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Psychometric Properties of the Highly Sensitive Child Scale Across Developmental Stage, Gender, and Country

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Abstract

Adolescents differ in their degree of *Environmental Sensitivity*, that is, the ability to perceive and process information about their environment. The present study aimed to investigate the psychometric properties of the Highly Sensitive Child scale (HSC), a self-report measure of *Environmental Sensitivity*, in two Belgian and UK samples with a total of 3056 adolescents. First, the factor structure, internal consistency, dimensionality, and construct validity of the HSC scale were examined. Second, measurement invariance of the HSC scale across developmental stage, gender, and country was tested. Results supported a bifactor model with a general sensitivity factor and three group factors: Ease of Excitation (EOE), Low Sensory Threshold (LST), and Aesthetic Sensitivity (AES). Cronbach's alpha and McDonalds's (hierarchical) omega indicated that the HSC scale is a reliable measure of *Environmental Sensitivity*, except for AES. Furthermore, AES was associated with different personality traits than EOE and LST. Second, the HSC scale was partially measurement invariant across developmental stage, gender, and country. The results provide important insights in the psychometrics of a first measurement of *Environmental Sensitivity* in early to late adolescents. Implications for further research are discussed.

Keywords: *Environmental Sensitivity*; sensory processing sensitivity; adolescence; bifactor model; measurement invariance; personality

Psychometric Properties of the Highly Sensitive Child Scale Across Developmental Stage, Gender, and Country

According to a large number of studies, children and adolescents differ in how sensitive they are to environmental influences (e.g., Belsky & Pluess, 2013; Pluess, 2015). Some appear generally more sensitive than others, which means that they are more affected by features of their developmental context (Pluess, 2015), such as parenting quality (Slagt, Dubas, Dekovic, & van Aken, 2016). Traditionally, much of research on such individual differences focused on variability in response to negative environmental influences, such as negative life events (i.e., Diathesis-Stress; Monroe & Simons, 1991). Over the last two decades, this perspective of Diathesis-Stress has been challenged by the observation that individuals who are more sensitive to negative environmental influences appear also more sensitive to positive environmental influences, such as psychological interventions (i.e., Vantage Sensitivity; Pluess, 2017; Pluess & Belsky, 2013). Several predictors and markers of sensitivity have been identified, from genetic factors to physiological and behavioral markers, capturing sensitivity at different levels of analysis (Belsky & Pluess, 2016). For example, it has been shown that individuals carrying the short allele of a polymorphism in the serotonin transporter gene (i.e., 5-HTTLPR) were more sensitive to stressful life events (Caspi et al., 2003), but also benefited the most from positive parenting (e.g., Kochanska, Kim, Barry, & Philibert, 2011; van IJzendoorn, Belsky, & Bakermans-Kranenburg, 2012). Comparable results have been found as a function of infant temperament (e.g., negative emotionality; Stright, Gallagher, & Kelley, 2008) and stress reactivity (e.g., Obradović, Bush, Stamperdahl, Adler, & Boyce, 2010; for a more detailed discussion see Pluess & Belsky, 2013).

The notion that some individuals are more sensitive to both negative and positive environmental influences has been conceptualized in three theoretical frameworks on individual differences to environmental influences: (a) Sensory Processing Sensitivity (SPS;

Aron and Aron, 1997), (b) Biological Sensitivity to the Context (BSC; Boyce & Ellis, 2005), and (c) Differential Susceptibility (DS; Belsky & Pluess, 2009). These three frameworks differ from each other with respect to the nature of individual characteristics they primarily focus on (for a more detailed discussion see Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2011; Pluess, 2015). Recently, Pluess (2015) integrated these three theories, together with Diathesis-Stress and Vantage Sensitivity, into a broad meta-framework of *Environmental Sensitivity*, capturing individual differences in how individuals perceive and process information about their environment.

Most authors in the field agree that individual differences in *Environmental Sensitivity* originate from a more sensitive central nervous system, which enables individuals to register environmental influences more easily and deeply (e.g., Aron, Aron, & Jagiellowicz, 2012; Ellis, Boyce, Belsky, Bakermans-Kranenburg, & van Ijzendoorn, 2011; Pluess, 2015). To date, most evidence for individual differences in *Environmental Sensitivity* stems from research focussing on relatively distal predictors and markers of sensitivity, such as genetic polymorphisms (e.g., Caspi et al., 2003) or infant temperament (e.g., Slagt et al., 2016), which, while capturing some aspects of the hypothesised higher-order trait of sensitivity, do not represent a direct measure of it. A more proximal phenotypic marker of *Environmental Sensitivity* is found in the Highly Sensitive Person (HSP) scale (Aron & Aron, 1997), designed to capture *Sensory Processing Sensitivity* (SPS). The construct was first introduced by Aron and Aron (1997) and conceptualizes as a personality trait that is characterized by (a) greater awareness of subtleties in the environment, (b) deeper cognitive processing of external stimuli, (c) ease of overstimulation, and (d) higher emotional reactivity (Aron & Aron, 1997). Environmental stimuli are believed to have a stronger effect for individuals high in SPS as these individuals are believed to process positive and negative experiences more deeply than individuals low in SPS (Aron et al., 2012). Evidence for these cognitive and behavioral

features is found in fMRI (Acevedo et al., 2014; Jagiellowicz et al., 2011) and behavioral studies (Aron, Aron, & Davies, 2005). Moreover, Sensory Processing Sensitivity seems to be associated with—but not identical to—other personality and temperament traits such as Neuroticism, Introversion, Negative emotionality (Aron & Aron, 1997), Openness, Behavioral Inhibition System (BIS) and Behavioral Activation System (BAS) (Smolewska, McCabe, & Woody, 2006), suggesting that SPS captures individual differences to *Environmental Sensitivity* more broadly than traditional personality and temperament traits. The measurement of Sensory Processing Sensitivity has been restricted to adults (i.e., The Highly Sensitive Person scale; Aron & Aron, 1997) until the recent development of a measure for children and adolescents (i.e., the Highly Sensitive Child scale; Pluess et al., 2018).

The Highly Sensitive Child scale

Individual differences in *Environmental Sensitivity* in children and adolescents can be measured with the *Highly Sensitive Child* (HSC) scale, a short (12-items) and adapted child version of the *Highly Sensitive Person* (HSP; Aron & Aron, 1997) scale, developed by Pluess and colleagues (2018). The HSC scale can be used in children as young as 8 years old and reflects the same three dimensions as the HSP scale: (a) Ease of Excitation (EOE) (i.e., being easily overwhelmed, for example, when one has to do a lot in a short amount of time), (b) Aesthetic Sensitivity (AES) (i.e., aesthetic awareness, for example by noticing subtleties in the environment), and (c) Low Sensory Threshold (LST) (i.e., proneness to unpleasant feelings caused by strong sensory stimuli such as bright lights or loud sounds; Pluess et al., 2018).

Pluess and colleagues (2018) investigated the psychometric qualities of the HSC scale in three different adolescent samples. Their exploratory and confirmatory factor analyses indicated that a bifactor model (i.e., a latent structure with each item loading on a general factor and on one additional group factor, from a group of two or more independent group

factors; Reise, Moore, & Haviland, 2010)) fits the HSC scale better than a one- or three-factor solution. The bifactor structure of the HSC scale (Fig. 1) shows that the common variance in the items of the HSC scale are simultaneously explained by a general underlying dimension, reflecting the construct of *Environmental Sensitivity* more broadly, and by one of the three group dimensions (i.e., Ease of Excitation, Aesthetic Sensitivity, or Low Sensory Threshold). This structure suggests that both the total sensitivity score as well as the three specific group dimensions are important to measure *Environmental Sensitivity* (Pluess et al., 2018). The results also indicated good internal consistency of the total scale, but lower internal consistencies of the subscale scores. Moreover, the results showed that the different group factors of the HSC scale were correlated with different domains of temperament and personality. Ease of Excitation and Low Sensory Threshold were related to temperament and personality traits reflecting sensitivity to negative environmental influences (e.g., (BIS), negative emotionality and neuroticism), whereas Aesthetic Sensitivity was related to temperament and personality traits that might reflect sensitivity to positive experiences (e.g., BAS, positive emotionality, extraversion, and openness; Pluess et al., 2018).

Several studies found support for the HSC scale as validly predicting individual differences in response to environmental influences. For example, HSC has been found to predict treatment response to a universal school-based resilience promoting intervention, with children scoring higher on HSC benefitting the most from the positive effects of the programme (Pluess & Boniwell, 2015). HSC also moderated the positive effects of a school-based anti-bullying intervention in a large randomized controlled trial (Nocentini, Menesini, & Pluess, 2018), the association between parenting and externalizing behaviour in children (Slagt, Dubas, van Aken, Ellis, & Dekovic, 2018), as well as the association between family environment and children's physical, academic, and social wellbeing (Scrimin, Osler, Pozzoli, & Moscardino, 2018). In all these studies, children scoring higher on HSC were consistently

more affected by the environment (i.e., intervention or parenting), whereas children scoring low on HSC were the least responsive. Importantly, in one study HSC, as a marker of a highly sensitive nervous system, emerged as a significant moderator of parenting quality whereas negative emotionality, a temperament trait that is traditionally used as a marker of sensitivity, failed to predict sensitivity to both negative and positive parenting. This suggests that HSC may be a better marker of *Environmental Sensitivity* than other more traditional susceptibility factors, such as temperament (Slagt et al., 2018).

Measurement Equivalence of *Environmental Sensitivity* Across Developmental Stage, Gender, and Country

Environmental Sensitivity, as measured with the HSC scale, has already been examined in several studies in the UK (Pluess et al., 2018; Pluess & Boniwell, 2015). Results indicated small gender and age differences, with girls and early adolescents scoring significantly higher than boys and middle to late adolescents, respectively. However, to make meaningful mean-level comparisons across groups, measurement invariance should be established first to ensure that the items and the underlying factors are interpreted in the same way across groups (Chen, 2007; Van de Schoot, Lugtig, & Hox, 2012). Moreover, these studies were conducted in children and adolescents residing in the UK (Pluess et al., 2018). No cross-country comparisons of *Environmental Sensitivity* have been conducted yet. Also, it is not clear whether the Dutch version of the HSC scale measures the same construct as the English version. In order to make meaningful mean-level comparisons across different countries, measurement invariance should be tested in this respect as well (Chen, 2007; Van de Schoot et al., 2012). More specifically, for both developmental stage, gender, and country, at least three hierarchical levels of measurement invariance should be tested: (1) configural invariance (i.e., the same factor structure across groups, which reflects whether the underlying constructs are conceptualized similarly across groups), (2) metric invariance (i.e., the same

factor loadings across groups, which reflects whether people across different groups attribute the same meaning to the latent construct), and (3) scalar invariance (i.e., the same factor loadings and intercepts across groups, which reflects whether means can be validly compared across groups or whether there are no systematic response biases) (Chen, 2007; Van de Schoot et al., 2012). A lack of measurement invariance indicates that participants who are identical on *Environmental Sensitivity* would score differently on the HSC scale (Schmitt, Golubovich, & Leong, 2011). Therefore, testing for measurement invariance is equally important as testing the validity and reliability of a scale (Vandenberg & Lance, 2000). When *Environmental Sensitivity* is not measured in the same way across groups, no valid mean-level comparisons across developmental stage, gender, and country can be made (Chen, 2007; Van de Schoot et al., 2012).

The Present Study

The present study builds on the recent paper by Pluess and colleagues (2018) who developed and investigated the psychometric properties of the HSC scale (12 items) in children and early to late adolescents in the UK. With the present study, we aim at replicating the factor structure, internal consistency, dimensionality, and construct validity of this scale, by investigating associations with other personality traits, in samples of early to late adolescents from the Dutch-speaking part of Belgium. In addition, we will test for measurement invariance of the HSC scale across developmental stage, gender, and country. First, we will test for measurement invariance of the HSC scale across developmental stage and gender within country: (a) within early to late adolescents from the Dutch-speaking part of Belgium and (b) within early to late adolescents from the UK samples used in (Pluess et al., 2018). Second, we will test for measurement invariance of the HSC scale across Belgium and the UK. Depending on the results of the measurement invariance analyses within Belgium and

the UK, we will test for measurement invariance across these countries for developmental stage and/or gender separately.

Method

Participants and Procedure

More information about sample size, age, sex, and ethnicity can be found in Table 1.

Belgium. For the early adolescent sample, data were collected in Flanders, the Dutch speaking part of Belgium. Both primary and secondary schools participated. In the present study, we excluded three participants because of overlap in age with the Belgian middle to late adolescent sample. All early adolescents completed the questionnaires during class. For the Belgian middle to late adolescent sample, we used data from the second wave of data collection of “Studying Transactions in Adolescence: Testing Genes in Interaction with Environments” (i.e., STRATEGIES), a longitudinal study in Flanders. To avoid overlap with the early adolescent sample in terms of age, and to make the Belgian and UK middle to late adolescent samples more comparable in terms of age, we used data from Grades 9 and 10 only. Participants completed questionnaires, measuring several variables such as *Environmental Sensitivity* and personality, during class.

United Kingdom. For both early and middle to late adolescents, the same samples as in (Pluess et al., 2018) were used. The early adolescent sample was created by collapsing two separate early adolescent samples from the UK. Sixty early adolescents were excluded because of missing data on the HSC measure. For the middle to late adolescent sample, data from the “Twins Early Developmental Study” (TEDS) project, a large UK population-representative sample of 16,810 twin pairs born in England and Wales between 1994 and 1996, was used (more information about this project is reported in (Haworth, Davis, & Plomin, 2013)). To avoid statistical dependency, we only used data from one randomly selected adolescent in each twin pair in the analyses.

Measures

Environmental Sensitivity. Across all four samples, *Environmental Sensitivity* was measured with the *Highly Sensitive Child* (HSC; 12 items) which was developed and tested for its psychometric properties by Pluess and colleagues (2018). Pluess and colleagues (2018) developed the scale by starting from 38 sensitivity items (Walda, 2007) which were suitable for children and were based on the 27 items and factor structure (Ease of Excitation, Aesthetic Sensitivity, and Low Sensory Threshold) of the original HSP scale (Aron & Aron, 1997; Smolewska et al., 2006). Based on the factor structure found in adults (Smolewska et al., 2006) and on Principal Component Analysis with varimax rotation on the 38 sensitivity items for children, the current 12 items were retained (Pluess et al., 2018). More information about the development and psychometric properties of the English version of the HSC scale can be found in Pluess et al. (2018). See Fig. 2 and Table 6 (in Appendix) for the original version and the scoring of the HSC scale.

The original English HSC questionnaire was translated into the target language (i.e., Dutch) by a translator native to the target language. Next, a native English speaker translated the Dutch questionnaire back into English. The back-translated English and original English version were compared and were very similar to each other. The technique of back-translation is preferred for the translation of instruments (e.g., Sperber, 2004). The translated version has been approved by experts in the field (i.e., A. Aron, E. Aron, and M. Pluess). Both the English and Dutch versions of the HSC scale are expected to assess three underlying factors: Ease of Excitation (EOE, n items = 5; e.g., “I get nervous when I have to do a lot in little time”), Aesthetic Sensitivity (AES, n items = 4; e.g., “I notice when small things have changed in my environment”), and Low Sensory Threshold (LST, n items = 3; e.g., “I don’t like loud noises”). Children and adolescents rated the questions on a 7-point Likert-type scale ranging

from 1 (*not at all true*) to 7 (*extremely true*). Information about the factor structure, reliability, and construct validity of the Dutch version of the HSC will be reported in the result section.

Personality. In the Belgian child sample, personality was measured with the “Hierarchical Personality Inventory for Children” (HiPIC; Mervielde, De Fruyt, & De Clercq, 2009). The HiPIC, which is based on the Five Factor Model of personality (i.e., Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness; McCrae & Costa, 1987), consists of 144 items that are meant to measure personality in children between 6 and 13 years of age on a 5-point Likert-type scale ranging from 1 (*very untypical*) to 5 (*very typical*). The instrument has five subscales, that is, Emotional stability (a label in the opposite direction for Neuroticism; e.g., “I worry quickly about things”), Extraversion (“I talk to people easily”), Imagination (a label for Openness; e.g., “I have a rich imagination”), Benevolence (a label for Agreeableness; e.g., “I grant also something to others”), and Conscientiousness (e.g., “I finish tasks to the very end”). The internal consistency of the subscales, as measured by means of Cronbach’s alpha, was good (Emotional stability: $\alpha = .88$, 95% CI[.86, .89]; $\omega = .88$, 95% CI[.86, .90], n items = 16, Extraversion: $\alpha = .87$, 95% CI[.85, .88]; $\omega = .87$, 95% CI[.85, .88], n items = 32, Imagination: $\alpha = .81$; 95% CI[.78, .84]; $\omega = .81$, 95% CI[.78, .84], n items = 24, Benevolence: $\alpha = .87$; 95% CI[.85, .89]; $\omega = .87$, 95% CI[.85, .89], n items = 40, and Conscientiousness: $\alpha = .85$; 95% CI[.83, .87]; $\omega = .86$, 95% CI[.83, .87], n items = 32). In the Belgian middle to late adolescent sample, personality was measured with the Quick Big Five (QBF; Goldberg, 1992; Vermulst & Gerris, 2005). The QBF consists of 30 items and measures personality traits according to the Big Five model: Neuroticism (e.g., “I am anxious”), Extraversion (e.g., “I am talkative”), Openness (e.g., “I am creative”), Agreeableness (e.g., “I am helpful”), and Conscientiousness (e.g., “I am tidy”). Items were responded on a 7-point Likert-type scale ranging from 1 (*totally incorrect*) to 7 (*totally correct*). The internal consistency, measured by Cronbach’s alpha, was good for all the scales

(Neuroticism: $\alpha = .84$, 95% CI[.81, .86]; $\omega = .84$, 95% CI[.81, .86], n items = 6 ,
 Extraversion: $\alpha = .90$, 95% CI[.88, .91]; $\omega = .90$, 95% CI[.89, .92], n items = 6, Openness: $\alpha = .70$, 95% CI[.66, .74]; $\omega = .73$, 95% CI[.69, .77], n items = 6 , Agreeableness, $\alpha = .83$,
 95% CI[.81, .86]; $\omega = .83$, 95% CI[.81, .86], n items = 6, and Conscientiousness: $\alpha = .90$,
 95% CI[.89, .91]; $\omega = .91$, 95% CI[.90, .92], n items = 6).

Analyses

Factor structure of the Dutch version of the Highly Sensitive Child scale. First, we examined whether we could replicate the bifactor structure, found by Pluess and colleagues (2018) in the UK, in both Belgian samples (i.e., early and middle to late adolescent sample). Confirmatory Factor Analyses were conducted in R (Version 3.3.1, Lavaan package) using maximum likelihood robust (MLR) estimation to deal with non-normality (Satorra & Bentler, 1994). The fit of three models was compared: (a) a bifactor model (i.e., a general sensitivity factor, and three subdimensions (i.e., EOE, LST, and AES) as group factors), (b) a one-factor model (i.e., HSC as a single factor), and (c) a three-factor model (i.e., with the three subscales as factors). Regarding the parametrization in the three models, the latent means were constrained to zero and the latent variances to one, because it allows the estimation of all the factor loadings and intercepts (Van de Schoot et al., 2012). When the variances of non-significant items were negative, we constrained them to be positive (.001), as suggested by Keith (2014).

Model fit was considered satisfactory if the Yuan-Bentler χ^2 was preferably non-significant, the Comparative Fit Index (CFI) was .90 or above, the Root Mean Square Error of Approximation (RMSEA) was .06 or below, and Standardized Root Mean Squared Residual (SRMR) was .08 or below (Kline, 2005). To compare different models, we relied on the guidelines of Chen (2007). We considered the model fit of two models as significantly different when (a) the difference in Yuan-Bentler χ^2 ($\Delta YB-\chi^2$) was significant, (b) the

difference in CFI (ΔCFI) was at least .010, (c) the difference in RMSEA (ΔRMSEA) was at least .015, and (d) the difference in SRMR (ΔSRMR) was at least .010. In addition, we looked at Akaike's Information Criterion (AIC) and (the Bayesian Information Criterion) BIC, which are comparative indices and should be as low as possible (Kline, 2005).

Internal consistency, dimensionality, and construct validity of the Dutch version of the Highly Sensitive Child scale. In both Belgian samples, we examined the internal consistency of the total scale and the subscales using three coefficients: (a) Cronbach's alpha (α), (b) McDonald's omega (ω), and (c) McDonald's hierarchical omega (ω_H), in R (Version 3.3.1, package semTools and MBESS). Cronbach's alpha (α) is the most common coefficient to evaluate internal consistency, but it assumes tau-equivalence, which relies on specific assumptions (i.e., unidimensionality, equal variances and covariances of the expected scores on the items) that are hardly met in practice (e.g., Cho, 2016; Dunn, Baguley, & Brunsden, 2014; Rodriguez, Reise, & Haviland, 2015). Despite these drawbacks, we still calculated Cronbach's α , in addition to McDonald's ω and ω_H , because it is the most commonly used estimate of internal consistency and thus allows comparability with other studies. We considered Cronbach's α 's of .60 or lower as low, between .60 and .70 as acceptable, and .70 or higher as a good (Leary, 2008). Omega (ω ; McDonald, 1999) is a factor analytic model-based coefficient of internal consistency that does not rely on tau-equivalence assumptions. Also for ω , we regarded values of .60 or lower as low, between .60 and .70 as acceptable, and .70 or higher as good. Finally, Omega Hierarchical (ω_H and ω_S ; McDonald, 1999), which is like ω also a model-based coefficient of internal consistency, was calculated. ω_H is recommended for bifactor models because it separates the proportion of variance attributed to the general factor from the proportion of variance attributed to the group factors (e.g., Reise, 2012; Rodriguez et al., 2015; Zinbarg, Revelle, Yovel, & Li, 2005). For the general factor, ω_H estimates the proportion of variance of the total score due to the general factor (i.e., the

general sensitivity factor) when the variance due to the group factors (i.e., EOE, LST, and AES) is removed (e.g., Reise, 2012; Rodriguez et al., 2015; Zinbarg et al., 2005). For the subscales, Omega Hierarchical subscale (ω_s) estimates the proportion of variance associated with each group factor (i.e., EOE, LST, and AES), after removing the variance due to the general factor (i.e., the general sensitivity factor). Higher values of ω_H , and ω_s indicate greater confidence in interpreting the total and subscale scores as due to the general factor (ω_H) or group factors (ω_s) respectively (Green & Yang, 2015). Revelle (1979) suggests that ω_H should be at least .50 to derive a general factor from a multidimensional set of items. A comparison between the ω and $\omega_{H(S)}$ is necessary, because it reveals the degree to which ω is inflated due to the contribution of a group or general factor (Reise, Bonifay, & Haviland, 2013; Rodriguez et al., 2015).

Regarding dimensionality, the Explained Common Variance (ECV; Sijtsma, 2008), which is an indicator of unidimensionality and can be derived from bifactor models, was calculated. The ECV reflects the strength of the general factor (i.e., the general sensitivity factor) as high values of ECV ($> .80$) supports the use of a unidimensional model (i.e., only a general factor) instead of a more complex multidimensional model (e.g., a bifactor model) which we estimated for HSC (Rodriguez et al., 2015). Finally, concerning construct validity, we examined the zero-order and partial bivariate correlations between the HSC group factors and different domains of personality in both Belgian samples using SPSS (Version 24).

Measurement Invariance of the Highly Sensitive Child scale. In order to test whether the HSC scale measures the same construct across developmental stage, gender, and country, we tested for configural (i.e., same factor structure across groups, which reflects whether the underlying constructs are conceptualized similarly across groups), metric (i.e., same factor loadings across groups, which reflects whether people across different groups attribute the same meaning to the latent construct), and scalar (i.e., same factor loadings and

intercepts across groups, which reflects whether means can be validly compared across groups or whether there are no systematic response biases) measurement invariance of the HSC scale, within each country and across countries. Specifically, we examined these three types of measurement invariance across the following groups: (a) Belgian early adolescents versus Belgian middle to late adolescents, (b) Belgian boys versus Belgian girls, (c) UK early adolescents versus UK middle to late adolescents, (d) UK boys versus UK girls, and (e) Belgium (total sample) versus UK (total sample). All analyses were conducted in R (Version 3.3.1, package Lavaan). For configural invariance, we fitted the bifactor model in multigroup CFAs without constraining any parameter. Next, we tested metric invariance by constraining the item factor loadings across groups. Finally, we tested for scalar invariance by constraining the factor loadings and item intercepts across groups. When we did not find evidence for metric and scalar measurement invariance, we tested for partial metric and partial scalar invariance by setting the non-invariant factor loadings or intercepts free (Byrne, Shavelson, & Muthén, 1989). Partial metric or scalar measurement invariance is established when, respectively at least two factor loadings and intercepts per latent variable can be considered as the same across groups (Van de Schoot et al., 2012). When at least partial measurement invariance was obtained, we examined the degree and the direction of the non-invariant factor loadings and intercepts (Chen, 2008). According to Chen (2007), (partial) metric measurement invariance is established when ΔCFI between the constrained model and non-constrained model was smaller than .010, $\Delta RMSEA$ was smaller than .015, and $\Delta SRMR$ was smaller than .030. (Partial) scalar measurement invariance was established when ΔCFI was smaller than .010, $\Delta RMSEA$ was smaller than .015, and $\Delta SRMR$ was smaller than .010 between the constrained and non-constrained model. In addition, we also checked for the $\Delta YB-\chi^2$, which is preferably as low as possible and not significant. However, $\Delta YB-\chi^2$ depends on sample size and is often biased in large samples (Chen, 2007).

Results

Descriptive statistics and bivariate correlations of the HSC scale in the Belgian early and middle to late adolescent sample are presented in Table 2. Correlations between the three subscales of the HSC scale showed that the EOE and LST subscale were highly positively associated, whereas the AES subscale was not (i.e., early adolescent sample) or slightly (i.e., middle to late adolescent sample) associated with the other subscales (Table 2).

Factor Structure of the Dutch Version of the Highly Sensitive Child Scale

In the early adolescent sample, CFA indicated good fit of the three-factor model ($\chi^2(51) = 103.83, p \leq .001$; CFI = .925; RMSEA = .051; SRMR = .047) and the bifactor model ($\chi^2(42) = 66.303, p = .010$; CFI = .967; RMSEA = .037 ; SRMR = .038). The fit of the one-factor model ($\chi^2(54) = 226.13, p \leq .001$; CFI = .738; RMSEA = .092; SRMR = .076) was inadequate. Strongest support was found for the bifactor model which was (significantly) better on all fit indices than the one-factor model ($\Delta\text{YB-}\chi^2(12) = 119.85, p < .001$; $\Delta\text{CFI} = .229$; $\Delta\text{RMSEA} = .055$; $\Delta\text{SRMR} = .038$; $\Delta\text{AIC} = -181.74$; $\Delta\text{BIC} = -135.36$) and the three-factor model ($\Delta\text{YB-}\chi^2(9) = 32.89, p < .001$; $\Delta\text{CFI} = .042$; $\Delta\text{RMSEA} = .014$; $\Delta\text{SRMR} = .009$; $\Delta\text{AIC} = -29.28$; $\Delta\text{BIC} = -144.35$).

In the middle to late adolescent sample, CFA indicated good model fit for the bifactor model ($\chi^2(43) = 127.410, p = .040$; CFI = .942; RMSEA = .060 ; SRMR = .039), but the model fit of the one-factor model ($\chi^2(54) = 619.089, p \leq .001$; CFI = .601; RMSEA = .141; SRMR = .093) and the three-factor model ($\chi^2(51) = 243.248, p < .001$; CFI = .869; RMSEA = .083; SRMR = .057) was inadequate. Strongest support was found for the bifactor model which was significantly better on all fit indices than the one-factor model ($\Delta\text{YB-}\chi^2(11) = 454.278, p < .001$; $\Delta\text{CFI} = .341.06$; $\Delta\text{RMSEA} = .081$; $\Delta\text{SRMR} = .054$; $\Delta\text{AIC} = -554,663$; $\Delta\text{BIC} = -506,061$) and the three-factor model ($\Delta\text{YB-}\chi^2(8) = 121.14, p < .001$; $\Delta\text{CFI} = .073$; $\Delta\text{RMSEA} = .023$; $\Delta\text{SRMR} = .018$; $\Delta\text{AIC} = -113,225$; $\Delta\text{BIC} = -77,877$). Thus, for both

Belgian early and middle to late adolescents, the data supported the bifactor model over the two other models. The standardized factor loadings for the final bifactor models are presented in Table 3.

Internal Consistency, Dimensionality, and Construct Validity of the Dutch version of the Highly Sensitive Child Scale

In the early adolescent sample, the internal consistency, as measured with Cronbach's α and McDonald's ω , was acceptable for the HSC total scale ($\alpha = .67$, 95% CI[.62, .72]; $\omega = .69$, 95% CI[.63, .73]), the EOE subscale ($\alpha = .69$, 95% CI[.63, .73]; $\omega = .69$, 95% CI[.64, .73]), and the LST subscale ($\alpha = .59$, 95% CI[.51, .66]; $\omega = .64$, 95% CI[.56, .71]). However, the internal consistency of the AES subscale was low ($\alpha = .50$, 95% CI[.41, .59]; $\omega = .51$, 95% CI[.41, .59]). Further, omega hierarchical of the general factor ($\omega_H = .56$), indicated that 56% of the total variance was due to individual differences on the general factor when we controlled for the variance explained by the group factors (EOE, AES, and LST). By comparing ω (.69) with ω_H (.56) of the general factor, we see a decrease of .13 indicating that only 13% of the reliable variance in total scores was attributed to the group factors. Further, ω_S per subscale indicated that 20% of the subscale score variance was due to EOE, 50% to AES, and 28% to LST. By comparing ω for the subscales (.69, .51, and .64, respectively) with ω_S (.20, .50, and .28, respectively), we see that the reliability estimates of the EOE and LST subscales are substantially reduced once controlling for the general factor. This was not the case for the AES subscale. Additionally, the ECV was .47, indicating that the general factor explained 47% of the common variance, whereas 53% of the common variance was spread across the group factors.

Similar results were found for the middle to late adolescent sample. The internal consistency was acceptable to good for the total scale ($\alpha = .75$, 95% CI[.72, .78]); $\omega = .76$, 95% CI[.72, .79]), the EOE subscale ($\alpha = .72$, 95% CI[.69, .76]; $\omega = .73$, 95% CI[.69, .76]),

and the LST subscale ($\alpha = .67$, 95% CI[.62, .72]; $\omega = .74$, 95% CI[.69, .78]), but the internal consistency of the AES subscale ($\alpha = .51$, 95% CI[.43, .58]; $\omega = .53$, 95% CI[.46, .60]) was low. Omega hierarchical of the general factor ($\omega_H = .68$), indicated that 68% of the total variance was due to the general factor. By comparing ω (.76) with ω_H (.68) of the general factor, we see that only 8% of the reliable variance in the total scores was due to individual differences on the group factors (i.e., EOE, AES, and LST). Further, ω_s per subscale indicated that 6% of the subscale score variance was due to EOE, 51% to AES, and 41% to LST. By comparing ω for the subscales (.73, .53, and .74, respectively) with ω_s (.06, .51, and .41, respectively), we see that the reliability estimates of the EOE and LST subscales are substantially reduced once controlling for the general factor, whereas for the AES subscale there was almost no influence of the general factor. Additionally, the ECV was .46, indicating that the general factor explained 46% of the common variance, whereas 54% of the common variance was spread across the group factors. These results confirm the representation of the data in a complex bifactor solution with both a general factor and group factors.

Finally, regarding construct validity, bivariate correlations between SPS and Personality (Table 4) indicated that the different subscales of the HSC scale were associated with different domains of personality. Only partial bivariate correlations are reported here because they control for the contribution of the other group factors (EOE, LST, or AES). In the early adolescent sample, the EOE and LST subscale of the HSC scale were moderately and positively associated with Neuroticism. EOE was low and negatively associated with Extraversion, Openness, Agreeableness, and Conscientiousness, and LST only with Extraversion. The AES subscale was moderately and positively associated with Extraversion and Openness. In the middle to late adolescent sample, the EOE subscale of the HSC scale was moderately and positively associated with Neuroticism and low and negatively with Extraversion. The LST subscale was low and positively associated with Conscientiousness.

The AES subscale was moderate and positively associated with Extraversion, Openness, and Agreeableness.

Measurement Invariance of the Highly Sensitive Child Scale

Measurement invariance was tested within and between Belgium and the UK (Table 5). First, we tested for measurement invariance across gender and developmental stage in each country. In the Belgian samples, results provided evidence for configural invariance (i.e., same factor structure across developmental stage), metric invariance (i.e., same factor loadings across developmental stage), and partial scalar invariance (i.e., at least two invariant intercepts per factor across developmental stage) when comparing the early and middle to late adolescent sample. Across boys and girls, we found evidence for configural invariance (i.e., same factor structure across boys and girls), partial metric invariance (i.e., at least two invariant factor loadings per factor across boys and girls), and partial scalar invariance (i.e., at least two invariant intercepts per factor across boys and girls) . In the UK sample, results provided evidence for configural invariance, partial metric invariance, and partial scalar invariance when comparing the early and middle to late adolescent samples. Across boys and girls, we found evidence for configural invariance, metric invariance, and partial scalar invariance. Second, we tested for measurement invariance across Belgium and the UK. Because the results indicated that the HSC scale is partially measurement invariant across gender and developmental stage for both Belgium and the UK, we compared the total Belgian sample (i.e., with boys, girls, and early to late adolescents) with the total UK sample (i.e., with boys, girls and early to late adolescents). Results provided evidence for configural invariance, partial metric invariance, and partial scalar invariance across Belgium and the UK.

Across all comparisons at least two items per factor had invariant factor loadings and/or intercepts across developmental stage, gender, and country. Non-invariant items were mainly from the EOE and AES subscales. For developmental stage and gender the direction

of non-invariant items was mixed (i.e., some factor loadings were higher in one group, such as for boys or early adolescents and some in the other group, such as for girls or middle to late adolescents) within Belgium and the UK. When comparing the Belgium versus UK sample, we found a more uniform pattern (i.e. the direction of non-invariant factor loadings/intercepts was the same across countries) with higher factor loadings and lower intercepts in the UK than in Belgium. Because full scalar invariance was not established, no observed mean-levels could be compared across groups (Van de Schoot et al., 2012). It should be pointed out that almost all $\Delta YB-\chi^2$ were significant (Table 5). This is possibly due to the large sample size (e.g., Chen, 2007), thus we based our results on the other fit indices (i.e., ΔCFI , $\Delta RMSEA$, $\Delta SRMR$).

Discussion

Growing evidence suggest that children and adolescents differ in their *Environmental Sensitivity*, with some being more sensitive to both negative and positive environmental features (Belsky & Pluess, 2009; Boyce & Ellis, 2005; Ellis et al., 2011; Pluess, 2015). However, until recently there was no phenotypic measure of *Environmental Sensitivity* for children and adolescents. The present study is one of the first that contributed to the measurement of *Environmental Sensitivity* in early to late adolescents. Recently, the HSC scale has been proposed as a phenotypic measure capturing *Environmental Sensitivity* in children from 8 years old (Pluess et al., 2018). The present study builds on Pluess et al. (2018), who developed and investigated the psychometric properties of the HSC scale within the UK. The first aim was to replicate the factor structure, internal consistency, dimensionality, and construct validity of the Dutch version of the HSC scale in Belgian early to late adolescents. The second aim was to test for measurement invariance of the HSC scale across developmental stage, gender, and country in order to examine the comparability of the

HSC scale scores across these groups. Measurement invariance of the HSC scale has not been studied so far.

Aim 1: Replicating the factor structure, internal consistency, dimensionality, and construct validity of the Dutch version of the HSC scale in Belgian early to late adolescents.

Factor structure. A bifactor model, with a general sensitivity factor and three established group factors (i.e., Ease of Excitation, Low Sensory Threshold, and Aesthetic Sensitivity), best fits the structure of the HSC scale in both Belgian early and middle to late adolescents. This is consistent with the findings of Pluess and colleagues (2018). The bifactor structure of the HSC scale implies that both the total sensitivity score, underlying all the items that capture the construct of *Environmental Sensitivity*, as well as the three subscale scores, capturing different aspects of *Environmental Sensitivity*, are important to measure *Environmental Sensitivity*. Moreover, with a bifactor model we can have more insight in the unique contribution (see internal consistency) of one group factor and its relation with external variables, such as personality traits (see construct validity), on top of the general sensitivity factor and the other group factors.

Internal consistency and dimensionality. Different indices of internal consistency (i.e., Cronbach's alpha, McDonald's omega, and McDonald's hierarchical omega), indicated that the total scale, the Ease of Excitation subscale, and the Low Sensory Threshold subscale had an acceptable to good reliability in both Belgian early and middle to late adolescents. The Aesthetic Sensitivity subscale, however, was less reliable in early to late adolescents. The low internal consistency of this subscale is possibly due to the high means and low variation in responses to the items. These results are partially in line with the results found in the UK samples, but in the UK sample this effect seemed less strong (Pluess et al., 2018). This difference between the Belgian and UK samples can be due to cultural differences in the

meaning of Aesthetic Sensitivity or in the interpretation of the items. The items were translated and back-translated in an appropriate manner, but it is possible that some wordings (e.g., “I **love** nice smells”) are interpreted differently across Belgium and the UK which in turn have led to a skewed response (i.e., high means on these items) in the Belgian samples. Therefore, results regarding the Aesthetic Sensitivity scale, at least in Belgium, should be interpreted with some caution.

McDonald’s hierarchical omega indicated that both the general sensitivity factor and the group factors explained an important amount of variability in the data. Also, the ECV, which was used as a measure of unidimensionality, supported a multidimensional structure with both the general sensitivity factor and the established group factors. These results indicate that both the total sensitivity score and subscale scores should be taken into account when measuring *Environmental Sensitivity* in early to late adolescents. In addition, we found that the reliability estimates of the Ease of Excitation and Low Sensory Threshold subscales were substantially reduced once controlling for the general sensitivity factor, whereas the reliability of the Aesthetic Sensitivity subscale did not drop after controlling for the general sensitivity factor. This pattern of findings indicates that there is overlap in the variance explained by the general sensitivity factor and the Ease of Excitation and Low Sensory Threshold group factors, whereas there was no overlap in the variance explained by the Aesthetic Sensitivity group factor. Therefore, the Aesthetic Sensitivity subscale seems to capture something else, such as sensitivity to positive experiences, than the other subscales capturing sensitivity to more negative experiences. Moreover, the items capturing sensitivity to more negative environments are in the majority, which might also explain the larger overlap in variance explained by the general sensitivity factor and the Ease of Excitation and Low Sensory Threshold factor.

Construct validity. The distinction among the subscales was also observed in the low correlations between the Aesthetic Sensitivity subscale and the other subscales and in the associations with other personality traits. These associations indicated that Ease of Excitation was positively associated with neuroticism in early to late adolescents and Low Sensory Threshold with neuroticism in early adolescents and with conscientiousness in middle to late adolescents, whereas Aesthetic Sensitivity was positively associated with extraversion and openness in both early and middle to late adolescents. According to Nigg (2006), neuroticism is related to a readiness to withdraw in unrewarding environments, conscientiousness to effortful control, and extraversion and openness to a willingness to approach reward. *Environmental Sensitivity* seems thus to be associated with both approaching behaviors towards positive environments, withdrawal behaviors towards negative environments, and with the regulation of both. This finding seems to be in line with the idea that individuals scoring high on *Environmental Sensitivity* can be more sensitive to both positive and negative environmental influences (e.g., Belsky & Pluess, 2009).

Thus, based on the results regarding the factor structure, internal consistency, and construct validity, it seems that Aesthetic Sensitivity is reflecting another aspect of *Environmental Sensitivity*, such as sensitivity to positive experiences, than Ease of Excitation and Low Sensory Threshold. This is in line with the study of Assary, Zavos, Krapohl, Keers, and Pluess (2017), who found that the Ease of Excitation and Low Sensory Threshold were genetically more similar to each other compared to Aesthetic Sensitivity.

Aim 2: Testing for measurement invariance of the HSC scale across developmental stage, gender, and country in order to examine the comparability of the HSC scale scores across these groups.

Regarding our second aim, we found evidence for configural, (partial) metric, and partial scalar invariance across developmental stage (i.e., early versus middle to late adolescents) and gender within Belgium and the UK. Across Belgium and the UK, we found evidence for configural, partial metric, and partial scalar invariance. Therefore, we can conclude that (a) the underlying bifactor structure of the HSC scale is conceptualized similarly across developmental stage, gender, and country (i.e., configural invariance), (b) early and middle to late adolescents, boys and girls, and Belgians and Brits attribute more or less the same meaning to *Environmental Sensitivity* (i.e., (partial) metric invariance), and (c) early and middle to late adolescents, boys and girls, and Belgians and Brits use not always the same anchor value of the scale (reference point; i.e., partial scalar invariance). For example, in all groups the overall bifactor structure with the general sensitivity factor and the three group factors was supported (i.e., configural invariance level). However, item 6 (“I am annoyed when people try to get me to do too many things at once”, which has no invariant intercept and factor loading across country), for example, seems to be more associated with Ease of Excitation in Belgium than in the UK (i.e., metric invariance level), and this item is rated more often as characteristic by the Belgian respondents than by the British respondents (i.e., scalar invariance level).

In all group comparisons, partial measurement invariance, instead of full measurement invariance, was due to non-invariant items, mainly from the Ease of Excitation and the Aesthetic Sensitivity factor. The direction of invariant items (i.e., higher versus lower intercepts and/or factor loadings) was mixed for the comparison across developmental stage and gender within Belgium and the UK. Across countries, lower associations (i.e., factor

loadings) between the items and *Environmental Sensitivity* and higher latent means (i.e., intercepts) of *Environmental Sensitivity* were found in the Belgian samples. This is a possible explanation for the lower reliabilities we found in the Belgian sample (Chen, 2008). These non-invariant item factor loadings can be due to differences in the meaning of Ease of Excitation and/or Aesthetic Sensitivity (Chen, 2008). Moreover, finding uniform patterns of non-invariance, which we found in the comparison across Belgium and the UK, seems to be associated with a larger measurement bias than finding mixed results, which we found in the comparison across developmental stage and gender (Chen, 2008). These findings might indicate that the Dutch version of the HSC scale, used in Belgium, and the English version of the HSC scale, used in the UK, are not fully equivalent. Because full scalar invariance was not established, no observed mean-levels could be compared across developmental stage, gender, and country (Van de Schoot et al., 2012). Inter-correlations, predictive relations with external variables, and latent means, on the other hand, can be compared across groups since (partial) metric and partial scalar invariance was established (Schmitt et al., 2011; Steinmetz, 2013).

Strengths and Limitations

The present study is one of the first studies that investigated the Dutch version of the HSC scale as a measure of *Environmental Sensitivity* in early to late adolescents. We examined the psychometric properties of this scale extensively across four different large samples with in total 3056 early to late adolescents from two different countries. The psychometric properties of the HSC scale were not yet tested in other countries than the UK and measurement invariance of the HSC scale had not yet been tested at all.

Several limitations, however, should be taken into account when interpreting our results. First, in the present study we relied exclusively on self-reports of *Environmental Sensitivity* and personality. In further research, it would be interesting to compare self-reports with parent and teacher reports and with more objective measures of *Environmental*

Sensitivity (e.g., experimental designs or observations). Second, the different samples across countries were not fully comparable in terms of age (i.e., the middle to late adolescents samples) and ethnicity (i.e., the early adolescent samples, see Table 1). Despite the different ethnicities and age boundaries, we found evidence for partial measurement invariance across developmental stage and across Belgium and the UK. To control for these differences in ethnicity and age boundaries across Belgium and the UK, we performed post-hoc sensitivity analyses by running the measurement invariance analysis across countries, but only in the middle to late adolescent sample since they were comparable in terms of ethnicity. These groups were not fully comparable in terms of age, and so we also controlled for age. The results of the additional sensitivity analyses (see Appendix 2) were similar to the results we reported for the total Belgium and UK sample. These findings indicate that the differences in ethnicity and age boundaries did not seem to influence the results of the measurement invariance analysis across countries, at least not for the middle to late adolescent subsample. In the early adolescent samples, the age groups were similar. However, since we did not have any information on ethnicity in the Belgian early adolescent sample, we could not run additional analyses to control for differences in ethnicity across the Belgian and UK early adolescent sample.

Further Research

Based on the results of this study, we can conclude that *Environmental Sensitivity* can be measured with both the total sensitivity score as well as the three subscale scores (i.e., Ease of Excitation, Aesthetic Sensitivity, and Low Sensory Threshold), capturing different aspects of *Environmental Sensitivity*. However, before using the subscale scores, it is important that all the subscales are reliable across samples. A more reliable measure, especially for Aesthetic Sensitivity, with items that allow more variation in responses while capturing the different underlying constructs of the HSC scale more broadly, is necessary. Because, Aesthetic

Sensitivity seems to capture different aspects of *Environmental Sensitivity*, it would be interesting to investigate whether subgroups can be distinguished of individuals scoring high on all three subscales compared to individuals scoring high on Aesthetic Sensitivity or on Ease of Excitation and Low Sensory Threshold only. To examine, whether the HSC scale indeed measures individual differences in *Environmental Sensitivity*, it would be interesting to validate the measure of *Environmental Sensitivity* at multiple levels of analysis (i.e., genetic, physiological, and psychological level), which already have been shown to reflect such individual differences (Belsky & Pluess, 2016). Moreover, research should further test whether *Environmental Sensitivity*, as measured with the HSC scale, is a moderator in the relation between several environmental influences (e.g., parenting and school functioning) and several positive and negative outcomes (e.g., internalizing and externalizing problems).

Conclusion

The present study has investigated the psychometric properties of a new measure of *Environmental Sensitivity* in four different samples with early to late adolescents from two different countries. Results indicated that (a) the HSC scale fits a bifactor model with a general sensitivity factor and three group factors (i.e., Ease of Excitation, Low Sensory Threshold, and Aesthetic Sensitivity), (b) the HSC scale is a reliable measure of *Environmental Sensitivity*, with some reservations for the Aesthetic Sensitivity subscale, (c) the different subscales of the HSC scale capture different aspects of *Environmental Sensitivity* and are differentially related to general personality traits, and (d) the HSC scale shows partial measurement invariance across developmental stage, gender, and country. Despite some methodological limitations, the present study has several important strengths and provided additional support for the quality of the HSC scale as a measure of *Environmental Sensitivity* in early to late adolescents. More insight in the psychometric properties of the HSC scale have

important implications for the assessment of individual differences in *Environmental Sensitivity* in both research and clinical settings.

Compliance with Ethical Standards

Conflict of Interest

All authors [omitted for blinded review] declare that they have no conflict of interest.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

This article does not contain any studies with animals performed by any of the authors.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

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Figures

Fig. 1 Bifactor model of the Highly Sensitive Child Scale. HSC = Highly Sensitive Child; EOE = Ease of Excitation; LST = Low Sensory Threshold, and AES = Aesthetic Sensitivity

Table 1*Summary Table of the Different Samples*

Belgium							UK					Total
	<i>n</i>	Grades	Age	Sex	Ethnicity		<i>n</i>	Grades	Age	Sex	Ethnicity	
			<i>M (SD)</i>	Range					<i>M (SD)</i>	Range		
Early	469	5-8	12.24	9.58-	43%	/	531	/	11.63	11-14	38.2%	14.5%
Adolescents			(1.17)	14.50	boys				(0.69)		boys	Caucasian
Middle to late	625	9-10	15.34	13.71-	47.5%	93%	1431	/	17.06	15-19	42%	93%
Adolescents			(0.71)	17.02	boys	Caucasian			(0.88)		boys	Caucasian
Total	1094	5-10	13.41	9.58-	45.6%	/	1962	/	15.59	11-19	40.7%	72%
			(1.37)	17.02	boys				(2.55)		boys	Caucasian

Note. / = not known

Table 2*Descriptive Statistics and Intercorrelations of the HSC Scale in Belgian Early to Late Adolescents*

Early adolescents					
	<i>M (SD)</i>	HSC	EOE	LST	AES
HSC	4.65 (0.77)	-	.86***	.74***	.35***
EOE	4.34 (1.16)		-	.46***	.04
LST	3.62 (1.45)			-	-.05
AES	5.81 (0.79)				-
Middle to late adolescents					
	<i>M (SD)</i>	HSC	EOE	LST	AES
HSC	4.36 (0.84)	-	.86***	.78***	.49***
EOE	3.95 (1.20)		-	.50***	.16***
LST	3.26 (1.46)			-	.15***
AES	5.71 (0.82)				-

Note. HSC = Highly Sensitive Child scale total score; EOE = Ease of Excitation; LST = Low Sensory Threshold, and AES = Aesthetic Sensitivity

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 3*Standardized General and Group Factor Loadings of the CFA Final Bifactor models of the HSC Scale in Belgian Early to Late Adolescents*

Items	Early adolescents				Middle to late adolescents			
	HSC	EOE	LST	AES	HSC	EOE	LST	AES
4. I get nervous when I have to do a lot in little time	.40***	.49			.61***	.79***		
6. I am annoyed when people try to get me to do too many things at once	.36***	.54			.53***	.29***		
8. I find it unpleasant to have a lot going on at once	.68***	.19			.76***	-.18**		
9. I don't like it when things change in my life	.45***	.10			.52***	-.10		
12. When someone observes me, I get nervous. This makes me perform worse than normal	.49***	.16			.59***	.03		
2. Loud noises make me feel uncomfortable	.65***		.19		.50***		.51***	
7. I don't like watching TV programs that have a lot of violence in them	.24***		.21***		.38***		.15**	
11. I don't like loud noises	.57***		.82***		.52***		.85***	
1. I notice when small things have changed in my environment	.05			.26***	.15**			.13***
3. I love nice smells	-.01			.68***	.12**			.77***

5. Some music can make me really happy	.04	.33***	.06	.38***
10. I love nice tastes	-.10	.55***	.05	.69***

Note. HSC = Highly Sensitive Child scale total score; EOE = Ease of Excitation; LST = Low Sensory Threshold, and AES = Aesthetic Sensitivity

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 4

	Early Adolescents						
	HSC	HSC_EOE		HSC_LST		HSC_AES	
	Zero-order correlation	Zero-order correlation	Partial correlation	Zero-order correlation	Partial correlation	Zero-order correlation	Partial correlation
Neuroticism	.53***	.57***	.48***	.38***	.16***	-.02	-.04
Extraversion	-.14***	-.29***	-.27***	-.16***	-.01	.36***	.34***
Openness	.02	-.17***	-.22***	.02	.13**	.32***	.34***
Agreeableness	-.16***	-.27***	-.28***	-.03	.11*	.05	.08
Conscientiousness	-.12***	-.27***	-.33***	.06	.21***	.05	.07
	Middle to Late Adolescents						
	HSC	HSC_EOE		HSC_LST		HSC_AES	
	Zero-order correlation	Zero-order correlation	Partial correlation	Zero-order correlation	Partial correlation	Zero-order correlation	Partial correlation

Neuroticism	.47***	.52***	.44***	.29***	.05	.13**	.06
Extraversion	-.20***	-.30***	-.26***	-.18***	-.06	.15***	.21***
Openness	.14**	.03	-.04	.09*	.07	.25***	.25***
Agreeableness	.11**	-.00	-.07	-.08*	.08	.23***	.24***
Conscientiousness	.09*	-.01	-.10*	.15***	.17***	.10*	.09*

Note. HSC = Highly Sensitive Child scale total score; EOE = Ease of Excitation; LST = Low Sensory Threshold, and AES = Aesthetic Sensitivity; Partial correlations control for the contribution of the other group factors, zero-order correlations do not; * $p < .05$; ** $p < .01$; *** $p < .001$

Table 5*Summary of the Measurement Invariance Analysis Within and Between Belgium and the UK*

Model	χ^2	<i>df</i>	<i>p</i>	CFI	RMSEA	SRMR	$\Delta YB\text{-}\chi^2$	Δdf	<i>p</i>	ΔCFI	$\Delta RMSEA$	$\Delta SRMR$	Non-invariant items
<u>Within Belgium and the UK</u>													
Belgium													
<i>Early adolescent versus middle to late adolescent sample</i>													
Model 1	192.698	84	<.001	.950	.052	.038							
Model 2a	226.820	108	<.001	.944	.049	.050	36.175	24	.053	.006	.003	.012	
Model 3a	291.710	116	<.001	.918	.057	.055	82.364	8	<.001	.026	.008	.005	
Model 3b	251.301	114	<.001	.936	.051	.052	26.658	6	<.001	.008	.002	.002	8, 9
<i>Boys versus girls</i>													
Model 1	156.610	84	<.001	.964	.043	.036							
Model 2a	206.654	108	<.001	.951	.044	.050	49.882	24	.002	.013	.001	.014	
Model 2b	194.131	106	<.001	.956	.042	.047	37.432	22	.020	.008	.001	.011	1, 6
Model 3a	298.081	114	<.001	.911	.058	.055	166.217	8	<.001	.045	.016	.003	

Model 3b	213.220	110	<.001	.949	.045	.049	22.207	4	<.001	.007	.003	.002	3, 4, 12
UK													
<i>Early adolescent versus middle to late adolescent sample</i>													
Model 1	255.277	84	<.001	.969	.050	.032							
Model 2a	362.005	108	<.001	.955	.054	.053	112.889	24	<.001	.014	.004	.021	
Model 2b	324.928	103	<.001	.961	.051	.045	75.110	19	<.001	.008	.001	.013	3, 6, 8, 9, 11
Model 3a	456.147	111	<.001	.943	.059	.050	802.763	8	<.001	.018	.008	.005	
Model 3b	401.326	110	<.001	.952	.055	.048	330.614	7	<.001	.009	.004	.003	5
<i>Boys versus girls</i>													
Model 1	271.287	84	<.001	.964	.054	.035							
Model 2a	313.345	108	<.001	.963	.049	.039	35.440	24	.062	.001	.005	.004	
Model 3a	456.470	116	<.001	.940	.060	.064	205.691	8	<.001	.023	.011	.025	
Model 3b	351.729	114	<.001	.957	.051	.041	35.113	6	<.001	.006	.002	.002	7, 12
<u>Across Belgium and the UK</u>													
Model 1	327.121	84	<.001	.967	.048	.030							
Model 2a	537.911	108	<.001	.944	.056	.073	220.183	24	<.001	.023	.008	.043	
Model 2b	424.830	102	<.001	.958	.046	.051	102.218	18	<.001	.009	.002	.021	5, 6, 8, 9, 10
Model 3a	523.887	110	<.001	.944	.055	.055	80.380	8	<.001	.014	.009	.004	

Model 3b	464.664	107	<.001	.953	.051	.053	37.832	5	<.001	.005	.005	.002	4, 6

Note. Model 1 = configural invariance; Model 2a = metric invariance; Model 2b = partial metric invariance; Model 3a = scalar invariance; Model 3b = partial scalar invariance. *CFI* = comparative fit index; *RMSEA* = root mean square error of approximation; *SRMR* = standardized root mean squared residual; $\Delta YB-\chi^2$ = difference in Yuan-Bentler chi-square; Δdf = difference in degrees of freedom; ΔCFI = difference in comparative fit index; $\Delta RMSEA$ = difference in root mean square error of approximation; $\Delta SRMR$ = difference in standardized root mean squared residual.

Appendix 1

INSTRUCTIONS: Answer each question according to the way you personally feel, using follow scale

1	2	3	4	5	6	7
Strongly Disagree	Moderately			Strongly Agree		
1. I notice when small things have changed in my environment						
2. Loud noises make me feel uncomfortable						
3. I love nice smells						
4. I get nervous when I have to do a lot in little time						
5. Some music can make me really happy						
6. I am annoyed when people try to get me to do too many things at once						
7. I don't like watching TV programs that have a lot of violence in them						
8. I find it unpleasant to have a lot going on at once						
9. I don't like it when things change in my life						
10. I love nice tastes						
11. I don't like loud noises						
12. When someone observes me, I get nervous. This makes me perform worse than normal						

Fig. 2 The Highly Sensitive Child scale

Table 6*Items of the HSC Scale Per Subscale*

Subscale	Items
Ease of Excitation	4. I get nervous when I have to do a lot in little time 6. I am annoyed when people try to get me to do too many things at once 8. I find it unpleasant to have a lot going on at once 9. I don't like it when things change in my life 12. When someone observes me, I get nervous. This makes me perform worse than normal
Aesthetic Sensitivity	1. I notice when small things have changed in my environment 3. I love nice smells 5. Some music can make me really happy 10. I love nice tastes
Low Sensory Threshold	2. Loud noises make me feel uncomfortable 7. I don't like watching TV programs that have a lot of violence in them 11. I don't like loud noises

Note. All items are rated on a 7-point Likert-type scale ranging from 1 (“not at all true”) to 7 (“extremely true”). None of the item scores should be reversed.

Appendix 2

Table 7

Summary of the Measurement Invariance Analysis Within and Between Belgium and the UK Including the Extra Sensitivity Analyses to Control for Age and Ethnicity Differences Between the Belgian and UK Middle to Late Adolescent Samples

Model	χ^2	df	p	CFI	RMSEA	SRMR	$\Delta YB-\chi^2$	Δdf	p	ΔCFI	$\Delta RMSEA$	$\Delta SRMR$	Non-invariant items
<u>Within Belgium and the UK</u>													
Belgium													
<i>Early adolescent versus middle to late adolescent sample</i>													
Model 1	192.698	84	<.001	.950	.052	.038							
Model 2a	226.820	108	<.001	.944	.049	.050	36.175	24	.053	.006	.003	.012	
Model 3a	291.710	116	<.001	.918	.057	.055	82.364	8	<.001	.026	.008	.005	
Model 3b	251.301	114	<.001	.936	.051	.052	26.658	6	<.001	.008	.002	.002	8, 9
<i>Boys versus girls</i>													
Model 1	156.610	84	<.001	.964	.043	.036							
Model 2a	206.654	108	<.001	.951	.044	.050	49.882	24	.002	.013	.001	.014	
Model 2b	194.131	106	<.001	.956	.042	.047	37.432	22	.020	.008	.001	.011	1, 6
Model 3a	298.081	114	<.001	.911	.058	.055	166.217	8	<.001	.045	.016	.003	

Model 3b	213.220	110	<.001	.949	.045	.049	22.207	4	<.001	.007	.003	.002	3, 4, 12
UK													
<i>Early adolescent versus middle to late adolescent sample</i>													
Model 1	255.277	84	<.001	.969	.050	.032							
Model 2a	362.005	108	<.001	.955	.054	.053	112.889	24	<.001	.014	.004	.021	
Model 2b	324.928	103	<.001	.961	.051	.045	75.110	19	<.001	.008	.001	.013	3, 6, 8, 9, 11
Model 3a	456.147	111	<.001	.943	.059	.050	802.763	8	<.001	.018	.008	.005	
Model 3b	401.326	110	<.001	.952	.055	.048	330.614	7	<.001	.009	.004	.003	5
<i>Boys versus girls</i>													
Model 1	271.287	84	<.001	.964	.054	.035							
Model 2a	313.345	108	<.001	.963	.049	.039	35.440	24	.062	.001	.005	.004	
Model 3a	456.470	116	<.001	.940	.060	.064	205.691	8	<.001	.023	.011	.025	
Model 3b	351.729	114	<.001	.957	.051	.041	35.113	6	<.001	.006	.002	.002	7, 12
<u>Across Belgium and the UK</u>													
Model 1	327.121	84	<.001	.967	.048	.030							
Model 2a	537.911	108	<.001	.944	.056	.073	220.183	24	<.001	.023	.008	.043	
Model 2b	424.830	102	<.001	.958	.046	.051	102.218	18	<.001	.009	.002	.021	5, 6, 8, 9, 10
Model 3a	523.887	110	<.001	.944	.055	.055	80.380	8	<.001	.014	.009	.004	
Model 3b	464.664	107	<.001	.953	.051	.053	37.832	5	<.001	.005	.005	.002	4, 6

<i>Only middle to late adolescents</i>													<i>N</i> = 2056
Model 1	315.18	84	<.001	.961	.057	.034							
Model 2a	465.70	108	<.001	.942	.061	.065	126.905	24	<.001	.019	.004	.022	8, 9, 10
Model 2b	401.740	105	<.001	.952	.056	.054	107.490	21	<.001	.009	.001	.020	
Model 3a	519.549	113	<.001	.932	.064	.061	106.134	8	<.001	.020	.008	.007	4, 6
Model 3b	448.570	111	<.001	.946	.058	.057	44.410	6	<.001	.006	.008	.004	
<i>Only middle to late adolescents</i>													<i>N</i> = 2056
<i>when controlling for age</i>													
Model 1	343.94	100	<.001	.960	.053	.033							
Model 2a	481.223	124	<.001	.942	.057	.061	129.778	24	<.001	.018	.004	.028	
Model 2b	426.071	121	<.001	.951	.053	.051	83.726	21	<.001	.009	.000	.018	8, 9, 10
Model 3a	/	/	/	/	/	/							Non- convergence
													4, 6
Model 3b	445.954	127	<.001	.949	.053	.052	20.000	6	.003	.002	.000	.001	

Note. Model 1 = configural invariance; Model 2a = metric invariance; Model 2b = partial metric invariance; Model 3a = scalar invariance; Model 3b = partial scalar invariance. *CFI* = comparative fit index; *RMSEA* = root mean square error of approximation; *SRMR* = standardized root mean squared residual; $\Delta YB-\chi^2$ = difference in Yuan-Bentler chi-square; Δdf = difference in degrees of freedom; ΔCFI = difference in comparative fit index; $\Delta RMSEA$ = difference in root mean square error of approximation; $\Delta SRMR$ = difference in standardized root mean squared residual.