175
Heat pain threshold					0.473 **	0.102
Heat pain tolerance						0.270

*** Significant at the 0.001 level (2-tailed)

* Significant at the 0.05 level (2-tailed)

** Significant at the 0.01 level (2-tailed)

Table 7

Participants with low back pain—bivariate correlations between the SHS total scale and subscales (i.e. pain, heat, cold), as well as QST measures of heat pain threshold, heat pain tolerance and cold pain tolerance

	SHS heat	SHS cold	SHS pain	Heat pain threshold	Heat pain tolerance	Cold pain tolerance
SHS total	0.471 **	0.572 ***	0.596 ***	−0.395 *	−0.311	−0.503 **
SHS heat		−0.013	0.342 *	0.006	−0.009	0.254
SHS cold			0.120	−0.399 *	−0.328	−0.547 **
SHS pain				−0.064	−0.055	−0.345 *
Heat pain threshold					0.716 ***	0.398 *
Heat pain tolerance						0.239

* Significant at the 0.05 level (2-tailed)

** Significant at the 0.01 level (2-tailed)

*** Significant at the 0.001 level (2-tailed)