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Environmental sensitivity in children: development of the highly sensitive child scale and identification of sensitivity groups — Source link

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Running Head: ENVIRONMENTAL SENSITIVITY

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Abstract

A large number of studies document that children differ in the degree they are shaped by their developmental context with some being more sensitive to environmental influences than others. Multiple theories suggest that *Environmental Sensitivity* is a common trait predicting the response to negative as well as positive exposures. However, most research to date relied on more or less proximal markers of Environmental Sensitivity. In this paper we introduce a new questionnaire—the *Highly Sensitive Child* (HSC) scale—as a promising self-report measure of Environmental Sensitivity. After describing the development of the short 12-item HSC scale for children and adolescents, we report on the psychometric properties of the scale, including confirmatory factor analysis and test-retest reliability. After considering bivariate and multivariate associations with well-established temperament and personality traits, we apply Latent Class Analysis to test for the existence of hypothesised sensitivity groups. Analyses are conducted across five studies featuring four different UK-based samples ranging in age from 8-19 years and with a total sample size of $N = 3{,}581$. Results suggest the 12-item HSC scale is a psychometrically robust measure that performs well in both children and adolescents. Besides being relatively independent from other common traits, the Latent Class Analysis suggests that there are three distinct groups with different levels of Environmental Sensitivity—low (approx. 25-35%), medium (approx. 41-47%), and high (20-35%). Finally, we provide exploratory cut-off scores for the categorisation of children into these different groups which may be useful for both researchers and practitioners.

KEYWORDS:

Environmental Sensitivity; Differential Susceptibility; Sensory Processing Sensitivity; Highly Sensitive Person; Temperament; Personality

Environmental Sensitivity in Children: Development of the Highly Sensitive Child Scale and Identification of Sensitivity Groups

Children's development is shaped by many factors, including various aspects of the environment in which they grow up (e.g., child care, see Belsky, Vandell, et al., 2007; socioeconomic status and parenting, see Bornstein & Bradley, 2014). One of the reasons for the often significant impact environmental factors have on developmental outcomes is children's ability to register and process specific characteristics of their developmental context (Pluess, 2015). This capacity for *Environmental Sensitivity* enables them to respond and adapt to the challenges and opportunities associated with particular environmental conditions. Although, at first glance, one may expect that all children should have a similar ability to adapt to the developmental context, given the fundamental importance of adaptation for successful development, a large number of empirical studies suggest that children differ substantially in Environmental Sensitivity, with some being more and some less affected by contextual factors (Belsky & Pluess, 2009, 2013; Ellis & Boyce, 2011; Obradovic & Boyce, 2009).

In this paper we address three empirical objectives related to the measurement of Environmental Sensitivity in children and adolescents. First, we provide extensive information on the development and psychometric properties of an Environmental Sensitivity self-report measure, the child version of the *Highly Sensitive Person* scale (HSP scale; Aron & Aron, 1997). Second, we examine bivariate and multivariate associations between this new measure of child Environmental Sensitivity and established measures of temperament and personality. Third, we investigate the distribution of Environmental Sensitivity in the sample population to test for the existence of groups with different degrees of sensitivity as proposed by several theories and suggest exploratory cut-off scores for these different groups. These objectives are addressed across five studies featuring four different UK-based samples with children ranging in age from 8-19 years and a total sample size of $N = 3{,}581$.

Individual Differences in Environmental Sensitivity

Environmental Sensitivity, defined as the *ability to register and process external stimuli* (Pluess, 2015), is one of the most basic individual characteristics and observable across most species. Without this ability, an organism would not be able to perceive, evaluate, and respond to various environmental conditions, whether these are of physical or psychosocial nature, and whether they are negative or positive (i.e., whether they threaten or promote the development, survival, and reproductive success of the individual). Although adaptation is relevant for all people, empirical studies suggest that individuals differ substantially in their degree of Environmental Sensitivity (for review, see Belsky & Pluess, 2009, 2013) with more and less sensitive types coexisting in the same population (Wolf, van Doorn, & Weissing, 2008). Differences in how people approach, respond and interact with their immediate environment are also reflected in concepts of temperament and personality. Although the various temperament theories differ significantly from each other, one thing they seem to have in common is that they all suggest that some individuals appear more reactive to contextual factors than others, with more environmentally sensitive individuals described as, for example, *inhibited*/*reactive* (Kagan, 1989). A growing number of empirical studies provide evidence that temperament traits do indeed predict differences in Environmental Sensitivity (for a meta-analysis, see Slagt, Dubas, Dekovic, & van Aken, 2016). For example, Pluess and Belsky (2010) found that infant temperament rated by mothers when children were 6 months old predicted children's sensitivity to the parenting quality they experienced during the first 4.5

years of life. Children with a more difficult temperament were both more negatively affected by low parenting quality and more positively by high parenting quality vis-à-vis teacher-rated social skills at age 11 years compared to children with a less difficult temperament (for a reanalysis applying more stringent methodology, see Roisman et al., 2012). Similarly, Kim and Kochanska (2012) reported that negative emotionality assessed at 7 months was associated with increased sensitivity to both low and high mother-child mutuality at 15 months regarding the development of self-regulation at 25 months. More negatively emotional infants had the lowest self-regulation when mother-child mutuality was low and the highest self-regulation when mutuality was high whereas low negatively emotional children were generally less affected by differences in mother-child mutuality. Although a large number of studies suggest that difficult temperament is associated with heightened sensitivity to the environment, it is important to acknowledge that it remains to be determined which component of the typically multidimensional concept of "Difficult Temperament" reflects such sensitivity. Furthermore, "Difficult Temperament" is often assessed with different measures, which makes comparison between studies challenging. However, according to a recent meta-analysis of temperament-parenting interactions, it may be negative emotionality, rather than surgency or effortful control, that predicts sensitivity to parenting (Slagt et al., 2016).

Several of the Big Five personality traits have also been shown to reflect individual differences in Environmental Sensitivity. For example, *low extraversion*—or *introversion*—has been associated with higher sensitivity to both high and low parental over-reactivity in the prediction of aggression in adolescence (De Haan, Prinzie, & Deković, 2010). Not surprisingly, childhood *neuroticism*—or *irritability*/*negative emotionality*—has repeatedly been shown to increase the response to environmental influences, albeit mostly negative ones, including exposure to violence in adolescence (Ho et al., 2013) and stressful life events in adulthood (van Os & Jones, 1999). Finally, *openness to experiences*, has recently been associated with increased parental environmental sensitivity to both low and high perceived social support (Slagt, Dubas, Denissen, Deković, & van Aken, 2015).

Gray's (1981, 1982) personality theory which originally proposed that individual differences in response to reward and punishment are driven by two distinct biological systems can also be considered from a perspective of Environmental Sensitivity: While the *Behavioural Inhibition System* (BIS) captures sensitivity to threatening stimuli, the *Behavioural Activation System* (BAS) describes sensitivity to rewarding (i.e. positive) experiences[1]. Several experimental studies provide evidence that BIS and BAS do indeed predict specific sensitivity to either negative or positive environmental influences. For example, BIS has been found to predict the negative emotional response to unpleasantly loud noises (Heponiemi, Keltikangas-Jarvinen, Puttonen, & Ravaja, 2003) and higher negative reactivity to negative life events (Gable, Reis, & Elliot, 2000). BAS, on the other hand, has been associated with positive emotional responsivity to anticipated monetary reward (Carver & White, 1994) as well as stronger brain activation in response to appetitive food pictures (Beaver et al., 2006).

Concepts for Individual Differences in Environmental Sensitivity

[1] It is important to acknowledge that Gray revised his original theory (see McNaughton & Gray, 2000). In brief, BIS is now thought to produce alert interest and a pause in activity that allows for the processing of conflicting information, a balancing of or negotiation between the urge to approach and satisfy needs (i.e., BAS), and the urge to stop and consider risks, costs, or how best to make use of an opportunity. In the case of threat, a third strategy of fight, flight, or freeze is suggested. However, popular measures of BIS-BAS (i.e., Carver & White, 1994) have been developed earlier and do not reflect that conceptual change.

There are several theoretical frameworks for variability in Environmental Sensitivity that have emerged since the mid to late 1990s with the three most prominent being *Sensory-Processing Sensitivity* (Aron & Aron, 1997; Aron, Aron, & Jagiellowicz, 2012), *Differential Susceptibility Theory* (Belsky, 1997b, 2005; Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2007; Belsky & Pluess, 2009, 2013), and *Biological Sensitivity to Context* (Boyce & Ellis, 2005; Ellis & Boyce, 2008). Each of the three concepts provides unique and important theoretical insights regarding individual differences in general Environmental Sensitivity—discussed in more detail elsewhere (Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van IJzendoorn, 2011; Pluess, 2015). However, the significant and distinctive contribution shared across all three frameworks is the notion that sensitive individuals differ not only in their response to environmental adversity (e.g., child maltreatment, stressful life events, poverty etc.)—as the traditional *Diathesis-Stress* model would imply—but also in response to positive supportive aspects of the environment (e.g., sensitive parenting, social support etc.). This new aspect of variability in sensitivity to positive experiences has recently been extracted from the more general models of Environmental Sensitivity and further developed into the framework of *Vantage Sensitivity* (Pluess, 2017; Pluess & Belsky, 2013). According to the concept of Vantage Sensitivity, people differ fundamentally in their response to *positive* environmental influences and exposures as a function of inherent characteristics with some being more sensitive and some being more resistant to the beneficial effects of positive experiences, including psychological interventions (e.g., Albert et al., 2015).

Recently, these different concepts have been integrated into an overarching meta-framework of *Environmental Sensitivity* (see Figure 1 for an illustration) according to which people differ in their sensitivity to environmental influences with some being more and some less affected by negative and/or positive exposures (Pluess, 2015).

Measuring Environmental Sensitivity

Most evidence for individual differences in Environmental Sensitivity is based on research reporting cross-over interactions between some contextual measure (e.g., parenting quality) and a wide range of individual traits that can be categorised into genetic (e.g., 5-HTTLPR; van IJzendoorn, Belsky, & Bakermans-Kranenburg, 2012), physiological (e.g., cortisol reactivity; Obradovic, Bush, Stamperdahl, Adler, & Boyce, 2010) and behavioural/psychological sensitivity factors (e.g., negative emotionality; Kim & Kochanska, 2012) in the prediction of some behavioural outcome measure (e.g., social skills). Although these sensitivity factors may represent important markers of Environmental Sensitivity at different levels of analysis—some more proximal than others—none of them describe and capture the hypothesised phenotypic trait of Environmental Sensitivity directly. In fact, to our knowledge explicit phenotypic measures of Environmental Sensitivity are currently not available with the exception of the *Highly Sensitive Person* scale (Aron & Aron, 1997), a 27-item questionnaire designed to measure *Sensory Processing Sensitivity* in adults (but some measures may capture important aspects of Environmental Sensitivity, for example Orienting Sensitivity measured with the Adult Temperament Questionnaire, see Evans & Rothbart, 2007, 2008). According to Aron (1996; Aron & Aron, 1997) *Sensory Processing Sensitivity* (SPS) is a relatively stable personality trait that reflects an individual's sensitivity to environmental influences and manifests itself in (a) greater awareness of sensory stimulation, (b) behavioural inhibition as described by McNaughton and Gray (2000) rather than Carver and White (1994) or Gray's earlier theory (1981, 1982), (c) deeper cognitive processing of environmental stimuli, and (d) higher emotional and physiological reactivity (for an extensive review, see Aron et al., 2012). The *Highly Sensitive Person* scale (HSP scale; Aron & Aron, 1997) aims at capturing these cognitive and behavioural components of sensitivity and appears to succeed at doing so, most notably in fMRI studies reporting deeper or more elaborate cognitive processing in individuals with higher HSP scores (Acevedo et al., 2014; Jagiellowicz et al., 2011), as well as behavioural studies. For example, Aron, Aron, and Davies (2005) were able to demonstrate consistent associations between HSP scores and heightened sensitivity to contextual factors in a series of studies, including an experimental one in which undergraduates completed a cognitive task. Students were randomly assigned to a situation that either implied they were doing much better or much worse than the peers sitting around them. Participants with high scores on the HSP Scale reported more negative affect than others after the task if they were led to believe they had done worse than others, but the least negative affect in the condition where they were led to believe they had done better. Those scoring low, on the other hand, did not differ significantly in negative affect regardless of condition, suggesting they were generally less affected by the experimental manipulation. More recently, Booth, Standage, and Fox (2015) tested in a cross-sectional study whether SPS assessed with the HSP Scale in adulthood moderated the effects of retrospectively reported childhood experiences on adult life satisfaction. A significant interaction emerged suggesting that those scoring high were more negatively affected by negative childhood experiences than those scoring low.

In contrast to other common personality traits, SPS has been suggested to follow a dichotomous rather than a normal distribution with about 20% of the general population falling into a highly sensitive category and about 80% into a less sensitive category (Aron et al., 2012; for an unpublished taxometric analysis of the HSP scale, see Borries, 2012). Interestingly, the proposition that a minority of the population is more sensitive to environmental influences is consistent with empirical findings on the distribution of temperament traits found to reflect heightened environmental sensitivity to both negative and positive aspects of the early environment. For example, a taxometric analysis of the distribution of *Infant Reactivity* or *Behavioural Inhibition* (Kagan, Reznick, & Snidman, 1987) suggested that such reactivity is distributed categorically rather than continuously, with about 10% of children being characterised with especially high reactivity (Woodward, Lenzenweger, Kagan, Snidman, & Arcus, 2000). Intriguingly, several of the candidate gene variants that have been repeatedly associated with increased environmental sensitivity to negative as well as positive exposures (Belsky et al., 2009; Belsky & Pluess, 2009, 2013) have a comparable frequency. For example, 18.4% of a large Dutch sample were homozygous for the 5-HTTLPR short allele (Pluess et al., 2011) which has been associated with increased sensitivity to both negative and positive influences (van IJzendoorn et al., 2012). The proposition that there might be two distinctive sensitivity patterns has been described in the popular *Orchid-Dandelion* metaphor (Ellis & Boyce, 2011) according to which *Orchids* represent the minority in the population who are generally more sensitive (i.e., they do exceptionally well in ideal conditions and exceptionally badly in poor ones) and *Dandelions* the majority who are generally less sensitive to environmental quality (i.e., they are resilient and can grow anywhere). However, although widely observed individual differences in environmental sensitivity may reflect the existence of different sensitivity groups with high sensitivity characterising a minority of the general population, this hypothesis has not been tested empirically in children yet.

Although Aron and Aron (1997) originally hypothesised that the 27 items of the HSP scale would reflect a single factor of environmental sensitivity, other studies have found that a three factor structure was a better fit for the data (Smolewska, McCabe, & Woody, 2006). The three factors that typically emerge are (a) *Aesthetic Sensitivity* (AES), capturing aesthetic awareness (e.g., being deeply moved by arts and music); (b) *Low Sensory Threshold* (LST), which reflects unpleasant sensory arousal to external stimuli (e.g., reaction to bright lights and loud noises); and (c) *Ease of Excitation* (EOE) which refers to being easily overwhelmed by external and internal demands (e.g., negative response to having a lot going on, to being hungry). Smolewska et al. (2006) investigated correlations between the HSP scale and personality measures in adults, including the Big Five personality traits and BIS/BAS scales by Carver and White (1994), and found that the HSP total score was significantly and positively correlated with neuroticism (r = .45) and openness (r = .19), as well as both BIS (r = .32) and BAS (r = .16 for the reward-responsiveness subscale). When investigating associations with the three HSP subscales, they found that while neuroticism and BIS were correlated with all three factors, openness had a significant association only with Aesthetic Sensitivity (r = .37), Low Sensory Thresholds with lower extraversion (r = -.12), and Ease of Excitation and AES with the BAS Reward-Responsiveness scale (r = .19 and r = .18, respectively) (for similar findings, see Gerstenberg, 2012). At first sight this correlation pattern appears to suggest that Aesthetic Sensitivity may reflect environmental sensitivity to more positive experiences, whereas Ease of Excitation and Low Sensory Thresholds reflect sensitivity to more negative experiences. Important to note is also that the three subscales tend to be correlated with each other, suggesting that there may exist a general sensitivity factor (Lionetti et al., submitted).

In summary, the HSP scale represents a promising self-report measure of environmental sensitivity in adults. However, there are currently no self-report versions of the scale for use with children and adolescents (but for the first evaluation of a parent-rated child scale, see Boterberg & Warreyn, 2016). In this paper we address this gap, across five studies, presenting a new brief child version of the HSP scale and investigating associations with common personality and temperament variables as well as testing for the existence of different sensitivity classes. More specifically, in Study 1 we describe the creation of a 12-item child HSP scale drawing on a pool of 38 child sensitivity items in a sample of 12-year old children. In Study 2, we test the psychometric properties of the new 12-item scale in an independent sample of 11-year olds. In Study 3 we report test-retest reliability of the 12-item scale in a different sample of 10-year old children. In Study 4 we apply the same scale to a large sample of adolescents at age 17 years. Finally, in Study 5, we report findings of latent class analyses across the different samples in order to test for the existence of hypothesised sensitivity groups in childhood and adolescence and provide exploratory cut-off scores that can be used to approximately categorise children and adolescents into the identified sensitivity groups.

Study 1

The main objective of Study 1 was to create a short and psychometrically robust *Highly Sensitive Child* (HSC) scale drawing on 38 existing sensitivity items for children, which have been adapted from the 27 items included in the adult HSP scale. Besides being brief and psychometrically sound, the self-report measure should be suitable for children and adolescents and reflect the same factor structure as the adult version. Once the HSC scale was created, it was then tested for its psychometric properties as well as for its associations with related constructs of behavioural inhibition and activation, temperament, and affect.

Methods

Participants. The sample included 334 children (251 girls and 83 boys) with a mean age of 12.06 years (range = 11-14 years; *SD* = 0.67) recruited from two secondary schools in East London, United Kingdom (one of the school was a girls-only school which explains the higher proportion of girls in this particular sample) . The sample was ethnically diverse with 55.4% of Asian, 15.9% of African/Caribbean, 8.1% of White/European, 2.1% of Middle Eastern, and 18.6% of mixed ethnicity.

Procedure and Development of Scale. Children were asked to complete all questionnaires on a computer at school during class. In order to create a short and psychometrically robust HSC scale that is comparable in content and structure to the adult scale, the factor structure of the adult scale was consulted. As reported by Smolewska et al. (2006) a three factor structure seemed to fit the data collected with the adult HSP scale best with 12 items loading on the factor “Ease of Excitation”, 7 items on “Aesthetic Sensitivity”, and 6 items on “Low Sensory Threshold” (two items did not load clearly on any of the three factors and were excluded). In order to create a HSC scale that is comparable to the HSP scale, we first selected among the remaining 25 HSP items from Smolewska et al.’s (2006) factor analysis those that (a) had a factor loading of >.5 and (b) could be easily adjusted for the use with children. Twelve items met these criteria. Then, we conducted a Principal Component Analysis (PCA), constrained to three components (given that the HSP scale reflects three factors) across a pool of 38 sensitivity items for children (HSC-38, provided in supplementary information) that have been developed based on the 27 HSP items for adults, in order to test whether the HSC items would reflect similar factor loadings as the corresponding adult HSP items as reported by Smolewska et al. (2006). The final 12-item HSC scale included 5 Ease of Excitation items, 4 Aesthetic Sensitivity items, and 3 Low Sensory Thresholds items (see Table 1 for a list of the specific items).

Measures. Children completed 38 items from an unpublished sensitivity scale (HSC-38, see supplementary information), which has been developed initially to measure *Sensory-Processing Sensitivity* in Dutch school-aged children (Walda, 2007). The 38 items aim at capturing the same information as the adult HSP scale (Aron & Aron, 1997). Items such as "*When someone is sad, that makes me feel sad too*", "*I find it unpleasant to have a lot going on at once*", and "*When I am hungry, I get in a bad mood*" were rated by children on a scale from 1 = "not at all", to 7 = "extremely", with higher scores indicating higher levels of sensitivity. The internal reliability of the 38 items was good with Cronbach's α = .92.

Behavioural inhibition and activation was measured with the 24-item *Behavioural Inhibition and Behavioural Activation Scales* (BIS-BAS; Carver & White, 1994). The Behavioural Inhibition Scale (BIS) is based on 7 items (e.g., "*Criticism or scolding hurts me quite a bit*", *"I worry about making mistakes"*) whereas the Behavioural Activation Scale (BAS) features three subscales (i.e. "Reward Responsiveness", "Drive", and "Fun Seeking"). For the current study, all 17 BAS items (e.g., *"It would excite me to win a contest", "I'm always willing to try something new if I think it will be fun"*) were pooled into one scale. BIS-BAS items are rated on a Likert scale ranging from 1 = "very false" to 4 = "very true". Higher scores indicate higher levels of behavioural inhibition (BIS) and activation (BAS). In the current sample the internal reliability of BIS and BAS were α = .80 and α = .91, respectively.

Temperament was measured with the 65-item *Early Adolescent Temperament*

Questionnaire-Revised (EATQR; Capaldi & Rothbart, 1992) which assesses 12 aspects of temperament (i.e. Activation Control, Affiliation, Attention, Fear, Frustration, High-Intensity Pleasure, Inhibitory Control, Perceptual Sensitivity, Pleasure Sensitivity, Depressive Moods, Aggression, and Shyness). Items (e.g., *"I feel shy about meeting new people", "I feel pretty happy most of the day", "When I am angry, I throw or break things")* are rated on a 5-point Likert scale, ranging from 1 = "almost always untrue of you", to 5 = "almost always true of you". For the current study, we combined these subscales—as recommended by others (Putnam, Ellis, & Rothbart, 2001; Snyder et al., 2015)—into three superordinate dimensions of temperament: (a) Effortful Control (EC; based on Attention, Activation Control, and Inhibitory Control), (b) Negative Emotionality (NE; based on Fear, Frustration and Shyness), and (c) Positive Emotionality (PE; based on Surgency, Pleasure Sensitivity, Perceptual Sensitivity and Affiliation). Higher scores on each subscale indicate higher levels on that temperament dimension. The internal consistency of the scales were acceptable with α = .86 for EC, α = .69 for NE, and α = .84 for PE.

Positive and negative affect were measured with the child version of the *Positive and Negative Affect Scales* (PANAS; Laurent et al., 1999). The Positive Affect (PA) scale includes 12 items (e.g., *"Interested", "Excited")* and the Negative Affect (NA) scale 15 items (e.g., *"Upset", "Guilty")*. All items are rated on Likert scale, ranging from 1 = "not at all" to 5 = "almost every day". Higher scores indicate higher state levels of positive or negative affect. The internal consistency of the PANAS was good with α = .92 for PA and α = .93 for NA.

Data Analysis. In order to create the HSC scale, we conducted Principle Component Analyses (PCA) on the 38 sensitivity items (applying Varimax rotation with Kaiser normalization). For the first PCA the number of components was defined by Eigen values >.1 and in a second analysis we constrained the model to three components, informed by the 3-factor structure of the adult HSP scale (Smolewska et al., 2006). We then selected 12 items, out of the 38 items, that were most similar to the highest loading items of the adult HSP scale as reported by Smolewska et al. (2006). The PCA was then repeated with the 12 selected items in order to verify whether items would load on the specific component they had been selected for. Next, we applied Confirmatory Factor Analyses (CFA) to the 12-item scale in order to test two competitive models (see Figure 2 for an illustration of the difference between the two models): (a) a 3-factor model with five items in factor 1 (Ease of Excitation), four items in factor 2 (Aesthetic Sensitivity) and three items in factor 3 (Low Sensitivity Threshold); and (b) a bi-factor model which includes a shared general factor in addition to the three separate factors based on recent findings which suggest that the adult HSP scale fits a bi-factor model better than a 3-factor model (Lionetti et al., submitted). In order to test the bi-factor model, one of the factor loadings in the general factor and one of the loadings in each of the domain specific factors were set to 1 (F. F. Chen, West, & Sousa, 2006). The robust maximum likelihood was used as estimation method. Two relative fit indices were considered for the evaluation of goodness of fit for each model: the Tucker Lewis index (TLI) and the comparative fit index (CFI), both of which perform well with small and large samples (the χ^2 statistic is extremely sensitive to sample size and not well suited for the current analysis). CFI and TLI values of > .95 and > .97, respectively, were considered as acceptable and good fit (Schermelleh-Engel, Moosbrugger, & Müller, 2003). The root mean square error of approximation (RMSEA) and the standardized root mean square residuals (SRMR) were also used. For RMSEA, values < .05 were considered as a good fit and values ranging from .05 and .08 as an adequate fit. For SRMR, values less than .08

were considered to reflect good fit (Schermelleh-Engel et al., 2003). The 3-factor and bi-factor models were compared according to three criteria: (a) qualitative evaluation of the fit indices of each model; (b) the *CFI* criterion according to which the null hypothesis of no differences between the two competing models should not be rejected if the difference in the *CFIs* between two nested models is smaller than |0.01| (Cheung & Rensvold, 2002); and (c) the scaled χ^2 difference test according to which the null hypothesis (i.e. no differences between the two competing models) should not be rejected if the associated *p* value is greater than .05 (Satorra, 2000) with lower χ^2 reflecting better model fit.

Internal reliability of the HSC scale was measured with Cronbach's α. A one-way ANOVA was conducted to test for ethnic differences in HSC and an independent samples t-test to investigate gender differences. We then tested bivariate correlations between the mean of the 38 child sensitivity items, the mean of our newly created 12-item HSC scale and its subscales as well as behavioural inhibition and activation, temperament, and affect. Furthermore, we ran multivariate regression models to investigate convergent validity and to estimate how much of the variance in HSC was explained by related measures, including all HSC scales simultaneously as dependent variables in the same model and thus taking the interdependence among variables into account. Finally, we tested divergent validity of the HSC scale with the heterotrait-monotrait (HTMT) ratio of correlations (Henseler, Ringle, & Sarstedt, 2015). The HTMT ratio represents the average of the correlations of items across different constructs (e.g. HSC, BIS, PA etc.) relative to the average of the correlations of items within the same construct (e.g., the 12 HSC items). HTMT ratio values that are equal or lower than .85 indicate that divergent validity is met.

The level of significance for all analyses was set at $\alpha = .05$. Analyses were conducted using R software and related packages (Rosseels, 2016; semTools Contributors, 2016). All other analyses were conducted with SPSS version 20 (IBMCorp., 2011).

Results

Principal Component and Confirmatory Factor Analyses. Principal component analysis (PCA) of the HSC-38 resulted in nine principle components that accounted for 61% of the cumulative variance. However, the scree plot pointed towards a three-component solution. After constraining the PCA to three principle components, 40% of the variance was explained (see supplementary information for detailed results). PCA of the 12 selected items suggested that the three principle components explained 55% of the cumulative variance. Table 1 shows the 12 selected items and their loadings on the three principal components, reflecting the same three factors as reported with the adult HSP scale (Smolewska et al., 2006).

The Confirmatory Factor Analysis (CFA) of the 3-factor model showed acceptable model fit with $\chi^2 = 106.84$, $df = 51$, $p <. 001$; RMSEA=.06, 90% [C.I = .05, .08]; CFI/TLI = .907/.880; SRMR = .06. Similar model fit indices emerged for the bi-factor model ($\chi^2 = 94.804$, $df = 46$, $p < .001$; RMSEA = .06, 90%, CIs [.05, .08]; CFI/TLI = .919/.884 SRMR = .06). However, although the two models showed comparable fit indices the CFI difference (CFI [DIFF] = .012) and the scaled χ^2 difference (χ^2 [DIFF] = 11.8, $df = 5$, $p = .04$) between them suggests that the bi-factor model is the better fitting solution (more details of these analyses are provided in the supplementary information document).

Descriptive Statistics and Internal Reliability. Table 2 shows the mean values and standard deviations for the mean of the 38 child sensitivity items (HSC-38), the

HSC total scale, the three HSC factors (Ease of Excitation, Aesthetic Sensitivity, and Low Sensory Thresholds), and all other measures used in this study. The HSC scale showed adequate internal consistency with α = .79, 90% CIs [.75, .82]. HSC subscales showed acceptable but lower internal consistency which was to be expected considering the low item numbers in each subscale with α = .71, CIs [.65, .76] for Ease of Excitation, α = .73, CIs [67-78] for Aesthetic Sensitivity, and α = .66, CIs [.58, .72] for Low Sensory Thresholds. There were no significant differences in HSC as a function of ethnicity ($F_{(51)} = 1.21$, $p = .45$). A small gender difference was observed, with females (*M* = 4.41, SD = .93) scoring significantly higher than males (*M* = 4.07, SD = 1.08) with $t_{(283)} = -2.55$, $p < .05$.

Bivariate Correlations. Bivariate associations between all variables are reported in Table 3. Most importantly, the mean of the12-item HSC scale is highly correlated with the mean of the 38 child HSP items (*r* = .93). BIS and BAS are correlated with HSC and the three subscales except for Low Sensory Thresholds which was not associated with BAS. Regarding temperament, Effortful Control, Negative and Positive Emotionality were correlated with HSC and all subscales except for Low Sensory Thresholds, which was not correlated with Positive Emotionality. Finally, Positive Affect was positively correlated with Aesthetic Sensitivity (*r* = .41) and Negative Affect with Ease of Excitation (*r* = .16) and Low Sensory Thresholds (*r* = .13). (Bivariate correlations between the EQTAR subscales and HSC are provided in supplementary information).

Multivariate Regression. The first model, which included BIS, BAS, EC, PE, NE, PA, and NA as predictor variables of HSC explained 34% of the variance. The second model with the three subscales as outcomes explained 30% of the variance of Ease of Excitation, 35% of Aesthetic Sensitivity, and 17% of Low Sensory

Thresholds. Standardized parameter estimates and associated *p*-values are reported in Table 4.

Divergent Validity. Heterotrait-monotrait (HTMT) ratio of correlations values for each pair of measures ranged from .14 for Ease of Excitation-PA to .67 for Ease of Excitation-BIS, suggesting that divergent validity was established. Furthermore, associations among the HSC total score and subscales Ease of Excitation, Low Sensory Thresholds and Aesthetic Sensitivity were consistently higher than associations between HSC and other measures (detailed HTMT results are provided in the supplementary information document).

Discussion

According to Study 1, the mean of the 12-item *Highly Sensitive Child* scale was strongly associated with the mean of the 38 child sensitivity items but reflected the identical 3-factor structure as the adult scale. Importantly, the confirmatory factor analyses suggested that although the measure consists of three distinct subscales, these subscales also load on a general factor of sensitivity. Hence, the total mean score of the scale can be used to indicate Environmental Sensitivity even though the three subscales appear to capture different components of sensitivity. For example, Aesthetic Sensitivity seems to capture sensitivity to more positive aspect of the environment, indicated by correlations with the behavioural activation system (BAS) and positive emotionality and affect, whereas Ease of Excitation and Low Sensory Thresholds tend to reflect sensitivity to more negative contextual factors, as shown in correlations with the behavioural inhibition system (BIS) as well as negative emotionality and affect. This may also explain why the total score was associated with both negative and positive emotionality. Finally, multivariate regression analyses provided evidence that Environmental Sensitivity as measured with the HSC scale does not simply reflect effects of well-known temperament traits and affect. Divergent validity was further supported by heterotrait-monotrait ratio of correlations analysis.

Study 2

In order to replicate the findings of Study 1, the same psychometric properties and associations with temperament, behavioural inhibition and activation were investigated in an independent sample.

Methods

Participants. The sample included 258 children (113 girls and 145 boys) from a secondary school in East London, United Kingdom. Children were on average 11.17 years old (range = 11-12 years, *SD* = .38) and were of ethnically diverse backgrounds: White (20.9%), African/Caribbean (20.2%), Asian (34.9%), Middle Eastern (4%) and mixed-ethnicity (23.3%).

Procedure and Measures. Children completed all measures on a computer during regular class at school. In order to measure Environmental Sensitivity, the 12-item HSC was used rather than the 38 child sensitivity items. In addition, children also reported on behaviour inhibition and activation with the BIS-BAS (Carver & White, 1994) and on temperament with the EATQR (Capaldi & Rothbart, 1992). Measures were used exactly the same way as described in Study 1. However, positive and negative affect (PANAS) were not measured in this sample.

Data Analysis. The same methods and statistical analyses were applied as described in detail in Study 1.

Results

Confirmatory Factor Analysis. The confirmatory factor analysis on the 12 items showed good model fit for the 3-factor model (χ^2 = 63.019, df = 51, p = .12; RMSEA = .03, 90% CIs [.00, .05]; CFI/TLI = .968/.959; SRMR = .05). For the bi-factor model, the negative variance of one statistically non-significant Ease of Excitation item was fixed to 0 (F. F. Chen et al., 2006). The results of the bi-factor model were satisfactory: $\chi^2 = 48.73$, df = 46, $p = .48$; RMSEA = .01, 90% CIs [.00, .04]; CFI/TLI = .995/.994; SRMR = .04. The 3-factor and bi-factor models showed comparable fit indices with slightly stronger support for the bi-factor model. The CFI difference was significant and equal to .027—confirmed by a significant scaled χ^2 difference (χ^2 [DIFF] = 13.1, df = 4, p = .01)—and, thus, supporting the use of both the HSC total score as well as the individual Ease of Excitation, Aesthetic Sensitivity and Low Sensory Thresholds subscales.

Descriptive Statistics and Internal Reliability. Table 2 shows the mean scores and standard deviations for HSC, the three HSC subscales and all other measures used in this sample. The HSC scale showed acceptable internal consistency with a Cronbach's α of .72, 90% CIs [.66, .77] while the HSC subscales had slightly lower internal consistencies with α = .66, 90% CIs [.59, .72] for Ease of Excitation, α = .62, 90% CIs [.54, .69] for Aesthetic Sensitivity, and α = .63, CIs [.54, .70] for Low Sensory Thresholds. Consistent with Study 1 there were no significant differences in HSC as function of ethnicity ($F_{(48)} = 1.27$, $p = .13$) but the gender difference was only marginally significant ($t_{(245)} = -1.93$, $p = .06$).

Bivariate Correlations. Similar to Study 1, all HSC scales were positively correlated with both BIS and BAS except for Low Sensory Thresholds which was not associated with BAS (see Table 5). The strongest associations with BIS/BAS emerged between Ease of Excitation and BIS, and between Aesthetic Sensitivity and the BAS ($r = .29$ and $r = .35$, respectively). Regarding temperament, Effortful Control, Negative and Positive Emotionality were associated with all HSC scales. However, the correlation between Ease of Excitation and Negative Emotionality and between

Aesthetic Sensitivity and Positive Emotionality stood out (r = .49 and r = .50, respectively). (Bivariate correlations between the EQTAR subscales and HSC are provided in supplementary information).

Multivariate Regression. The multivariate regression models included BIS, BAS, EC, PE and NE as predictor variables of HSC and subscales. The model predicting HSC explained 26% of the variance and the model predicting the subscales explained 26% of the variance of Ease of Excitation, 26% of Aesthetic Sensitivity, and 15% of Low Sensory Thresholds (see Table 6).

Divergent Validity. HTMT values for each pair of constructs ranged from .12 for Low Sensory Thresholds-BAS to .71 for Aesthetic Sensitivity-PE and, hence, confirm divergent validity. Associations between the HSC total score and its subscales were consistently higher than association with the other measures (see supplementary information document for HTMT results).

Discussion

The findings of Study 2 confirm the bi-factor structure of the HSC measure, suggesting that the total scale reflects three components whose items also load on a general sensitivity factor. The bivariate correlations provide further suggestive evidence that Aesthetic Sensitivity may reflect sensitivity to more positive environmental aspects, whereas Ease of Excitation (and Low Sensory Thresholds) seems to capture sensitivity to more negative contextual factors (with the total HSC score correlating again with both negative and positive emotionality, see discussion in Study 1). According to the regression results the different temperament traits fail to account for the majority of the variance of HSC, suggesting that Environmental Sensitivity is not fully explained or captured by existing concepts as confirmed in the heterotrait-monotrait ratio of correlations findings.

Study 3

Study 3 aimed at investigating test-retest reliability of the created 12-item HSC measure in an independent child sample.

Methods

Participants. Data for this study were obtained from the *Pictures and Words Study* (PAWS). PAWS is a longitudinal study of information processing and mood featuring a sample of 155 children (Brown et al., 2014). Data were collected across three data waves with children recruited from two primary schools in London. For the current study, data were collected during the third wave resulting in a sample of 104 children (59 girls and 45 boys) at age 9.82 years (range = 8-11 years, *SD* = .45). Eighty-one percent of the sample identified as white.

Procedure and Measures. The original study included several psychological measures of information processing and mood. For the current study, only data from the 12-item HSC scale collected at the third wave of data collection were used. The third wave of data collection comprised of two data collection sessions scheduled to take place approximately two-three weeks apart (mean interval = 15 days, range 9-22 days, *SD* = 2.46). Children were seen individually in a quiet classroom and completed a computerised version of the HSC scale at both sessions (via EPrime 2.0) with responses made using the computer keyboard. Items were presented onscreen but also read aloud to ensure comprehension.

Data Analysis. Internal reliability of the 12-item HSC scale was examined with Cronbach's α and test-retest reliability was calculated by correlating scores for HSC and the three subscales from session 1 with scores of repeated measurement at session 2. A test-retest reliability of .70 or higher was considered adequate (McCrae, Kurtz, Yamagata, & Terraciano, 2011).

Results

Descriptive Statistics and Internal Reliability. Mean scores and standard deviations for the HSC sum score and the three subscales are provided in Table 2, separately for each of the two data collection sessions. The HSC scale showed acceptable internal consistency with α = .71 and .74 for session 1 and session 2, respectively. The subscales showed lower internal consistency with α = .73/.69 for Ease of Excitation, α = .49/.46 for Aesthetic Sensitivity, and α = .49/.55 for Low Sensory Thresholds.

Test-Retest Reliability. Test-retest reliability estimates for the HSC score (r = .68) and the subscales (r = .57-.78) are presented in Table 7 and were acceptable. Furthermore, estimates remained stable when the interval between data collection sessions was partialled out.

Discussion

Findings of Study 3 confirm the internal consistency found in Studies 1 and 2 and suggest that test-retest reliability of the HSC scale is acceptable in a sample of children whose ages range from 8-11 years. Although there is substantial stability across measurements, mean scores do show some variability over time, which suggests that the measure may pick up measurement error or short-term changes in self-reported sensitivity. It is conceivable that stability would be higher at older age, which remains to be tested.

Study 4

In Study 4 the performance of the developed 12-item HSC scale was tested in a large sample of adolescents followed by exploring associations with the Big Five personality traits.

Methods

Participants. Data for Study 4 were obtained from a subset of the *Twins Early Development Study* (TEDS), a large epidemiological study of over 16,000 twin pairs born in England and Wales in 1994, 1995, and 1996. TEDS includes extensive data on various aspects of development, including cognitive abilities, personality, behaviour, educational achievement and family environment, collected at regular intervals from a sample that is representative of the UK population (Kovas et al., 2007). Data and recruitment procedures are reported in detail elsewhere (Haworth, Davis, & Plomin, 2013). Data on the 12-item HSC scale was collected for 2,945 individuals when twins were approximately 17 years old. Data on the Big-Five personality was available for a subset of the same sample (1,174 individuals). Participants with severe medical disorders, history of perinatal complications, or unknown zygosity were excluded from the analyses (n = 77). Furthermore, only data from one sibling per twin pair was included (random selection) in order to account for relatedness between individuals in this particular sample. The final HSC sample included 1,431 adolescents (595 males, 836 females), with a mean age of 17.06 (range = 15-19 years, SD = .88) on return of the HSC questionnaires. The ethnicity of the majority (93%) of the sample was identified as Caucasian.

Procedure and Measures. Data for the measures used in the current analysis were obtained by self-report via online or paper questionnaires.

Personality. *Environmental Sensitivity* was measured with the 12-item HSC scale. Big-Five personality traits *Agreeableness, Extraversion, Neuroticism, Openness to Experience* and *Conscientiousness* were measured with the 30 item *Five Factor Model Rating Form* (Mullins-Sweatt, Jamerson, Samuel, Olson, & Widiger, 2006). Items (e.g., *"fearful, apprehensive versus relaxed, unconcerned, cool", "strange, odd, peculiar, creative versus pragmatic, rigid.")* were rated on a Likert scale ranging from 1 = "low" to 5 = "high". Higher scores indicate higher levels of the personality trait. Internal reliability of the scale was acceptable with α = .73 for Neuroticism, α = .70 for Extraversion, α = .65 for Openness, α = .65 for Agreeableness, and α = .75 for Conscientiousness.

Data Analysis. The factor structure (confirmatory factor analysis) and internal reliability of the HSC scale was examined by applying the same methodological approach as in Studies 1 and 2. Association between HSC, HSC subscales and the Big-Five personality traits were investigated with bivariate correlations. Furthermore, multivariate regression and heterotrait-monotrait ratio of correlations analysis were applied to investigate divergent validity, following the same procedures adopted in Studies 1 and 2.

Results

Confirmatory Factor Analysis. The 3-factor model (Ease of Excitation, Aesthetic Sensitivity , Low Sensory Thresholds) yielded good model fit ($\chi^2 = 323.88$, $df = 51$, $p < .001$; RMSEA = .06, 90% CIs [.06, .07], CFI/TLI = .935/.91; SRMR = .05). The bi-factor model also fit the data well ($\chi^2 = 286.53$, $df = 46$, $p < .001$, RMSEA = .06, 90% CIs [.05, .07], CFI/TLI = 945/921, SRMR = .70). The two models showed comparable fit indices with slightly stronger support for the bi-factor model. The CFIs difference was trivial (equal to .01) though in the presence of a significant scaled χ^2 difference (χ^2 [DIFF] = 47.2, $df = 5$, $p < .001$).

Descriptive Statistics and Internal Reliability. Mean scores and standard deviations for HSC, the three HSC subscales, and the Big-Five personality traits are presented in Table 2. Females (*M* = 4.13, *SD* = .96) scored significantly higher than males (*M* = 3.78, *SD* = .92) with $t_{(1429)} = 6.81$, $p < .001$. Internal consistency was good for the HSC total scale (α = .82) and acceptable for the subscales (Ease of Excitation with α = .81; Aesthetic Sensitivity with α = .65; Low Sensory Thresholds with α = .71).

Bivariate Correlations. Unadjusted associations between HSC and the Big-Five personality traits are presented in Table 8. HSC was positively associated with Neuroticism (*r* = .31) and Openness (*r* = .18) and negatively with Extraversion (*r* = -.18) but did not correlate with Agreeableness and Conscientious. While Ease of Excitation and Low Sensory Thresholds correlated with Neuroticism (*r* = .38, and *r* = .22, respectively) and Extraversion (*r* = -.28 and *r* = -.22, respectively), Aesthetic Sensitivity was not associated with Neuroticism but correlated positively with Extraversion (*r* = .20), Openness (*r* = .25), and Conscientiousness (r = .16).

Multivariate Regression. The multivariate regression model with the five personality traits as predictor variables explained 14% of the variance of HSC. A second model with the HSC subscales as outcome variables explained 17% of the variance of Ease of Excitation, 10% of Aesthetic Sensitivity, and 14% of Low Sensory Thresholds (See Table 9 for the standardized parameter estimates).

Divergent Validity. HTMT values ranged from .12 for Low Sensory Thresholds–Conscientiousness to .48 for Ease of Excitation-Neuroticism providing evidence of divergent validity. Similar to the previous studies reported in this paper, associations among the HSC total score and subscales Ease of Excitation, Low Sensory Thresholds and Aesthetic Sensitivity were consistently higher than associations with other measures (detailed results are provided in the supplementary information document).

Discussion

The 12-item HSC scale performed just as well with 15-19 year old adolescents as with 8-12 year old children. The observation that a bi-factor model fit the data best further confirms that the scale reflects both a general sensitivity factor and three separate sensitivity components. Bivariate correlations also provide additional evidence that the subscales capture different aspects of sensitivity with Aesthetic Sensitivity reflecting Openness and to a lesser degree Conscientiousness, while Ease of Excitation and Low Sensory Thresholds are associated with higher Neuroticism and lower Extraversion. Future studies should investigate these correlations further by considering associations with the different facets of the identified personality traits. However, in the current study all five personality traits accounted for no more than 14% of the variance of HSC and the .85 HTMT criterion was always met, suggesting that HSC is not well captured with common personality traits and that divergent validity is established.

Study 5

The aim of Study 5 was to explore whether there exist different sensitivity groups as suggested by theory (e.g., Aron et al., 2012; Boyce & Ellis, 2005) and empirical studies (e.g., Wolf et al., 2008). Although Environmental Sensitivity—like many other personality traits—is a continuous and normal distributed dimension (see supplementary information for the distribution of HSC in all the samples included in this paper), people may fall into different sensitivity categories. For example, Boyce and Ellis (2005) suggested that there are two kinds of children: *"Orchids"* who are more sensitive to their environment, requiring particularly supportive contexts in order to thrive, and *"Dandelions"* who are less sensitive and do well in most environments. The general understanding is that about 20-30% of the population fall into the highly sensitive *Orchid*-category and 70-80% into the less sensitive *Dandelion*-category (e.g., Aron et al., 2012; Boyce & Ellis, 2005). However, this proposition, although very popular, has not yet been tested empirically with HSC data. In the current study we applied *Latent Class Analysis*—a data-driven and hypothesis-free approach—to the combined samples of Studies 1 and 2 (children) as well as to the sample of Study 4 (adolescents) in order to investigate, for the first time, the existence of two or more sensitivity groups in children and adolescents. A recent similar analysis in multiple adult samples featuring the 27-item HSP scale, yielded a three- rather than a two-class solution with 31% of the sample population falling into a high sensitive group, about 40% into a medium sensitive group, and the remaining 29% into a low sensitive groups (Lionetti et al., submitted). In keeping with the *Orchid-Dandelion* metaphor, individuals belonging to the medium sensitive group have been described as *"Tulips",* who are less sensitive than Orchids but more sensitive than Dandelions.

In addition to testing for the existence of different sensitivity groups, Study 5 also aimed at exploring whether it would be possible to identify preliminary cut-off scores that could be used to determine the specific sensitivity group individual children and adolescents fall into based on their HSC scores.

Method

Participants. Study 5 made use of the samples used in studies 1, 2 and 4. The samples from Studies 1 and 2 were combined into a large child sample with $N = 592$.

For the adolescent sample we used the twin sample from Study 4 which included one randomly selected sibling from each twin pair (sample A, n = 1,470). In order to replicate findings in adolescents, we reran the same analysis on the other half of the sample made up of the non-selected twin pair sibling (sample B, n = 1,473).

Procedures and Measures. All participants provided data on the same 12-item HSC scale (see Study 1 for more details). These 12 items were the basis for the Latent Class Analysis.

Data Analysis. In order to test for the existence of different sensitivity groups we performed a series of Latent Class Analyses (LCA) on the HSC scale, testing models with 1 to 6 classes. The optimal number of classes was determined based on the following criteria: (a) Akaike's Information Criterion (AIC), (b) Bayesian Information Criterion (BIC), (c) Lo-Mendell-Rubin adjusted likelihood ratio test (LMR-A), and (d) Entropy. AIC and BIC are comparative indices, the lower the values the better the model. The LMR-A compares the fit of the specified class solution to a model with one fewer class. A significant p-value suggests that the specified model provides a better fit to the data than the more parsimonious model. Entropy refers to the confidence with which individuals can be clearly categorised into the different classes, with values approaching 1 indicative of a clear delineation of class membership (Nylund, Asparouhov, & Muthén, 2007). Once the optimal number of sensitivity classes was determined, based on the criteria outlined above as well as in consideration of theory and parsimony, we investigated the distribution and overlap between the different sensitivity classes in order to identify exploratory cut-off scores for children and adolescents. Sensitivity (i.e., probability of correctly identifying all individuals that belong to a particular group) and specificity (i.e., probability of correctly identifying those individuals that don’t belong to the particular group) for these cut-off scores were estimated by comparing agreement between LCA class membership and the categorisation based on the proposed cut-off scores. For children, the agreement between LCA class membership and cut-off categorisation was estimated within the same sample. For adolescents, the agreement was tested using two samples by applying cut-offs based on the sample A LCA results in sample B.

Latent Class Analysis was performed using Mplus version 7 (Muthén & Muthén, 1998-2015) and programme R (Pastore, 2016) was used for visual inspection of class distributions.

Results

Latent Class Analysis for Child Sample. Model fit indices are reported in Table 10. The one-class model had the highest AIC and BIC values (25727.97 and 25830.56, respectively). The 2-class model had the lowest entropy (.77), but was significantly better than the baseline model with one class according to LMR-A (p = .02). The three-class model yielded a significant LMR-A ($p < .001$), entropy increased to .85, and BIC and AIC values decreased substantially (24682.61 and 24896.35 respectively), suggesting that the three-class model fit the data significantly better than the two-class model. Models with four, five or six classes were explored but all rejected because none of them had a significantly better fit than the three-class model.

According to the best fitting three-class LCA model, 24.67% of children belong to a low sensitive group, 41.24% of children to a medium sensitive group, and 34.08% to a high sensitive group. Means and standard deviations of HSC and subscales for each of the three groups are reported in Table 11.

Latent Class Analysis with Adolescent Sample. Results of the different models are reported in Table 10. For sample A (same as in Study 4) the one-class model yielded the highest AIC and BIC values (67497.81 and 67157.04, respectively). The two-class model had a better fit to data when compared to the one-class model, but it was the three-class model that fitted data best, presenting lower AIC and BIC scores compared to the two-class model. LMR-A results also confirmed the three-class solution as significantly better than the two-class model ($p < .001$) and entropy was satisfactory with .80. Models with four, five and six classes were also explored. LMR-A results suggested an improvement in models with four and five classes while entropy remained constant. The four-class solution identified an additional class with 13.2% of the sample characterised with particularly low HSC scores while the three groups identified in the three-class model (low, medium, high) remained largely unchanged. The five-class solution identified one additional medium class, between medium and high groups, on top of the four-class model with 11.9% of the sample. However, the three initial classes (low, medium, high) remained. Considering these findings in light of the results of the child sample and in combination with the parsimony principle in selecting the best number of classes (Masyn, 2013), the three-class solution was identified as the best candidate.

In order to explore the robustness of the three-class solution further, we repeated the LCA in the other half of the TEDS sample (sample B with n = 1,473). Again, the two-class model was significantly better than the one-class baseline model. The three-class model had a significantly better fit that the two-class model, manifested in lower AIC and BIC scores compared to the two-class model. In contrast to findings with sample A, data from sample B suggested that models with four, five and six classes did not fit the data better than the three-class model better (see Table 10).

The three-class solution for both adolescent samples was similar to the one that emerged for the child sample: 34.90 - 34.98 % of adolescents belonged to a low sensitive group, 41.04 - 46.90 % to a medium sensitive group, and 21.20 - 23.97% to a highly sensitive group. For means and standard deviations of HSC and subscales for each of the three classes see Table 11.

Exploratory Cut-Off Scores for Child Sensitivity Groups. Intersection points between the distributions of HSC scores for the three sensitivity groups are presented in Figure 3. The overlap of distributions suggest 4.17 and 4.75 as the intersection points for the low and high sensitivity group, respectively, resulting in the following exploratory cut-off scores: ≤ 4.17 for the low-sensitive HSC group, > 4.17 and ≤ 4.75 for the medium-sensitive, and > 4.75 for the high-sensitive group. Applying these cut-off scores to the sample and comparing the resulting categorisation with the LCA classification, we obtained a sensitivity of .51 (i.e., 51% of children were correctly categorised as members of the specific sensitivity group) and specificity of .78 (i.e., 78% of children were correctly identified as not being part of the specific sensitivity group) for the low-sensitive versus medium-sensitive group and a sensitivity of .77 and specificity of .72 for the medium-sensitive versus high-sensitive groups.

Exploratory Cut-Off Scores for Adolescent Sensitivity Groups. Given that the adolescent sample was based on twin pairs which were randomly divided into two subsamples, we were able to determine cut-off criteria in subsample A and then apply them to subsample B. Intersection points between the three groups in sample A were 3.64 between low and medium sensitive groups and 4.65 between medium and high sensitive groups (see Figure 4), resulting in the following cut-off scores: ≤ 3.64 for the low-sensitive HSC group, > 3.64 and ≤ 4.65 for the medium-sensitive, and > 4.65 for the high-sensitive group. Applied to sample B, satisfactory sensitivity and specificity values emerged with .88 and .92, respectively, for the classification between low-sensitive and medium-sensitive individuals, and .69 and .86 for medium-sensitive versus high-sensitive ones.

Discussion

Consistent with theory, the Latent Class Analyses confirmed the existence of a highly sensitive group making up 20-35% of the population. However, the best fitting models suggested three rather than two distinct sensitivity groups, a new finding which none of the current theories on Environmental Sensitivity predicted. Besides the highly sensitive group (20-35%), there was also a medium sensitivity group (approx. 41-47%) and a low sensitive group (approx. 25-35%). The three group solution emerged consistently across all three samples. Importantly, these LCA results are very similar to the three-class solution that emerged recently when the same analysis was conducted in adult samples with the 27-item HSP scale (Lionetti et al., submitted), suggesting that there are not only *Orchid-* and *Dandelion-* (Boyce & Ellis, 2005) but also *Tulip*-children. The exploratory cut-off scores for the categorisation of individuals into the three different sensitivity groups were characterised by moderate to weak sensitivity and specificity, performing better in adolescents than children. While the cut-off scores between medium and highly sensitive individuals were similar for children and adolescents, the cut-off scores between medium and low sensitive groups differed as a function of age with a higher cut-off score found in children. Some of this difference might be explained by the observation that the overlap between medium and low sensitive groups was substantially higher in the child compared to the adolescent sample. This suggests that it may be more difficult to differentiate between low and medium sensitive children at age 11 compared to adolescents at 17. However, given that measurement invariance of the HSC scale has not been tested and demonstrated yet, this interpretation has to be considered preliminary at this stage. Taking results from adult samples into account (Lionetti et al., submitted), we propose a general average cut-off of 3.8 between the low and medium sensitivity groups and a general average cut-off of 4.7 between the medium and high sensitivity groups. However, in the absence of validation studies that these three groups capture qualitative differences, these exploratory cut-off scores should only be used as rough indicators of an individual's sensitivity group membership when considering their position on the continuous HSC/HSP scales which range from 1 to 7. Given that HSC mean scores may vary between cultures, which is yet to be investigated, it may be more helpful to divide a sample into bottom 30% (i.e., low sensitive group) and top 30% (i.e., highly sensitive group) with the remaining 40% making up the medium sensitive individuals, in order to create the three identified sensitivity groups. Once a sample has been divided into the three groups by applying the proposed 30/40/30 split approach, it is then also possible to determine the specific cut-off scores between these groups. Importantly, the total score of the HSC scale appears to be normally distributed which suggests that sensitivity exists on a continuum. Hence, it may be most appropriate to consider sensitivity as a continuous dimension along which people can be categorised into three different groups. Further research should aim at investigating this *continuous-versus-categorical* nature of sensitivity and test whether and how the three detected groups differ qualitatively from each other. In addition, future work should validate whether group membership based on the proposed preliminary cut-off scores predicts behavioural differences in sensitivity to environmental influences.

General Discussion

A growing number of empirical studies provide evidence for the theoretical proposition that children differ in their *Environmental Sensitivity,* with some being more affected by the quality of their environment than others (Belsky & Pluess, 2009; Boyce & Ellis, 2005; Ellis et al., 2011; Pluess, 2015). The first objective of the current study was to investigate the psychometric properties of a new self-report measure of *Environmental Sensitivity* for children and adolescents—the *Highly Sensitive Child* (HSC) scale. The second aim was to test associations between the HSC scale and well-established temperament and personality traits. The third objective aimed at investigating whether children and adolescents can be categorised into distinct groups that differ in their Environmental Sensitivity.

Psychometric Properties and Construct Validity of the HSC Scale

Findings of the current study suggest that it is possible to assess Environmental Sensitivity with a 12-item questionnaire in children as young as 8 years. Consistent with a recent confirmatory factor analysis of the adult HSP scale (Lionetti et al., submitted), the HSC scale seems to fit a bi-factor model which includes the three established factors but also a general sensitivity factor across all 12 items. Hence, although the scale captures different components of Environmental Sensitivity, it does also reflect a general trait of Environmental Sensitivity.

The observed associations with temperament and personality traits provide more insight into the three sensitivity components of the measure. Whereas Ease of Excitation and Low Sensory Thresholds seem to be more strongly associated with traits that reflect sensitivity to negative environmental factors (e.g., BIS, Negative Emotionality, Negative Affect, and Neuroticism), Aesthetic Sensitivity correlates with measures that may confer sensitivity to more positive experiences (e.g., BAS, Positive Emotionality, Extraversion, Openness, Conscientiousness). The co-occurrence of sensitivity to negative and positive environmental influences may also explain the finding that the total scale correlates with both BIS and BAS as well as both negative and positive emotionality. This interpretation fits well with the literature on the different theoretical models of Environmental Sensitivity (Pluess, 2015). While *Diathesis-Stress* (Monroe & Simons, 1991; Zuckerman, 1999) describes primarily individual differences in vulnerability to adverse exposures, *Vantage Sensitivity* (Pluess, 2017; Pluess & Belsky, 2013) refers to inter-individual variability in the propensity to benefit from positive experiences. *Differential Susceptibility* (Belsky, 1997a, 2005; Belsky, Bakermans-Kranenburg, et al., 2007; Belsky & Pluess, 2009, 2013; Ellis et al., 2011), on the other hand, described the combination of both *Diathesis-Stress* and *Vantage Sensitivity* with susceptible individuals being more affected by both negative as well as positive environmental influences as a function of general sensitivity factors (e.g., genes, physiological reactivity, personality traits). Applied to the HSC measure, the total score of the scale may capture general sensitivity as described in the *Differential Susceptibility* model combining both *Diathesis-Stress* (i.e., sensitivity to adversity as measured with Ease of Excitation and Low Sensory Thresholds subscales) and *Vantage Sensitivity* (i.e., sensitivity to positive experiences as reflected in the Aesthetic Sensitivity subscale). A recent twin study provides additional support for categorising the three HSC components into sensitivity to negative (Ease of Excitation /Low Sensory Thresholds) and positive (Aesthetic Sensitivity) environmental influences based on the finding that Ease of Excitation and Low Sensory Thresholds are genetically more similar to each other than to Aesthetic Sensitivity (Assary, Zavos, Krapohl, Keers, & Pluess, submitted). However, although this interpretation may seem reasonable in light of the discussed theoretical models and observed empirical findings, it has to be acknowledged that the adult HSP scale was originally developed to capture a unidimensional construct of *Sensory-Processing Sensitivity* rather that different sensitivity components (Aron &

Aron, 1997). The three factors— Ease of Excitation , Low Sensory Thresholds, and Aesthetic Sensitivity —emerged in subsequent studies conducted by other research groups (Booth et al., 2015; Liss, Mailloux, & Erchull, 2008; Smolewska et al., 2006; Sobocko & Zelenski, 2015) and do not represent a-priori designed subscales. Hence, it is important to be cautious when interpreting the meaning of the typically observed three-factor structure (and in particular when trying to use the subscales separately).

Existence of Sensitivity Groups

Theoretical reasoning (Aron & Aron, 1997; Aron et al., 2012; Belsky, 1997b) and accompanying empirical research (Pluess, 2017; Pluess & Belsky, 2015; Wolf et al., 2008) suggest that people fall into different sensitivity groups with about 10-35% of the population considered to be highly sensitive. Given that the majority of existing research on Environmental Sensitivity appears to focus on this more sensitive group it is not surprising that much less is known about the less sensitive 65-90%. Hence, the finding of the current study that there appear to be three rather than two distinct categories of Environmental Sensitivity is of great importance. Although we found that a highly sensitive group made up 20-35% of the sample, our analyses suggested that the less sensitive individuals can be categorised into two distinct groups rather than one: a medium sensitive group representing approx. 41-47% of the population and a low sensitive group (approx. 25-35%). Importantly, this three group solution emerged consistently across multiple and independent samples in childhood, adolescence, as well as adulthood (Lionetti et al., submitted). These findings provide empirical evidence for the proposition that most people are sensitive to their environment but to different degrees (Pluess, 2015). While we know a fair bit about the highly sensitive group (Aron & Aron, 1997; Aron et al., 2012) our understanding of the medium and particularly the low sensitive group is very limited. It is conceivable that the medium sensitive group is simply somewhat less sensitive than the highly sensitive group. The low sensitive group, on the other hand, may capture those that are particularly resilient to adverse conditions but also less able to benefit from positive exposures (i.e., showing Vantage Resistance; Pluess & Belsky, 2013).The existence of three groups is certainly reconcilable with classic findings in research on infant temperament. For example, Kagan (1997) found that about 20% of 4 months old infants were highly reactive (i.e., behavioural inhibition) to environmental stimulation whereas about 40% showed low reactivity (i.e., behavioural disinhibition) with the remaining 40% not clearly fitting either group. Our LCA findings suggest that the undefined 40% may represent the medium sensitive individuals (i.e., Tulips), which are distinct from the 20% highly sensitive (i.e., high reactive or Orchids) and the 40% low sensitive children (i.e., low reactive or Dandelions). Future research should replicate the three group structure and investigate characteristics associated with these three sensitivity groups in more detail (e.g., developmental history, personality and temperament differences, genetic differences etc.). A further point to be investigated is whether the proportions of the three groups change over time. The current findings suggest that in middle childhood more children fall into the high sensitive and less children into the low sensitive group compared to adolescence. This may indicate that younger children are more sensitive to their environment than adolescents or adults (Lionetti et al., submitted). However, longitudinal research is needed to investigate the development and stability of sensitivity over the life course in order to reject the alternative hypothesis that these differences are simply due to the scale performing differently at the different ages.

Cut-Off Scores for Sensitivity Groups

According to the current study, the detected cut-off scores should be used with caution when trying to categorise individual children and adolescents into the three detected sensitivity groups. Although the cut-off scores were comparable between children and adolescents, they seemed to work slightly better for adolescents than for children and were slightly better at differentiating the highly sensitive individuals from medium sensitive ones than distinguishing the low sensitive from the medium sensitive children. One reason for this difference may be that the scale was developed to measure the high end rather than the low end of the sensitivity spectrum. Additional studies are required to test and confirm the validity and usefulness of the exploratory cut-off scores. The proposed general cut-off scores (i.e., 3.8 and 4.7), based on all available results from child, adolescent and adult samples, should only be used as rough indicators of sensitivity group membership, and only in addition to considering the continuous mean score. As an alternative approach we propose to divide a sample into top and bottom 30% (i.e., high and low sensitivity, respectively) with the remaining 40% making up the medium sensitivity group.

Empirical Evidence for the Moderating Effects of the HSC Scale

Although the HSC scale appears to be a promising and psychometrically sound phenotypic marker of environmental sensitivity, it remains to be determined whether it does indeed predict individual differences in response to environmental influences as theory suggests. Recently, several findings emerged providing first empirical evidence for the validity of the HSC scale as a measure of environmental sensitivity. For example, HSC was found to predict treatment response related to a universal school-based resilience-promoting intervention (Pluess, Boniwell, Hefferon, & Tunariu, in press) in a sample of 166 11-year old girls in London, United Kingdom, with those scoring in the top 25% of HSC benefitting from the intervention regarding the reduction of depression symptoms while girls in the bottom 25% of HSC completely failed to do so (Pluess & Boniwell, 2015). Similarly, HSC moderated the effects of a school-based anti-bullying intervention in a large randomised controlled trial involving 2,042 children from 13 schools in Italy (Nocentini, Menesini, & Pluess, submitted). Although the intervention was effective across the whole sample, treatment effects were moderated by HSC and gender, with boys scoring high on HSC benefitting from the effects of the intervention regarding the reduction of self-reported victimization and internalizing symptoms. In contrast, boys scoring low on HSC did not respond to the intervention at all. In girls, HSC did not moderate treatment effects which may be explained by the fact that boys were generally more likely to be victimized than girls. Environmental sensitivity measured with the HSC scale has also been found to play a significant role among juvenile offenders in the USA as reported by Donley, Fine, Simmons, Pluess, and Cauffman (submitted). The longitudinal study on reoffending behaviours featured a sample of 1,216 male adolescents aged 13-17 years who have been arrested for low-level crimes. The juvenile offenders completed the HSC scale and were interviewed repeatedly across 1.5 years on the quality of their home environment and reoffending behaviours. Adolescents living in adverse home environments were on average more likely to reoffend than those living in more supportive home environments, but HSC significantly moderated the effect of the home environment on the risk for reoffending. Consistent with a hypothesis of Environmental Sensitivity, more sensitive individuals benefited more from positive home environments compared to the less sensitive adolescents. Focusing on natural variation in parenting quality, Slagt, Dubas, van Aken, Ellis, and Deković (submitted) investigated whether parent-rated HSC moderated the effects of both negative and positive parent-reported parenting practices on the development of teacher-rated externalizing and prosocial behaviour in a longitudinal study involving 264 4-7 year old Dutch children and their mothers. The 12-item HSC scale was adapted for the use as parent-rated measure of children's sensitivity. Several significant interaction effects emerged. Most notably, HSC moderated effects of changes in negative and positive parenting between assessment points in the prediction of teacher reported externalizing behaviour problems: Children rated high on the HSC scale had fewer problems if positive parenting increased and negative parenting decreased, but also more problems when positive parenting decreased and negative parenting increased. Children with low scores on HSC, on the other hand, were not affected by changes in parenting quality.

The findings from these four studies not only validate the HSC scale as a measure of environmental sensitivity to both negative and positive environmental influences but also emphasise the importance of considering individual differences in Environmental Sensitivity in different fields, from developmental to clinical psychology (Pluess, 2015).

Strengths and Limitations

The five original studies reported in this paper are characterised by significant strengths, including large samples, replication of results and the application of sophisticated statistical procedures, but the findings should be considered in light of methodological limitations. Most importantly, all data are based on self-report. Future research should aim at identifying more objective markers of child Environmental Sensitivity. Furthermore, all data were provided by children and adolescents residing in the United Kingdom. Although some of the included samples were highly diverse, future studies should test whether similar findings emerge in other populations. Furthermore, although the HSC scale has been designed to reflect the same factor structure as the adult HSP scale, measurement invariance between child and adult samples has not been established yet.

Conclusion

Environmental Sensitivity is an important individual characteristic that is related to, but largely distinct from, other common temperament and personality traits. The current study suggests that it is possible to measure Environmental Sensitivity reliably in children and adolescents with the *Highly Sensitive Child* scale, a 12-item self-report measure with good psychometric properties. Furthermore, recent studies featuring samples from four different countries confirm the validity of the HSC scale by providing empirical evidence that HSC reflects individual differences in response to a wide range of environmental influences (Donley et al., submitted; Nocentini et al., submitted; Pluess & Boniwell, 2015; Slagt et al., submitted).

Future research should continue to investigate the hypothesised moderating function of Environmental Sensitivity regarding the effects of various environmental factors (e.g., parenting quality, education etc.) and psychological intervention. Of particular interest are differences between the three sensitivity groups as well as the development over the life course. In order to be able to do so, it will be necessary to develop measures of Environmental Sensitivity for younger children, including infants. Future work should also aim at identifying the specific psychological and biological mechanisms underlying individual differences in Environmental Sensitivity, including neuroimaging studies (for fMRI studies on the adult HSP scale, see Acevedo et al., 2014; Jagiellowicz et al., 2011) as well as quantitative behavioural genetics (Assary et al., submitted) and molecular genetics studies (C. Chen et al., 2011; Keers et al., 2016). Finally, it is important to investigate differences in Environmental Sensitivity across different cultures.

In conclusion, children and adolescents differ substantially in their sensitivity to environmental influences. Such differences in Environmental Sensitivity can be measured in children and adolescents with a short and simple yet psychometrically robust self-report measure—the *Highly Sensitive Child* (HSC) scale. Most children and adolescents appear to fall into one of three sensitivity groups: About 30% of children are characterised by high sensitivity, 40% by medium sensitivity and the remaining 30% by low sensitivity.

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Table 1

HSC Rotated Component Matrix (Study 1)

Items		Factor		
		1 (EOE)	2 (AES)	3 (LST)
1	I find it unpleasant to have a lot going on at once	**.53**	.07	.15
2	Some music can make me really happy	.04	**.79**	-.02
3	I love nice tastes	.18	**.83**	.00
4	Loud noises make me feel uncomfortable	.35	.02	**.67**
5	I am annoyed when people try to get me to do too many things at once	**.71**	.26	-.02
6	I notice it when small things have changed in my environment	.29	**.44**	.03
7	I get nervous when I have to do a lot in little time	**.66**	.26	.23
8	I love nice smells	.13	**.79**	.24
9	I don't like watching TV programs that have a lot of violence in them	.05	.04	**.66**
10	I don't like loud noises	.10	.06	**.86**
11	I don't like it when things change in my life	**.48**	.22	.45
12	When someone observes me, I get nervous. This makes me perform worse than normal	**.70**	.00	.14

Table 2

Means and Standard Deviations of all Measures (Study 1, 2, 3 and 4)

	Study 1	Study 2	Study 3		Study 4
			Session 1	Session 2	
HSC-38	4.15 (.90)	-	-	-	-
HSC	4.33 (.98)	4.68 (.93)	4.01 (.86)	4.04 (.84)	3.98 (.96)
HSC-EOE	4.13 (1.18)	4.59 (1.21)	3.70 (1.26)	3.67 (1.14)	3.81 (1.37)
HSC-AES	5.15 (1.23)	5.56 (1.08)	5.15 (1.02)	5.23 (0.91)	5.16 (1.00)
HSC-LST	3.58 (1.53)	3.67 (1.68)	3.01 (1.32)	3.10 (1.29)	2.70 (1.38)
BIS	18.88 (4.04)	19.66 (3.58)	-	-	-
BAS	37.36 (7.51)	39.11 (6.68)	-	-	-
EC	3.14 (.60)	3.30 (.57)	-	-	-
NE	3.00 (.58)	3.06 (.62)	-	-	-
PE	3.09 (.54)	3.26 (.52)	-	-	-
PA	44.54 (9.95)	-	-	-	-
NA	27.70 (10.7)	-	-	-	-
Neuroticism	-	-	-	-	15.97 (4.37)
Extraversion	-	-	-	-	21.75 (3.92)
Openness	-	-	-	-	21.70 (3.66)
Agreeableness	-	-	-	-	21.94 (3.52)
Conscientiousness	-	-	-	-	22.41 (3.65)

Note. HSC-38 = Mean of 38 Highly Sensitive Child Items; HSC = HSC-EOE = Ease of Excitation; HSC-AES = Aesthetic Sensitivity; HSC-LST = Low Sensitivity Threshold; BIS = Behavioural Inhibition System; BAS = Behavioural Activation System; EC = Effortful Control; NE = Negative Emotionality; PE = Positive Emotionality; PA = Positive Affect; NA = Negative Affect.

Table 3

Bivariate Correlations (Study 1)

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	HSC-38	—												
2	HSC	**.93****	—											
3	HSC-EOE	**.80****	**.86****	—										
4	HSC-AES	**.68****	**.71****	**.43****	—									
5	HSC-LST	**.63****	**.69****	**.44****	**.18****	—								
6	BAS	**.42****	**.41****	**.31****	**.50****	.11	—							
7	BIS	**.55****	**.55****	**.49****	**.38****	**.36****	**.62****	—						
8	PE	**.29****	**.27****	**.17****	**.37****	.08	**.40****	**.32****	—					
9	NE	**.38****	**.37****	**.36****	**.19****	**.26****	**.21****	**.40****	**.61****	—				
10	EC	**.29****	**.27****	**.18****	**.29****	**.15***	**.39****	**.33****	**.82****	.71**	—			
11	PA	**.16****	**.14***	-.01	**.41****	-.06	**.38****	**.14***	**.34****	.08	**.33****	—		
12	NA	**.15***	.09	**.16****	-.09	**.13***	-.08	.10	.04	**.19****	-.02	**-.38****	—	
13	Age	-.10	-.10	-.04	**-.17****	-.02	**-.18****	**-.19****	**-.18****	**-.12***	**-.21****	**-.15****	**.30****	—
14	Gender	**.18****	**.15***	.10	.10	**.15***	.06	**.19****	.09	**.13***	.10	-.08	.08	-.01

Note. HSC-38 = Mean of 38 Highly Sensitive Child Items; HSC = Highly Sensitive Child Scale; HSC-EOE = Ease of Excitation; HSC-AES = Aesthetic Sensitivity; HSC-LST = Low Sensitivity Threshold; BIS = Behavioural Inhibition System; BAS = Behavioural Activation System; EC = Effortful Control; NE = Negative Emotionality; PE = Positive Emotionality; PA = Positive Affect; NA = Negative Affect; Gender: 1=male, 2=female; * p <.05; ** p <.01.

Table 4

Multivariate Regression (Study 1)

	HSC			HSC-EOE			HSC-AES			HSC-LST		
	β	z	*p*	*β*	z	*p*	*β*	z	*p*	*β*	z	*p*
BAS	.13	1.73	.08	.14	1.72	.09	**.26**	**3.56**	**<.01**	-.11	-1.29	.20
BIS	**.38**	**5.36**	**<.01**	**.33**	**4.31**	**<.01**	**.16**	**2.37**	**.02**	**.37**	**4.39**	**<.01**
PE	.01	.09	.93	-.06	-.57	.57	**.26**	**3.29**	**<.01**	-.187	-1.38	.17
NE	**.24**	**3.24**	**<.01**	**.34**	**4.19**	**<.01**	.01	.19	.85	.16	1.57	.12
EC	-.12	-1.20	.23	-.18	-1.76	.08	-.18	-1.89	.06	.12	.89	.38
PA	.10	1.53	.13	-.02	-.22	.83	**.28**	**3.86**	**<.01**	-.01	-.22	.83
NA	.09	1.64	.10	.10	1.52	.13	.04	.70	.48	.07	1.21	.23

Note. HSC = Highly Sensitive Child Scale; HSC-EOE = Ease of Excitation; HSC-AES = Aesthetic Sensitivity; HSC-LST = Low Sensitivity Threshold; BIS = Behavioural Inhibition System; BAS = Behavioural Activation System; EC = Effortful Control; NE = Negative Emotionality; PE = Positive Emotionality. Two models were run, the first including the HSC total score as the only dependent variable and the second model with EOE, AES and LST simultaneously included as dependent variables.

Table 5

Bivariate Correlations (Study 2)

		1	2	3	4	5	6	7	8	9	10
1	HSC	—									
2	HSC-EOE	**.83****	—								
3	HSC-AES	**.61****	**.32****	—							
4	HSC-LST	**.69****	**.37****	.11	—						
5	BAS	**.25****	**.23****	**.35****	-.01	—					
6	BIS	**.32****	**.29****	**.24****	**.15***	**.66****	—				
7	PE	**.41****	**.28****	**.50****	**.15***	**.59****	**.44****	—			
8	NE	**.50****	**.49****	**.25****	**.31****	**.37****	**.50****	**.39****	—		
9	EC	**.48****	**.40****	**.43****	**.23****	**.61****	**.55***	**.67****	**.59****	—	
10	Age	.09	.05	.10	.07	.03	.02	-.08	-.12	-.06	—
11	Gender	.12	.06	.02	**.19****	.10	.12	.10	**.22****	.05	.02

Note. HSC = Highly Sensitive Child Scale; HSC-EOE = Ease of Excitation; HSC-AES = Aesthetic Sensitivity; HSC-LST = Low Sensitivity Threshold; BIS = Behavioural Inhibition System; BAS = Behavioural Activation System; EC = Effortful Control; NE = Negative Emotionality; PE = Positive Emotionality; Gender: 1=male, 2=female; * p <.05; ** p <.01.

Table 6

Multivariate Regression (Study 2)

	HSC			HSC-EOE			HSC-AES			HSC-LST		
	B	z	*p*	*β*	Z	*p*	*β*	z	*p*	*β*	Z	*p*
BAS	-.16	-1.94	.05	-.06	-.63	.53	.07	.84	.40	**-.34**	**-3.71**	**<.01**
BIS	.04	.48	.63	.02	.28	.78	-.07	-1.50	.29	.12	1.31	.19
PE	**.24**	**2.69**	**.01**	.05	.51	.61	**.40**	**5.24**	**<.01**	.13	1.28	.20
NE	**.30**	**4.08**	**<.01**	**.39**	**4.37**	**<.01**	-.03	-.41	.69	**.23**	**2.57**	**.01**
EC	.19	.08	.08	.14	1.21	.23	.15	1.42	.16	.14	1.15	.25

Note. HSC = Highly Sensitive Child Scale; HSC-EOE = Ease of Excitation; HSC-AES = Aesthetic Sensitivity; HSC-LST = Low Sensitivity Threshold; BIS = Behavioural Inhibition System; BAS = Behavioural Activation System; EC = Effortful Control. Two models were run, the first including the HSC total score as the only dependent variable and the second model with EOE, AES and LST simultaneously included as dependent variables.

Table 7

Test-Re-Test Reliability of HSC across 15 Days (Study 3)

	r
HSC	.68**
HSC-EOE	.66**
HSC-AES	.57**
HSC-LST	.78**

Note. HSC = Highly Sensitive Child Scale; HSC-EOE = Ease of Excitation; HSC-AES= Aesthetic Sensitivity; HSC-LST= Low Sensitivity Threshold; ** p <.01.

Table 8

Bivariate Correlations (Study 4)

	1	2	3	4	5	6	7	8	9	10
1 HSC	—									
2 HSC-EOE	**.89****	—								
3 HSC-AES	**.58****	**.29****	—							
4 HSC-LST	**.74****	**.54****	**.18****	—						
5 Neuroticism	**.31****	**.38****	-.00	**.22****	—					
6 Extraversion	**-.18****	**-.27****	**.20****	**-.22****	**-.36****	—				
7 Openness	**.18****	.05	**.25****	**.17****	-.05	**.27****	—			
8 Agreeableness	.03	-.03	.04	.08	**-.21****	**.19****	**.25****	—		
9 Conscientiousness	-.01	**-.13****	**.16****	.03	**-.19***	**.29****	**.09***	**.26****	—	
10 Age	.02	**.01**	**.07****	-.01	**-.01***	.05	.04	.04	-.02	—
11 Gender	**-.18****	**-.15****	**-.07****	**-.18****	**-.22****	.04	-.08	**-.12****	-.08	-.03

Note. HSC = Highly Sensitive Child Scale; HSC-EOE = Ease of Excitation; HSC-AES = Aesthetic Sensitivity; HSC-LST = Low Sensitivity Threshold; Gender: 1=male, 2=female; * p <.05; ** p <.01.

Table 9

Multivariate Regression (Study 4)

	HSC			HSC-EOE			HSC-AES			HSC-LST		
	β	z	*p*	β	Z	*p*	β	z	*p*	β	Z	*p*
Neuroticism	**.28**	**6.39**	**<.01**	**.31**	**6.83**	**<.01**	.07	1.44	.15	**.18**	**3.88**	**<.01**
Extraversion	**-.15**	**-3.33**	**<.01**	**-.17**	**-3.86**	**<.01**	**.14**	**2.96**	**<.01**	**-.25**	**-5.29**	**<.01**
Openness	**.19**	**4.31**	**<.01**	.07	1.45	.15	**.22**	**4.62**	**<.01**	**.21**	**5.21**	**<.01**
Agreeableness	.04	.87	.39	.05	1.11	.27	-.06	-1.26	.21	.07	1.70	.09
Conscientiousness	.04	1.03	.30	-.06	-1.34	.18	**.12**	**2.77**	**<.01**	.10	2.33	.02

Note. HSC = Highly Sensitive Child Scale; HSC-EOE = Ease of Excitation; HSC-AES = Aesthetic Sensitivity; HSC-LST = Low Sensitivity Threshold. Two models were run, the first including the HSC total score as the only dependent variable and the second model with EOE, AES, and LST simultaneously included as dependent variables.

Table 10

Latent Class Analysis (Study 5)

Model	AIC	BIC	LMR-A (*p*)	Entropy
Children				
1 class	25727.97	25830.56		
2 classes	25086.17	25244.34	659.71 (.016)*	.77
3 classes	**24682.61**	**24896.35**	**410. 49 (< .001)****	**.85**
4 classes	24535.97	24805.29	170.55 (.159)	.82
5 classes	24344.16	24669.04	215.18 (.196)	.86
6 classes	24259.14	2463959	109.67 (325)	.84
Adolescents (subsample A)				
1 class	67497.81	67624.84		
2 classes	64639.20	64835.04	2854.50 (< .001)**	.82
3 classes	**63703.86**	**63968.51**	**951.30 (< .001)****	**.80**
4 classes	63141.62	63475.08	582.10 (.003)**	.80
5 classes	62718.95	63121.22	443.98 (.002)**	.82
6 classes	62465.54	62936.62	276.49 (.314)	.80
Adolescents (subsample B)				
1 class	67030.28	67157.36		
2 classes	64286.91	64482.82	2740.47 (<.001)**	.81
3 classes	**63352.08**	**63616.83**	**950.81 (<.001)****	**.81**
4 classes	62873.54	63207.13	499.27 (.07)	.82
5 classes	62542.41	62944.83	353.40 (.06)	.81
6 classes	62353.56	62824.82	212.61 (0.56)	.82

Note. Subsample A refers to data used in study 4; Subsample B refers to the other half of the TEDS sample described in study 4; * p <.05; ** p <.01.

Table 11

Descriptives for the Three Latent Classes (Study 5)

Groups	1	2	3
		Children	
Frequency	24.67%	41.24%	34.08%
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
HSC	3.68 (0.80)	4.24 (0.67)	5.39 (0.63)
HSC-EOE	3.68 (1.02)	4.06 (1.13)	5.17 (0.97)
HSC-AES	3.87(0.84)	5.74 (0.85)	5.91 (0.78)
HSC-LST	3.42(1.29)	2.54 (1.12)	5.07(1.14)
		Adolescents (subsample A)	
Frequency	34.98%	41.04%	23.97%
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
HSC	3.00 (0.51)	4.22 (0.45)	5.06 (0.63)
HSC-EOE	2.38 (0.72)	4.33 (0.79)	5.07 (0.97)
HSC-AES	4.70 (1.12)	5.41 (0.77)	5.40 (0.85)
HSC-LST	1.76 (0.77)	2.65 (0.88)	4.56 (0.92)
		Adolescents (subsample B)	
Frequency	34.90%	46.90%	21.20%
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
HSC	3.02 (0.50)	4.20 (0.46)	5.08 (0.60)
HSC-EOE	2.36 (0.69)	4.28 (0.76)	5.13 (0.96)
HSC-AES	4.82 (1.06)	5.32 (0.81)	5.48 (0.91)
HSC-LST	1.70 (0.72)	2.55 (0.90)	4.46 (0.91)

Note. Subsample A refers to data used in study 4; Subsample B refers to the other half of the TEDS sample described in study 4.

Figure Captions

Figure 1. Illustration of the different models describing individual differences in Environmental Sensitivity: *Diathesis-Stress* (A) describes variability in response to adverse exposures, and *Vantage Sensitivity* (B) variability in response to supportive exposures, whereas the remaining three models *Sensory Processing Sensitivity* (C), *Differential Susceptibility* (D), and *Biological Sensitivity to Context* (E) describe individual differences in response to both negative and positive experiences. Consequently, models C, D, and E, reflect the combination of models A and B.

Figure 2. Graphical illustration of A) 3-factor model: EOE, LST and AES factors; B) bi-factor model: EOE, LST and AES factors plus a HSC general factor.

Figure 3. The distributions of the HSC mean score for each of three sensitivity groups in the child sample with cut-off scores for the low, medium, and high sensitivity groups.

Figure 4. The distributions of the HSC mean score for each of three sensitivity groups in the adolescent subsample A with cut-off scores for the low, medium, and high sensitivity groups.

Figure 1

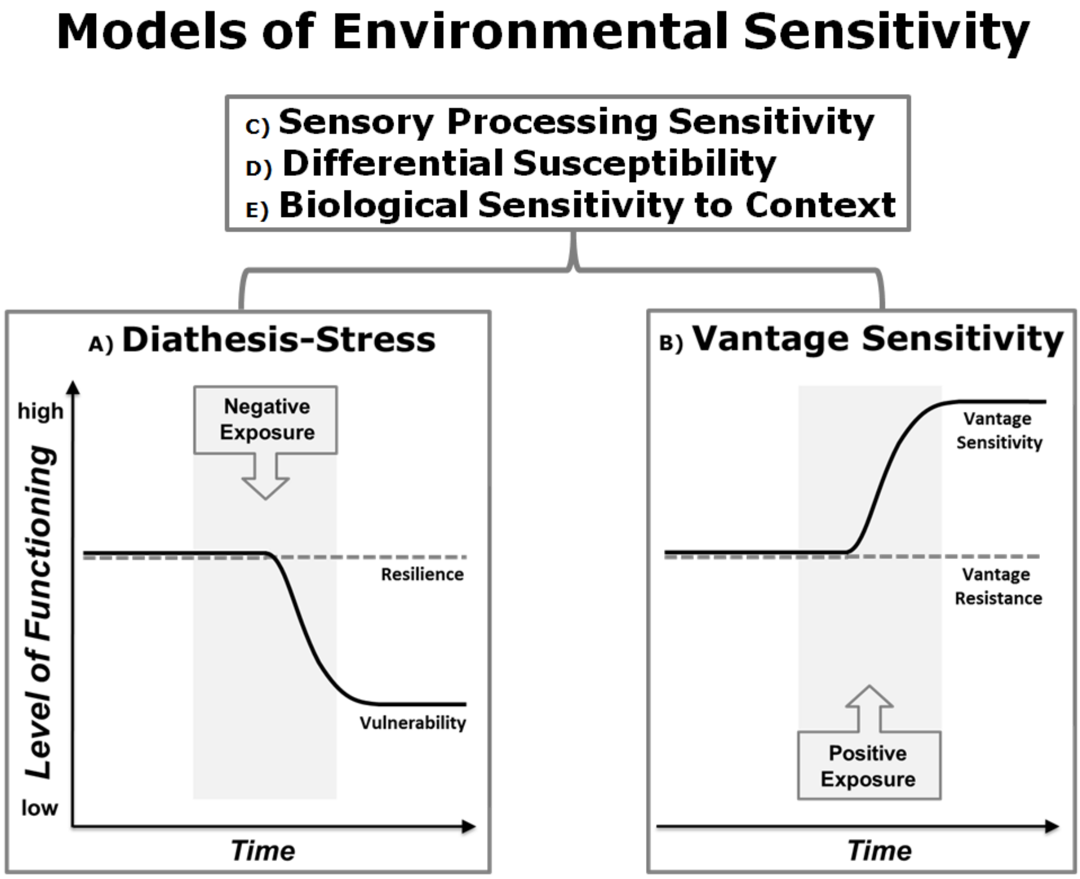
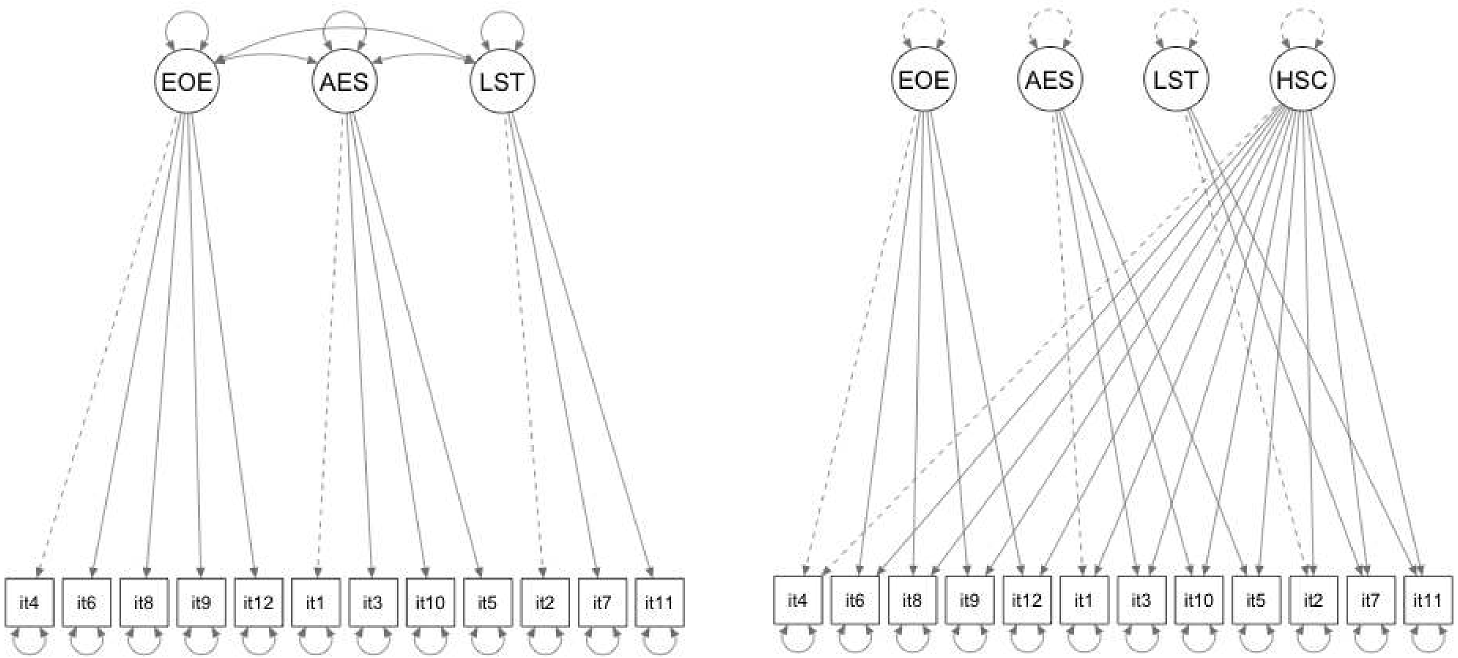

Models of Environmental Sensitivity
C) Sensory Processing Sensitivity
D) Differential Susceptibility
E) Biological Sensitivity to Context
A) Diathesis-Stress
high
Level of Functioning
low
Negative Exposure
Resilience
Vulnerability
Time
B) Vantage Sensitivity
Vantage Sensitivity
Vantage Resistance
Positive Exposure
Time

Figure 2

A) B)


EOE
AES
LST
it4
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it10
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it11
EOE
AES
LST
HSC
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it10
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it2
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Figure 3

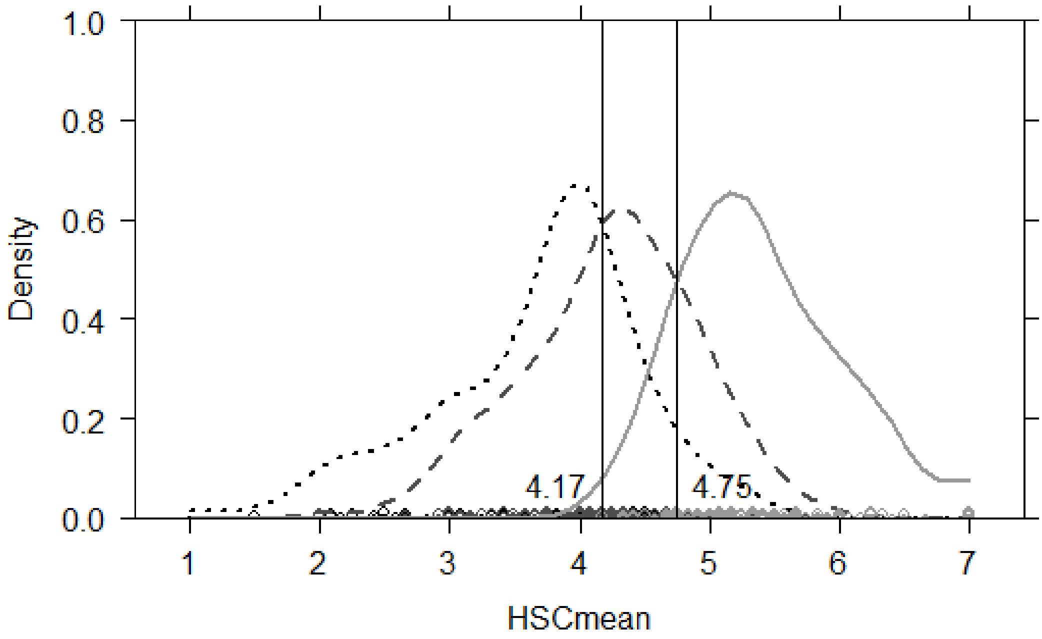

Figure 4