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Regular Article

Investigating sensitivity through the lens of parents: validation of the parent-report version of the Highly Sensitive Child scale

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Abstract

Children differ in their environmental sensitivity (ES), which can be measured observationally or by self-report questionnaire. A parent-report scale represents an important tool for investigating ES in younger children but has to be psychometrically robust and valid. In the current multistudy, we validated the parent-report version of the Highly Sensitive Child (HSC-PR) scale in Italian children, evaluating its factorial structure (Study 1, $N = 1{,}857$, 6.2 years, age range: 2.6–14 years) through a multigroup Confirmatory Factory Analysis in preschoolers ($n = 1{,}066$, 4.2 years) and school-age children ($n = 791$, 8.8 years). We then investigated the HSC-PR relationship with established temperament traits (Study 2, $N = 327$, 4.3 years), before exploring whether the scale moderates the effects of parenting stress on children's emotion regulation (Study 3, $N = 112$, 6.5 years). We found support for a bi-factor structure in both groups, though in preschoolers minor adaptations were suggested for one item. Importantly, the HSC-PR did not fully overlap with common temperament traits and moderated the effects of parenting stress on children emotion regulation. To conclude, the HSC-PR performs well and appears to capture ES in children.

Keywords: children; differential susceptibility; environmental sensitivity; Highly Sensitive Child scale; parent report

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Introduction

Over the last two decades, empirical evidence has been showing that children and adults differ in the degree they react to their rearing and surrounding environments, both negative and positive ones (for review, see Greven et al., 2019; Obradović & Boyce, 2009; Pluess & Belsky, 2010; Slagt et al., 2016). More recently, the meta-framework of environmental sensitivity (ES; Pluess, 2015) has been proposed to integrate several theoretical models developed to capture these individual differences in response to environmental factors (Aron & Aron, 1997; Belsky et al., 1998; Belsky & Pluess, 2009; Boyce & Ellis, 2005; Pluess & Belsky, 2013), and a series of markers of environmental sensitivity have been identified at different levels of analysis, including genetic, physiological, and psychological ones (Aron & Aron, 1997; Aron et al., 2012; Belsky & Pluess, 2009; Belsky & van Ijzendoorn, 2017; Boyce & Ellis, 2005; Keers et al., 2016; Lionetti, Aron, et al., 2019; Pluess & Belsky, 2013). Pertaining to the psychological level of analysis, questionnaires are popular because they are relatively easy to administer, with potential to be also used in clinical settings (Greven et al., 2019; de Villiers et al., 2018).

In order to measure environmental sensitivity in children, the self-report Highly Sensitive Child (HSC, Pluess et al., 2018) is one of the most widely used scale. It has been originally validated with UK resident children aged 8–19 years (Pluess et al., 2018), and subsequently adapted into a parent-report format for a Dutch sample involving parents of 3–7 years old children (Slagt et al., 2018). While the HSC self-report psychometric properties and convergent validity with related temperamental traits have been extensively explored (Pluess et al., 2018), the same is lacking for the HSC parent-report form. With the current paper we aim to fill this gap, examining the Highly Sensitive Child scale parent-report version's (HSC-PR; Slagt et al., 2018) psychometric properties and bivariate associations with established and related temperament traits. We then test the moderating role of HSC-PR with parenting stress (a marker of the emotional climate in the parent–child relationship experienced at home) in predicting children's emotion regulation competences (for similar studies see Mathis & Bierman, 2015; Spinelli et al., 2021). As individual differences in environmental sensitivity predict different responses to the environment, ranging from the development of behavioral problems to social competence, the availability of a reliable parent-report questionnaire may allow to early identify, with a relatively easy tool, children who are more at risk of dysfunctional developmental trajectories but also more likely to exceptionally benefit from supportive environmental conditions.

The meta-framework of environmental sensitivity

Environmental sensitivity is the name of a meta-framework as well as of a basic trait – with genetic, neurophysiologic and behavioral

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correlates – found in most organisms, and capturing and explaining individual differences in registering, processing, and responding to internal and external stimuli, both negative and positive ones (Pluess, 2015). In short, individuals tend to differ in their sensitivity to the environment, with some being significantly more sensitive than others (Aron et al., 2012). Across populations, a continuum from low to high sensitivity to the environment has been observed, with a majority (around 40% of the general population) having a medium sensitivity, and two substantial minorities characterized by particularly high (31%) and low (∼29%) sensitivity (Lionetti et al., 2018).

Traditionally, psychological concepts that focused on individual differences in sensitivity to environmental influences have been framed within a Diathesis–Stress model (Monroe & Simons, 1991; Zuckerman, 1999), according to which heightened sensitivity is seen primarily as a vulnerability for the development of dysfunctional outcomes when exposed to negative environments. The central understanding of this framework is that more reactive or sensitive individuals are more vulnerable to the impact of dysfunctional environments, while less reactive or sensitive people are more resilient when facing adversities. In contrast to this traditional diathesis-stress model, new concepts and theories moved beyond a psychopathology perspective by considering the possibility that sensitivity may extend to positive environments and adaptive outcomes too (Pluess & Belsky, 2013). These theories include differential susceptibility (DS; Belsky et al., 1998; Belsky & Pluess, 2009), Biological Sensitivity to Context (BSC; Boyce & Ellis, 2005), and sensory processing sensitivity (SPS; Aron & Aron, 1997). According to the DS theory, individuals differ in their sensitivity to both negative and positive environments. DS is based on an evolutionary perspective, positing that such differences in susceptibility are related to low or high developmental plasticity and represent alternative developmental strategies maintained by natural selection. BSC theory posits that differences in sensitivity reflect differences in physiological reactivity (e.g., arterial pressure, cortisol reactivity) developed in response to either very negative or very positive environments, starting from early in life (Del Giudice et al., 2011; Ellis & Boyce, 2011; Hartman & Belsky, 2018; Hartman et al., 2018). Consistent with the notion of conditional adaptation, BSC emphasizes the role of early environmental influences in shaping these differences at a physiological level. Finally, SPS (Aron & Aron, 1997; Aron et al., 2012) posits that individual differences in ES are due to heightened sensory sensitivity and deeper processing of sensory inputs at the level of the central nervous system (for a review see Acevedo, 2020). The trait perspective of SPS suggests that it is possible to measure an individual's sensitivity to environmental influences behaviourally, adopting observational measures (Davies et al., 2021; Lionetti, Aron, et al., 2019), self-report questionnaires for adults and children (Aron & Aron, 1997; Pluess et al., 2018, 2020), and parent-report for preschoolers (Slagt et al., 2018). Though each of these theories provides a unique contribution to the study of the interaction between the environment and the individual, all three agree that sensitive individuals differ not only in their response to environmental adversities but also in response to nurturing and positive environments. Further, the more recent framework of Vantage Sensitivity (VS; Pluess & Belsky, 2013) focuses and captures the bright side of sensitivity in contrast to the dark side posited by the Diathesis-Stress model, with important implications for intervention programs (de Villiers et al., 2018). Unique to VS is the understanding that attributes that make some people more sensitive to the benefits of supportive experiences, do not make them necessarily also more susceptible to the negative effects of adverse conditions (although that may be the case for many identified sensitivity markers).

Psychological assessment of environmental sensitivity

A reliable psychological marker that captures sensitivity to both negative and positive stimuli in children and adults is the biologically based individual trait of SPS (Aron & Aron, 1997; Aron, 2002; Aron et al., 2012; Assary et al., 2020; Keers et al., 2016; Slagt et al., 2018). According to the literature on SPS, the core mechanism underlying sensitivity is an in-depth processing of environmental stimuli, associated with heightened sensory sensitivity, emotional/physiological reactivity, and behaviour inhibition with a pause to check approach when exploring new environments (Aron et al., 2012). Important from a developmental psychopathology point of view, when the quality of environment is low or less than optimal, a high SPS is a risk factor for externalizing behavioral problems in early childhood (Lionetti, Aron, et al., 2019; Slagt et al., 2018), and for internalising symptoms, including depression and rumination, from middle childhood to pre-adolescence (Lionetti et al., 2021; for similar findings with adults see Booth et al., 2015 and Liss et al., 2008). At the same time, SPS predicts an increased sensitivity to positive environmental conditions, including the positive effects of prevention and intervention programs (Kibe et al., 2020; Nocentini et al., 2018; Pluess & Boniwell, 2015; Pluess et al., 2017) and positive parenting (Lionetti, Aron, et al., 2019; Slagt et al., 2018), a result holding important implications for practice.

The first psychological measure specifically developed to assess environmental sensitivity as reflected in the SPS trait is the Highly Sensitive Person (HSP) scale for adults (Aron & Aron, 1997), whose development was informed by a series of qualitative interviews with individuals that self-identified as "highly sensitive" (Aron & Aron, 1997). Further testing resulted in the 27-item self-report scale, systematically validated over several studies (for a review see Greven et al., 2019), and then adapted to the more recent 12-item version (HSP-12; Pluess et al., 2020).

Building on SPS theory and on the original HSP scale, a range of self-report and observational measures has been subsequently developed to assess sensitivity in children, including the 12-item Highly Sensitive Child (HSC) scale (Pluess et al., 2018), a self-report questionnaire for children aged 8–19 years, subsequently adapted for the use with younger children in a parent-report format (Slagt et al., 2018). The HSC scale, in its self-report format (Pluess et al., 2018), fits a bi-factor structure and consists of 12 items. These items capture a general sensitivity factor as well as three sensitivity components which are an increased appreciation for positive environmental stimuli and subtleties (e.g., "some music can make me really happy"; "I notice when small things have changed in my environment", loading on a common factor labelled Aesthetic Sensitivity (AES)), a stronger feeling of getting overwhelmed when exposed to potentially adverse experiences (e.g., "I am annoyed when people try to get me to do too many things at once", reflecting the Ease of Excitation (EOE) factor), and lower sensory thresholds which reflect unpleasant sensory arousal (e.g., "Loud noises make me uncomfortable, reflecting the Low Sensory Threshold (LST) factor") (Pluess et al., 2018). The 12-item HSC scale captures sensitivity to both negative and positive environmental factors as reported across several independent studies (Nocentini et al., 2018; Pluess & Boniwell, 2015; Pluess et al., 2017). Originally adopted with children living in the UK, it has been subsequently validated, with some adaptations, in several languages, including Italian (Nocentini et al., 2017), German (Konrad & Herzberg, 2017; Tillmann et al., 2018),

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Turkish (Şengül-İnal & Sümer, 2017), Japanese (Kibe et al., 2018), Icelandic (Þórarinsdóttir, 2018), and Dutch (Weyn et al., 2021). The HSC scale also features partial measurement invariance across age, gender, and country based on Dutch and UK versions (Weyn et al., 2021). Besides having good psychometric properties, the self-report HSC scale correlates with related temperament traits, but is not fully captured by these: negative affect, positive affect, effortful control, behaviour inhibition, and behaviour activation explain in total 34% of the variability in the HSC score in children (Pluess et al., 2018). Meta-analytic data further reported that HSC total score correlates with negative ($r = .29$) and positive ($r = .21$) affect only moderately (Lionetti, Pastore, et al., 2019). Recently, an analysis of longitudinal data on the parent-report version of the HSC scale in a Dutch sample of preschoolers (Slagt et al., 2018) showed the HSC total score capturing an increased sensitivity to the environment. However, to the best of our knowledge, no studies have yet explored the factorial structure of the parent-report version, nor investigated associations with related temperamental traits.

Another parent-report questionnaire, the 23-item Highly Sensitive Person Scale – child version (HSPS), has also been proposed to assess sensitivity in children aged 3–16 years, but the scale has relatively low fit indices (Boterberg and Warreyn, 2016) and its interaction with the environment has not been tested yet. With regard to observational and laboratory based procedures, there is the Highly Sensitive Child-Rating System (HSC-RS; Lionetti, Aron, et al., 2019), a recently validated measure which captures a unique sensitivity factor found to moderate the role of the environment on emotional and behavioral outcomes longitudinally (Lionetti, Aron, et al., 2019; Lionetti et al., 2021). Another observational measure is the dove temperament trait coding scheme, suitable for preschoolers (Davies et al., 2021), and for primary school children a series of ad-hoc laboratory stimuli, based on items derived from the HSC scale, have been recently proposed and preliminary validated in interaction with physiological measures in at-risk family contexts (Moscardino et al., 2021).

In the current paper, we will specifically focus on the HSC scale parent-report version (HSC-PR, Slagt et al., 2018), adapted from the self-report scale for children (Pluess et al., 2018), as one of the most widely used and promising measure of environmental sensitivity in children. The parent-report version has the potential to be an effective tool to capture sensitivity when children, for methodological or developmental reasons, cannot directly report on their own sensitivity levels.

Overview of the current paper

The current paper addressed three objectives across three studies. First, in Study 1, we explored the factorial structure of HSC-PR applying a series of CFA, testing and comparing competing models derived from the literature. To do so, we involved $N = 1{,}857$ children between 2.6 and 14 years of age living in Italy, considering age as the grouping variable ($n = 1{,}066$ in the preschool-age group and $n = 791$ in the school-age group). We involved children from kindergarten, which constituted the target age-range of the first study adopting the HSC-PR scale (Slagt et al., 2018), as well as children attending primary and secondary schools, to cover the developmental period that goes up to early adolescence. Second, in Study 2, we examined bivariate associations between the HSC-PR and an established measure of temperament in a convenience subsample of $n = 327$ preschoolers (age range: 2.6–5.9 years). Third, in Study 3, we investigated in an independent sample of $N = 112$ school-age children (age range: 5–8 years) whether HSC-PR moderates the association between parenting stress and children emotion regulation. That is, we explored whether the parent-report measure does capture individual differences in sensitivity to environmental influences (Davies et al., 2021; Lionetti, Aron, et al., 2019; Lionetti et al., 2021; Nocentini et al., 2018; Pluess et al., 2017; Pluess & Boniwell, 2015; Slagt et al., 2018). We considered emotion regulation as the target outcome given that it might be particularly challenging for highly sensitive individuals, who tend to experience stronger emotional responses than less sensitive individuals (Acevedo et al., 2014, 2017; Aron et al., 2012; Lionetti et al., 2018), to cope with emotions. This may be particularly true in less supportive family environments, as when parents perceive high levels of stress in their caregiving role (Lionetti et al., 2021).

The studies were approved by the Department of Neuroscience, Imaging and Clinical Sciences of the G. d'Annunzio University of Chieti-Pescara and by the Ethical Committee of the University (n° 4186). The participants provided their written informed consent to participate in this study. These studies were not preregistered.

Study 1

The aim of Study 1 was to explore the factorial structure of the Highly Sensitive Child scale parent-report (HSC-PR), testing and comparing competitive models with a series of CFAs on the total sample, and exploring potential differences between preschoolers and school-age children.

Method

Participants

Participants were 1,857 families in Italy. Children's mean age was 6.2 years (range: 2.6–14 years; $SD = 2.8$) and 50.3% were female. Of these, $n = 1{,}066$ were preschoolers (mean age = 4.23; age range = 2.6–5.9 years; $SD = .90$; 48.83% were female) and $n = 791$ were school-age children (mean age = 8.83; age range = 6–14 years; $SD = 2.13$; 52.33% were female). The sample was recruited in two regions of central Italy. We recruited parents at kindergartens and primary and secondary schools with flyers over a period of 3 months, aiming to reach a sample as large as possible, and we asked mothers to fill out paper questionnaires.

Measures

Environmental sensitivity was assessed with the 12-item Highly Sensitive Child scale parent-report (HSC-PR), adapted from the self-report version (Pluess et al., 2018) and previously used in a Dutch sample (Slagt et al., 2018). For the current study, the original Italian HSC self-report translation was adapted (Nocentini et al., 2017) by replacing in each item the original "I" with "My child". In the HSC-PR version, items capture exactly the same information as the self-report format for children (Pluess et al., 2018), such as an increased appreciation for positive environmental stimuli and great attention for subtleties (e.g., "some music can make my child really happy"; "my child notices when small things have changed in his/her environment", reflecting a common factor labelled Aesthetic Sensitivity (AES) factor), a lower sensory threshold related to unpleasant sensory arousal (e.g., "loud noises make my child feel uncomfortable", reflecting Low Sensory Threshold (LST) factor), and a stronger feeling of getting overwhelmed when exposed to potentially adverse experiences (e.g., "my child gets nervous when he/she has to do a lot in little time", reflecting Easy of Excitation (EOE) factor). Each item was rated on a 7-point

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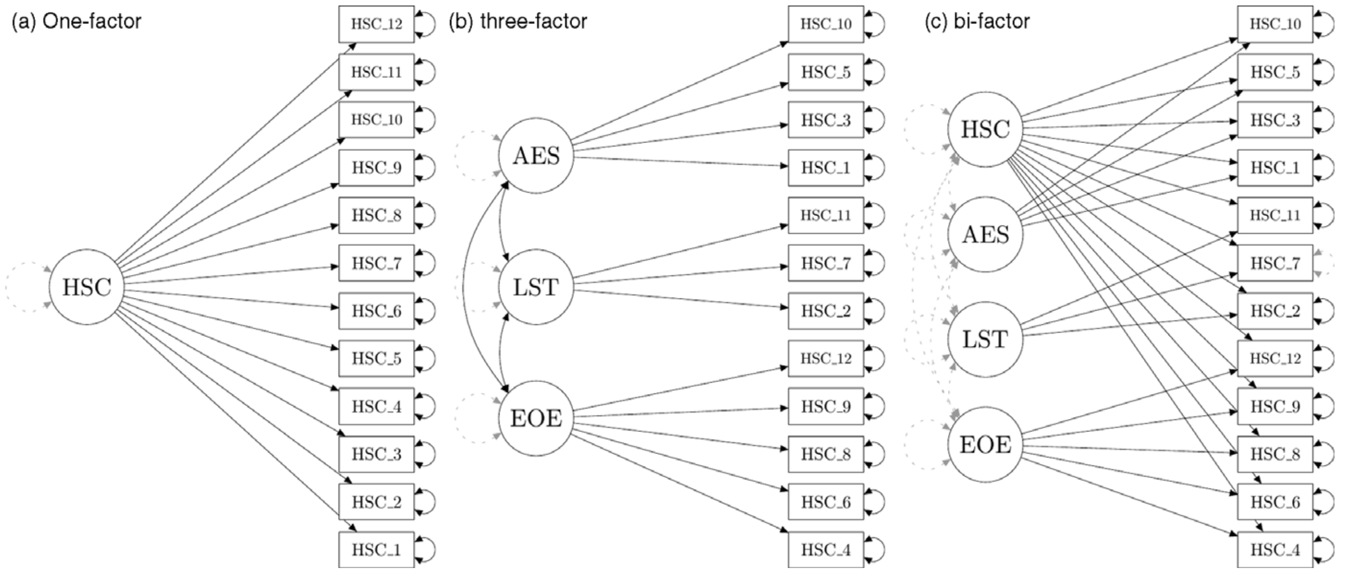

Figure 1. Study 1. Path diagrams of CFA models (N = 1857). Continuous black lines represent estimated parameters. Grey dotted lines represent fixed parameters respectively latent variable variance = 1 and latent variable correlation = 0. The residual variance of item 7 in the bi-factor model was also fixed.

Likert scale ranging from "1 = Not at all" to "7 = Extremely", with higher scores indicating higher levels of sensitivity.

Data analysis

We first explored the percentage and distribution of missing values across the 12 items of the HSC-PR scale. Then, in order to evaluate the scale's psychometric properties, we applied a series of CFAs. We compared three competing models in the total sample in line with the extant literature on the HSC self-report scale (Pluess et al., 2018), considering age as the grouping variable (i.e., children between 2.6 and 5.9 years in the preschool group and children between 6 and 14 years in the school-age group). After having performed a parallel analysis for exploratory purposes (reported in the supplementary documentation), three competitive factors models informed by the literature were compared. More specifically, we considered the following models, also depicted in Figure 1: (a) a one-factor model, (b) a three-factor model, and (c) a bi-factor model. We tested the one-factor model for methodological reasons as a baseline and more parsimonious solution and in line with the theoretical original proposition of sensitivity to be a unique factor (Aron & Aron, 1997). We then tested the three-factor solution, as previously identified in Smolewska et al. (2006) with an adult sample, and the bi-factor model as described in Lionetti et al. (2018) and Pluess et al. (2018) in children and adults. In the bi-factor model a general sensitivity factor was added in addition to the three separate factors, constrained to be orthogonal (i.e., uncorrelated). The maximum likelihood estimation method was used to estimate model parameters. We compared the three competing models according to the following criteria: (a) a qualitative evaluation of the fit indices of each model; (b) the Δ CFI criterion, according to which two nested models do not differ if the difference in their CFIs is smaller than |.01| (Cheung & Rensvold, 2002); and (c) the widely used scaled χ2 difference test (Satorra, 2000), with lower χ2 reflecting better model fit. For the evaluation of model goodness of fit, two relative fit indices were considered: the CFI and the TLI. Cut-off values for fit are considered adequate if CFI and TLI values are >.95 (Hu & Bentler, 1999). Two absolute fit indices were also used: the RMSEA and the SRMR. For RMSEA, values ranging from .05 to .08 reflect adequate fit; for SRMR, values <.08 are considered a good fit (Schermelleh-Engel et al., 2003). After having identified the best fitting model, we explored the invariance across age considering factor loadings and intercepts (i.e., metric and scalar invariance) in order to test whether the HSC-PR measures the same construct across age. As χ2 indicator strongly depends on sample size, and it is often biased in large samples, we considered CFI, RMSEA and SRMR to evaluate measurement invariance. More specifically, we assumed metric measurement invariance to be established when ΔCFI between the constrained model and nonconstrained model was smaller than .010, ΔRMSEA was smaller than .015, and ΔSRMR was smaller than .030 (Chen, 2007; Cheung & Rensvold, 2002). We assumed scalar measurement invariance to be established when ΔCFI was smaller than .010, ΔRMSEA was smaller than .015, and ΔSRMR was smaller than .010 between the constrained and non-constrained model (Chen, 2007).

All analyses were run using the statistical software R (R Core Team, 2020), with package lavaan (Rosseel, 2012). The fully anonymized dataset is available upon request to the corresponding authors.

Results

Preliminary analyses

The percentage of missing data in the total sample ($N = 1{,}857$) was very low (0.59%). Notably, concerning missing values at an item level, the percentage of missing data per item was lower than .6% for all items except for item 7 ("My child doesn't like watching TV programs with a lot of violence in them") where a higher, though overall relatively low number of missing values, was identified ($N = 28$, 1.51%). Of the 28 missing values, 27 were for children aged between 2.6 and 5.9 years (see Figure S1 in supplementary material file). Given the overall low number of missing data, we adopted a robust method for approximating unbiased parameter estimates in the CFAs by utilizing all available data, namely FIML estimation (Enders, 2010). Results of CFAs using listwise deletion were similar and are reported in supplementary materials (Table S2). For the total sample, Cronbach's α for HSC-PR total score was .78 with [.77, .80] as 95% CI, and for EOE, LST, and AES factors Cronbach's α was .82 with 95% CI [.81, .83], .62 with 95% CI [.59, .65], and .66 with 95% CI [.64, .69], respectively. An exploratory parallel analysis, reported in the supplementary documentation, suggested a three-factor solution to be a plausible option.

Confirmatory factor analysis, model selection

Fit indices of the one-factor model in the total sample ($N = 1{,}857$ of which $n = 1{,}066$ in the preschool group and $n = 791$ in the school-age group) were not satisfactory (CFI = .667, TLI = .593, RMSEA = .145, SRMR = .109), whereas comparable and acceptable model fit indices emerged for the three-factor and the bi-factor solution (respectively, CFI = .929, TLI = .908, RMSEA = .069, and SRMR = .048 for the three-factor solution, and CFI = .947, TLI = .917, RMSEA = .066, and SRMR = .042 for the bi-factor model). However, important to note, in the bi-factor model we identified a large negative variance for item 7 in the preschool sample. Hence, we replicated the analysis fixing the residual to the 20% of the total (observed) item variance. Fit indices were stable with CFI = .945, TLI = .915, RMSEA = .066, and SRMR = .041. Although the three-factor and bi-factor model showed comparable goodness of fit, both the $\chi 2\text{DIFF}(16) = 120$, $p < .001$ and the ΔCFI criterion (CFI [DIFF] = .02) provided stronger support for the bi-factor solution as fitting data better than the three-factor model (χ2DIFF and the ΔCFI criterion were almost the same when the comparison was done with the model with no fixed variance, i.e. 136.88, $p < .001$ and .02, respectively). Furthermore, we considered the bifactor solution as the most plausible model for the HSC-PR also for theoretical reasons. The bi-factor solution was previously reported to be the best fitting model for the self-report HSC scale with children (Pluess et al., 2018), and it supports the existence of a general sensitivity factor as originally proposed by Aron and Aron in relation to the sensitivity construct assessed at a phenotypic level (1997). All details of factor loadings and residual variances related to the bi-factor model are reported in the supplementary documentation (Box S1, S2, S3, S4).

Measurement invariance

After having identified the best fitting model across groups (i.e., after the configural invariance), we tested for metric and scalar measurement invariance. In all models, we fixed the residual variance of item 7 in both groups to the 20% of the total (observed) item variance in order to avoid negative variance problem. Pertaining to metric invariance, the ΔCFI criterion, ΔRMSEA, and ΔSRMR, provided evidence for same factor loadings across age groups. In relation to scalar measurement invariance, ΔCFI criterion for scalar invariance was .014, closely approaching the cut-off of .010 for which invariance is supported, and fully support was provided according to ΔRMSEA and ΔSRMR. Results of measurement of invariance are reported in Table 1.

Table 1. Study 1. Summary of measurement invariance between the preschool and the school-age group

Model	*df*	CFI	RMSEA	SRMR	ΔCFI	ΔRMSEA	ΔSRMR
Configural	86	.945	.066	.041			
Metric	106	.936	.064	.049	.009	.002	.008
Scalar	114	.922	.069	.053	.014	.005	.004

Note. ΔCFI = difference in comparative fit index; ΔRMSEA = difference in root mean square error of approximation; ΔSRMR = difference in standardized root mean-squared residual. Important to note, in all models, we fixed the residual variance of item 7 in both groups to the 20% of the total (observed) item variance.

Discussion

In Study 1, we explored the internal consistency of the HSC-PR scale and we investigated its factorial structure, testing and comparing three competitive models informed by the scientific literature by applying CFAs in a large sample of parents reporting on their children's sensitivity, and considering age (preschool and school years) as the grouping variable. Finally, we followed-up analyses testing invariance between age groups. Internal consistency values were comparable to that reported for the self-report scale (Pluess et al., 2018) and for the parent-report version (Slagt et al., 2018). Results from the multigroup CFAs suggested that the HSC-PR fits a bi-factor structure, consisting both of three independent factors that capture different aspects of sensitivity – sensitivity to sensory stimuli (LST), sensitivity to overstimulation (EOE), and sensitivity to the aesthetic quality of the environment (AES) – and a general sensitivity factor across all items. The bi-factor structure is consistent with recent empirical evidence both from child (Pluess et al., 2018) and adult samples (Lionetti et al., 2018; Pluess et al., 2020), and provides statistical justification for the use of the mean score across all items as a measure of general environmental sensitivity. Important to note, however, we identified potential issues in relation to item 7 in preschoolers. The negative variance of item 7, taken together with the relatively high number (compared to the other items) of missing values, suggested that this item may be problematic or not very well applicable to preschoolers in the context of a bi-factor structure. We hypothesize that this may be due to the item content ("My child doesn't like watching TV programs with a lot of violence in them"), which might not apply as much to younger children. Younger children generally are likely to have less exposure to violence in TV programs, at least in low-risk, normative samples. Future studies may contribute to clarify this aspect further, providing alternative versions of this item. Alternative item versions may consider children's response to conflict with other family members and peers or children's reactions when exposed to animations with cartoon characters fighting or making a fuss. Alternatively, LST items may include contents referring to children's responses to sensory, tactile stimuli (e.g., children responses to scratchy clothing or labels against skin, or to sandy or wet clothes, see Aron, 2002; Boterberg & Warreyn, 2016).

Pertaining to measurement invariance, which nonetheless was tested fixing residual variance of item 7, results suggested that the two age groups are overall comparable in relation to factor loadings and intercepts and, hence, that latent means and associations with external variables can be compared across age groups.

Study 2

Study 2 aimed at exploring bivariate associations between the HSC-PR scale and temperament dimensions in a convenience subsample of preschoolers from Study 1. We anticipated the HSC-PR to correlate only moderately with other temperament traits. More specifically, based on the validation of the self-report measure in a UK sample (Pluess et al., 2018), and on meta-analytic data on the associations between sensitivity and temperament dimensions (Lionetti, Pastore, et al., 2019), we expected the HSC-PR to correlate positively with effortful control and negative affect, and negatively with surgency/extraversion. For descriptive purposes, we further explored associations including and excluding item 7 (which had estimation problems, see Study 1) from the HSC-PR total score and from the LST factor due to estimation problems found in Study 1.

Method

Participants

Data for Study 2 were obtained from a convenience subsample of Study 1, which completed a broader set of paper questionnaires, including measures of temperament. Participants were 327 Italian mothers of preschoolers (48.9% were female) with a mean age of 4.26 years (range = 2.6–5.9 years, *SD* = .94).

Measures

Children's environmental sensitivity was assessed using the HSC-PR. In the current sample, good internal consistency was found for the HSC-PR total score (Cronbach's α = .79 with [.75, .82] as 95% CI) and for EOE factor (α = .82 with 95% CI [.79, .85]), while a slight lower Cronbach's α was found for the AES factor (α = .63, with 95% CI [.56, 69]). Cronbach's α for LST factor was .67 with 95% CI [.60, .73], and increased to .82 with 95% CI [.78, .86] when dropping out item 7. The relatively low Cronbach's α for AES is in line with other studies featuring the self-report HSC (Pluess et al., 2018) and it was expected given the low number of items of the scale and the multiple aspects of aesthetic sensitivity that AES captures.

In addition, mothers reported on children's temperament using the 36-item Children's Behaviour Questionnaire – Very Short Form (CBQ-VSF, Putnam & Rothbart, 2006), Italian validated version (Albiero et al., 2007). The very short form of CBQ is composed of three 12-item scales aimed at measuring three superordinate temperamental dimensions: Negative Affect (NA), Surgency/Extraversion (EXTR), and Effortful Control (EC). NA is conceptually similar to Neuroticism and it can be described as the tendency to get easily overwhelmed; it is defined by high positive loadings for Sadness, Fear, Anger/Frustration, and Discomfort and negative loadings for Falling Reactivity/Soothability. EXTR reflects a predisposition to be actively involved with the environment; it is based on high positive loadings on the Impulsivity, High Intensity Pleasure, and Activity Level scales and strong negative loadings on the Shyness scale. Finally, EC reflects the capacity to inhibit a behavioral response and to direct attention; it is based on high positive loadings for Inhibitory Control, Attentional Control, Low Intensity Pleasure, and Perceptual Sensitivity (Putnam & Rothbart, 2006). Items are rated by parents on a 7-point Likert Scale, ranging from "1 = Absolutely False" to "7 = Absolutely True". Parents could also select "Not applicable" as response in case they have never observed their child in the situation described in the items. In the current sample, good internal consistency was found for NA (α = .81 with [.77, .84] as 95% CI) and EC (α = .77 with 95% CI [.73, .81]), and a slightly lower Cronbach's α, though in accordance with international studies, was identified for EXTR (α = .73 with 95% CI [.68, .77]) (Allan et al., 2013).

Data analysis

After having explored the percentage of missing data and descriptive statistics (i.e., mean and standard deviations of study variables), in order to explore associations between sensitivity and temperament, we computed bivariate zero-order correlations between the HSC-PR total score and its three factors (including and excluding item 7 from the total score and from the LST factor) with the CBQ-VSF dimensions. We also examined partial correlations between each HSC-PR factor (i.e., EOE, LST, and AES) and temperament dimensions, in order to identify the unique association between each HSC-PR factor and temperament, controlling for the contribution of the other two sensitivity dimensions. For interpreting results, we considered the effect size of Pearson's *r*: low if *r* varies around .10 or less, medium if *r* varies around .30, and large if *r* is higher than .50 (Cohen, 1988, 1992). In addition, we ran a series of multiple regression models with all three temperament dimensions simultaneously included as predictors of the sensitivity total score, and of each HSC-PR factor (i.e., EOE, LST, and AES), in order to estimate how much of the variance of the HSC-PR and its factors is accounted for established temperament traits. Finally, we tested all correlations between HSC-PR and the temperament dimensions that were equal to or higher than *r* = .50 for divergent validity (i.e., whether traits are distinguishable from each other) by considering the heterotrait-monotrait (HTMT) ratio of correlations in a multitrait-multimethod matrix. This approach includes computing the average of the correlations of items across constructs that measure different dimensions relative to the average of the correlations of items within the same construct. HTMT values equal or lower than .85 are considered to satisfy divergent validity (Henseler et al., 2015). Analyses were run using R package semTools (semTools Contributors, 2016) for estimating divergent validity.

Results

Overall, missing data in the total sample (*N* = 327) were very limited (1.13%) and hence mean imputation was applied. Descriptive statistics and bivariate correlations without applying mean imputation were stable and are reported in Table S3 in the supplementary material file. Descriptive statistics were *M* = 4.57 (*SD* = .90) for the HSC-PR total score, and *M* = 3.62 (*SD* = 1.31), *M* = 4.49 (*SD* = 1.56), and *M* = 5.84 (*SD* = .88), for EOE, LST, and AES factors, respectively. The sensitivity total score was slightly associated with gender (*r* = .16), but not with age (*r* = .09). Pertaining to associations between sensitivity and temperament, according to zero-order correlations (see Table 2) the total score of HSC-PR was moderately and positively correlated with temperament dimensions of negative affect (*r* = .38, *r* = .39, including and excluding item 7, respectively) and effortful control (*r* = .34, *r* = .33, including and excluding item 7, respectively). The association between the sensitivity total score and negative affect was mostly driven by the EOE factor (*r* = .45) whereas the associations with effortful control seemed to be mostly due to the strong association with the AES factor (*r* = .50). After controlling for the two other HSC-PR factors in the partial correlation, EOE kept being strongly associated with negative affect (*r* = .41), and the same was true for AES regarding effortful control (*r* = .45). Similarly, the association between AES and negative affect was overall stable whether controlling (*r* = .06) or not (*r* = .10) for the other two sensitivity factors. Conversely, LST and negative affect association decreased and became negative (from *r* = .18 to *r* = −.05) when controlling for EOE and AES, likely due to the strong contribution of EOE to negative affect. With regard to the temperament dimension of effortful control, LST and EOE were positively associated with effortful control with a moderate effect size for LST (*r* = .27) and a relatively low effect size for EOE (*r* = .10). Their association with effortful control decreased (*r* = .16 for LST and *r* = −.03 for EOE) when controlling

Table 2. Study 2. Bivariate zero-order and partial associations between the HSC-PR total scales and subscales with temperament dimensions ($N = 327$)

	Mean (*SD*)	1	2	3	4	5	6	7	8	9	10	11
1 HSC-PR	4.57 (.90)	–										
2 HSC-PR – no item 7	4.53 (.91)	.98	–									
3 HSC-EOE	3.62 (1.31)	.84	.86	–								
4 HSC-LST	4.49 (1.56)	.78	.71	.47	–							
5 HSC-LST – no item 7	4.18 (1.84)	.72	.73	.46	.90	–						
6 HSC-AES	5.84 (.88)	.48	.48	.11	.20	.16	–					
7 CBQ-NA	4.21 (1.02)	.38	.39	.45 (.41)	.18 (−.05)	.17	.10 (.06)	–				
8 CBQ-EXTR	4.62 (.84)	−.26	−.27	−.26 (−.16)	−.26 (−.16)	−.29	.01 (.07)	−.07	–			
9 CBQ-EC	5.63 (.76)	.34	.33	.10 (−.03)	.27 (.16)	.24	**.50** (.45)	.08	−.12	–		
10 Gender		.16	.15	.08	.11	.07	.20	.12	−.11	.28	–	
11 Age		.09	.09	.05	.13	.11	.02	.05	−.10	.15	.06	–

Note. In brackets are showed the partial correlations between HSC-PR subscales and temperament dimensions. HSC-PR = Highly Sensitive Child scale Parent-Report Total Score; HSC-PR – no item 7 = Highly Sensitive Child scale Total Score excluding item 7; HSC-EOE = Ease of Excitation; HSC-LST = Low Sensitivity Threshold; HSC-LST – no item 7 = Low Sensitivity Threshold excluding item 7; HSC-AES = Aesthetic Sensitivity; CBQ-EC = Effortful Control; CBQ-EXTR = Surgency/Extraversion; CBQ-NA = Negative Affect. Gender: 1 = male, 2 = female. Given the sample size, $n = 327$, correlation values greater than .11 are significantly different from zero. According to Cohen (1988, 1992): trivial associations: r lower than $r = .10$; moderate associations: $r = 25–45$; strong association: r equal to or higher than .50. Association that was tested for divergent validity are marked in bold.

Table 3. Study 2. Multiple regression model. CBQ-VSF temperament dimensions predicting HSC-PR total score, EOE, LST, and AES ($N = 327$)

	HSC-PR			EOE			LST			AES		
Variable	B (*SE*)	β	*p*	B (*SE*)	β	*p*	B (*SE*)	β	*p*	B (*SE*)	β	*p*
Effortful control	.34(.06)	.29	<.001	.07(.08)	.04	.37	.47(.11)	.23	<.001	.58(.06)	.50	<.001
Extraversion	−.22(.05)	−.21	<.001	−.35(.08)	−.23	<.001	−.41(.10)	−.22	<.001	.08(.05)	.08	.12
Negative affect	.30(.04)	.34	<.001	.54(.06)	.43	<.001	.22(.08)	.15	<.001	.05(.04)	.07	.15

Note. HSC-PR total score: $R^2 = .28$; EOE: $R^2 = .25$; LST: $R^2 = .14$; AES: $R^2 = .26$.

for the other two sensitivity factors, likely due to having partialized out the strong correlation between AES and effortful control. In relation to the surgency/extraversion temperament dimension, we found a comparable trend: the association between EOE and LST with surgency/extraversion was $r = -.26$ at a bivariate level and decreased to $r = -.16$ in the partial correlation (with the same value for both factors). Conversely, the association between AES and surgency/extraversion was close to zero at the zero-order correlation level ($r = .01$), and it slightly increased when controlling for the contribution of the other sensitivity factors in the partial correlation ($r = .07$). Bivariate associations between all sensitivity and temperament dimensions were overall stable when removing item 7, which resulted to be problematic with preschoolers based on Study 1, and are reported in Table 2.

When all temperament dimensions were included simultaneously in a multiple regression model as predictors of the HSC-PR total score, the three dimensions combined explained 28% (29% excluding item 7) of the variance of the HSC-PR scale. Pertaining to the HSC-PR factors, the three temperament dimensions combined explained 25%, 14%, 26% for EOE, LST, and AES, respectively. Estimated parameters are reported in Table 3.

Divergent validity between HSP-PR and temperament dimensions was explored limited to the association between AES and effortful control, as this was the only correlation with Pearson's r equal to .50. The HTMT ratio value was .60, providing support for divergent validity.

Discussion

Study 2 aimed at exploring bivariate associations between sensitivity and established temperament dimensions, providing a picture of how sensitivity assessed with the HSC-PR format is associated with other individual traits assessed with traditional temperament measures. Overall, sensitivity was moderately associated with the three temperament dimensions of surgency/extraversion, negative affect and effortful control. This result is in line with recent studies and a meta-analysis that showed that sensitivity measured with either the child-report HSC scale or the observational rating system HSC-RS is relatively distinct from other common individual traits (Lionetti, Aron, et al., 2019; Lionetti, Pastore, et al., 2019; Pluess et al., 2018). When excluding item 7 from the sensitivity total score, correlational values remained stable (as expected, given it represented only one item out of 12), and only a slightly stronger negative association was found between LST and surgency/extraversion when excluding item 7. Furthermore, sensitivity was slightly associated with gender in the absence of a correlation with age, which is consistent with a previous study on observed sensitivity (Lionetti, Aron, et al., 2019). Regarding association between sensitivity and negative affect, we found a moderate correlation. This correlation was mainly driven by the EOE factor, and was stable when controlling for the other two sensitivity dimensions. Conversely, the association between LST and negative affect decreased when controlling for AES and EOE, suggesting a

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stronger contribution of the EOE factor to the dark side of sensitivity. The association between sensitivity and negative affect is consistent with the literature reporting positive and moderate associations between sensitivity and neuroticism in adolescent and adult samples, and sensitivity and negative affect in child samples (Lionetti, Pastore, et al., 2019). Our study suggested that this association is likely driven by the perception of being overwhelmed by stimuli, as reflected in EOE items. We also found a moderate association between sensitivity and the temperament dimension of effortful control, mainly driven by the contribution of the AES factor. This strong association remained stable after controlling for the other two sensitivity dimensions. Similarly, the bivariate association between effortful control and both LST and EOE decreased when taking into account the contribution of AES. Important to note, the effortful control (EC) scale in the very short version of the CBQ, used in the current study, includes items referring to intensity pleasure and perceptual sensitivity (e.g., "my child is quickly aware of some new item in the living room"). These items are similar to those of the AES scale, and they are also included in the openness personality factor, previously found to correlate with AES in adolescent and adult samples (Bröhl et al., 2022; Lionetti et al., 2018). Though both AES and effortful control capture aspects of attention to environmental details and perceptual sensitivity, the follow-up test with HTMT provided evidence that AES can still be discriminated from the effortful control dimension, suggesting that AES may capture sensitivity to specifically positive experiences.

Notwithstanding the associations between sensitivity and temperament, results from the multiple regression model suggest that the three temperament dimensions in total accounted for only around a third of the variance in HSC-PR, a result comparable to that found in relation to the child-report version of the scale (Pluess et al., 2018). When considering each HSC-PR factor as an outcome variable separately, results were comparable to that of the total score, except for LST, for which temperament dimensions in total accounted for only 14% of its variance. This suggests that LST may capture aspects that are more specific to sensitivity and not otherwise reflected in existing temperament questionnaires.

Study 3

Study 3 aimed to investigate the moderating role of the HSC-PR scale regarding the association between parenting stress and children's emotion regulation in an independent sample of $N = 112$ school-age children (age range: 5–8 years) in order to explore whether the parent-report version of the HSC scale does capture individual differences in sensitivity. We expected the HSC-PR to significantly interact with parenting stress in predicting children's emotion regulation competences, in line with recent empirical findings based on self-reported (Nocentini et al., 2018; Pluess et al., 2017, Pluess & Boniwell, 2015), parent-reported (Slagt et al., 2018), and observer-rated sensitivity (Davies et al., 2021; Lionetti, Aron, et al., 2019; Lionetti et al., 2021), with higher sensitivity reflecting stronger responses to parenting.

Method

Participants

The sample included 112 mothers and their school-age children. Children were on average 6.53 years old (range: 5–8 years; $SD = .58$) and 51.8% were female. We recruited participants from three different primary schools in central Italy with flyers over a period of three months. Mothers were asked to fill out paper questionnaires.

Measures

Environmental Sensitivity. Children's environmental sensitivity was assessed using the HSC-PR. For the current sample, Cronbach's α for HSC-PR total scale was .75 with [.74, .78] as 95% CI.

Emotion regulation. Children's emotion regulation was measured using the Emotion Regulation (ER) subscale of the ERC (Shields & Cicchetti, 1997), Italian validated version (Molina et al., 2014). The 8 items are rated by parents on a 4-point Likert scale and assess the frequency of behaviors and situationally appropriate affective displays, empathy, and emotional self-awareness with higher scores indicating greater capacity to manage one's emotional arousal (Molina et al., 2014). In the current sample, internal consistency of the ER subscale was low ($\alpha = .54$ dropping out item 23 with [.39, .66] as 95% CI), but consistent with internal reliability shown in the Italian validation of the measure ($\alpha = .59$; Molina et al., 2014).

Parenting stress. Parenting stress was assessed using the 36-item PSI-Short Form (Abidin, 1995), Italian version (Guarino et al., 2008). The scale measures on a 5-point rating scale the parent's perception of insufficient resources to cope and foster everyday demands and their child's demands, as well as the parent–child interaction and factors that may affect parenting practices. For the current sample, internal consistency for PSI total scale was good ($\alpha = .90$ with [.87–.92] as 95% CI).

Data analysis

First, we conducted analysis on missing data and descriptive statistics. Then, we computed bivariate associations among HSC-PR total score, ER subscale, and PSI total score. In order to interpret results, we considered the effect size of Pearson's r as low if r varies around .10 or less, as medium if r varies around .30, and large if r is higher than .50 (Cohen, 1988, 1992). Afterwards, we ran a series of multiple regression models with three steps. In the first step, we included parenting stress as predictor of children's emotion regulation competences. In the second step, we added HSC-PR as predictor variable, and in the last step, we performed an interaction model that included HSC-PR in interaction with PSI total score. In order to evaluate whether the inclusion of the interaction term improved predictive capability of the model, we compared the main effect model (with parenting stress total score and HSC-PR as predictors) with the interaction model using the AIC (Akaike, 1974), the BIC (Schwarz, 1978), and Akaike weights (Burnham & Anderson, 2002). In addition, for descriptive purposes, we also considered the variance explained by the model. According to AIC and BIC criteria, the lower the value the better the model is at predicting new data, while for Akaike weights, ranging from 0 to 1, the higher the value, the better the model is at describing data accurately (McElreath, 2016; Vandekerckhove et al., 2015; Wagenmakers & Farrell, 2004). Finally, we followed up the statistically significant interaction by means of a conditional interaction plot with simple slopes to represent the relation between parenting stress and emotion regulation at the 30th and the 70th percentile of HSC-PR (Lionetti, Aron, et al., 2019 and Pluess et al., 2018), before calculating the Proportion of the Interaction index (PoI; Roisman et al., 2012), according to which values ranging between .20 and .80 (Del Giudice, 2017) are supportive of a Differential Susceptibility effect. All analyses were run using the statistical software R (R Core Team, 2020), with package stats. The fully anonymized dataset is available under request to corresponding authors.

Table 4. Study 3. Bivariate associations between HSC-PR total and subscales, PSI total, and ER ($N = 112$)

	Mean (*SD*)	1	2	3	4	5
1 HSC-TOT	4.76 (.93)	–				
2 ER	3.32 (.33)	−.001	–			
3 PSI-TOT	1.82 (.46)	.29	−.31	–		
4 Age		.05	.001	.10	–	
5 Gender		.09	.21	−.17	−.14	–

Note. HSC = Highly Sensitive Child scale Total Score; ER = Emotion Regulation; PSI-TOT = Parenting Stress Total Score. Gender: 1 = male, 2 = female. Given the sample size, $N = 112$, correlation values greater than .19 are significantly different from 0. According to Cohen (1988, 1992): trivial associations: r lower than $r = .10$; moderate associations: $r = 25–45$; strong association: r higher than .50.

Table 5. Study 3. Comparison of regression models ($N = 112$)

Models	R^2	BIC	AIC	delta	Akaike weights
Interaction model (parenting stress * HSC-PR total score)	.15	62.66	49.29	.00	.68
Parenting stress	.10	58.02	49.99	2.42	.20
Main effects model (parenting stress + HSC-PR total score)	.11	62.58	51.89	3.48	.12

Note. HSC-PR = Highly Sensitive Child scale – parent report.

Results

Bivariate associations

Overall, missing data in the total sample ($N = 112$) affected a very small proportion (0.80%) and hence, as in Study 2, mean imputation was applied. The HSC-PR total score mean was 4.76 ($SD = .93$). All descriptive statistics and bivariate associations among the HSC-PR total score, ER subscale, PSI total score, gender, and age are reported in Table 4. Bivariate associations varied from trivial to low/moderate, with the HSC-PR correlating with gender (1 = male, 2 = female) and age at $r = .09$ and $r = .05$, respectively, and with parenting stress at $r = .29$, but not with emotion regulation ability ($r = -.001$).

Main effect model

The model including only main effects suggested that parenting stress was negatively and significantly related to emotion regulation (B = −0.23 (.06), $p \leq .001$). No significant associations were identified between HSC-PR and emotion regulation ability (B = 0.03 (.03), $p = .30$). The model R-square, the AIC, the BIC, and model weighs are reported in Table 5.

Interaction effect model

When the interaction term was added to the regression model, values of information criteria decreased, suggesting a better prediction capability of the interaction model compared to the main effect model, and AIC weight increased (the BIC criteria was comparable between main and interaction effects). More specifically, HSC-PR significantly interacted with parenting stress in predicting emotion regulation ability (B = −0.16 (.07), $p = .01$).

Follow-up exploration of the interaction effect

In Figure 2, we provide a conditional interaction plot, with simple slopes to illustrate the relationship between parenting stress and emotion regulation conditioned at the 30th and the 70th percentile of HSC-PR (4.17 and 5.33, respectively). The plot suggested a Differential Susceptibility pattern, for better and for worse, though the response to the benefit of low levels of parenting stress seemed to be less pronounced than the disadvantage when exposed to high levels of stress. The PoI index of .32 was confirming this interpretation, providing support for a Differential Susceptibility effect (Del Giudice, 2017).

Discussion

The aim of Study 3 was to examine whether sensitivity captured with the parent-report measure moderates the association between parenting stress and children's emotion regulation. HSC-PR was found to interact with parenting stress in the prediction of children's emotion regulation with highly sensitive children showing less emotion regulation when parenting stress was high, but more when parenting stress was low. According to the follow-up analysis of the interaction effect, both the conditional plot and the PoI index were supportive of a Differential Susceptibility pattern, suggesting an interaction effect for better and for worse, though the advantage seemed slightly less pronounced than the disadvantage. These results are consistent with previous findings in a Dutch sample where parent-reported sensitivity of children moderated effects between parenting quality and children's externalizing behavior problems (Slagt et al., 2018). Alternatively, it might be that less stressed parents perceive their children as better able to regulate their own emotions, or that parents with lower levels of distress are less disturbed by their child's emotional reactions. Future studies should continue to investigate if the parent-report version of the HSC also moderates the impact of other environmental influences – such as the emotional climate in the parent-child relationship experienced at home – on children's socio-emotional outcomes. Further research should also consider independent informants (e.g., see Lionetti, Aron, et al., 2019; Moscardino et al., 2021) such as teacher reporting on child behaviors (Pluess & Belsky, 2010), and investigate predictors and/or outcomes at an observational level in larger samples.

General discussion

A growing number of empirical studies have shown that children differ in their environmental sensitivity with some more reactive to the quality of their rearing environment than others (Belsky & Pluess, 2009; Boyce & Ellis, 2005; Ellis et al., 2011; Pluess, 2015). The first aim of the current paper was to investigate the psychometric properties of the parent-report measure of the Highly Sensitive Child scale (HSC-PR; Slagt et al., 2018). The second aim was to explore associations between the HSC-PR and well-established temperament traits. The third objective aimed at investigate whether environmental sensitivity captured by the parent-report questionnaire would moderate the impact of parenting stress on child emotion regulation.

Psychometric properties of the HSC-PR

Findings of Study 1 suggest that the parent-report version of the HSC has good psychometric properties across a wide age range. Consistent with recent CFAs of the self-report measure for

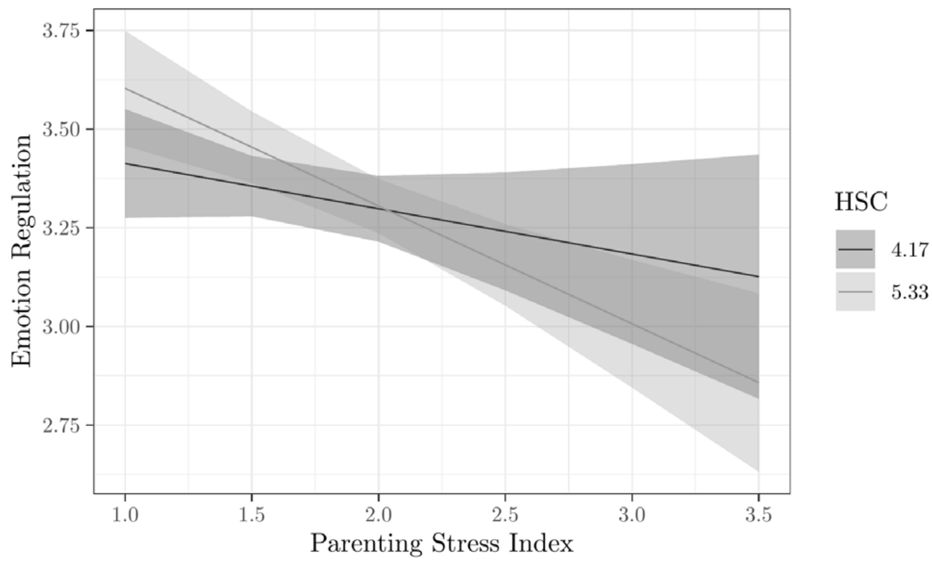

Figure 2. Study 3. Conditional interaction plot. Each line represents the relation between parenting stress and emotion regulation conditioned to the 30th and the 70th percentile of HSC-PR scores (respectively 4.17 and 5.33) bands represent the uncertainty of estimates (95% Confidence Interval) (N = 112).

children (Pluess et al., 2018) and for adults (Lionetti et al., 2018; Pluess et al., 2020), the HSC-PR seems to fit best with a bi-factor model which includes the three factors but also a general sensitivity factor across all 12 items for school-age children. Hence, though the scale captures different components of environmental sensitivity – sensitivity to sensory stimuli (LST), sensitivity to overstimulation (EOE), and sensitivity to the aesthetic quality of the environment (AES) – it does also reflect a general sensitivity trait, consistent with the empirical literature and the theoretical definition of the environmental sensitivity. Pertaining to preschoolers, some estimation problems were found in relation to item 7, which refers to exposure to violence on TV, and performed poorly in preschoolers. Besides being the item with the highest number of missing values in younger children in our sample, it had a negative variance when tested in the context of a bi-factor model, suggesting that this item might be problematic in this age range. In addition, in Study 2, the internal consistency of the specific factor item 7 belonged to (i.e., LST) increased when the item was removed. Most likely, the low performance of this item is due to the fact that younger children generally are less likely to experience exposure to violent content in TV programs. Hence, alternative items may need to be developed for this age range. For example, considering the exposure to conflict in the family environment or among characters in cartoon animations for children (e.g., “my child doesn't like watching TV programs and child movies where characters are fighting and loudly arguing”), or items referring to children’s reactions to sensory stimuli (e.g., “my child doesn't like chaotic and noisy situations”, “my child complains about scratchy clothing, seams in socks, labels against skin, or to sandy or wet clothes”, see Aron, 2002; Boterberg & Warreyn, 2016).

Associations with temperament

The moderate associations with temperament dimensions provide empirical support that the sensitivity trait is relatively distinct from other common individual traits, consistent with recent studies and a meta-analysis (Lionetti, Aron, et al., 2019; Lionetti, Pastore, et al., 2019; Pluess et al., 2018). Further, Study 2 provides in-depth information on how the three sensitivity factors of HSC-PR are associated with temperament dimensions. More specifically, whereas EOE seems to be more strongly associated with traits that reflect sensitivity to negative environmental factors (e.g., negative affect), AES correlates with measures that may confer sensitivity to more positive experiences (e.g., effortful control which includes items referring to intensity pleasure, perceptual sensitivity, and facets related to openness personality dimension). Findings from partial correlations support such relatively strong contribution of both EOE and AES factors to the association between sensitivity and temperament dimensions of negative affect and effortful control, respectively. Indeed, when controlling for the other two dimensions, associations between EOE and negative affect as well as AES and effortful control remained stable, while the associations with the other two dimensions (LST and AES or LST and EOE) decreased or remained trivial. These findings fit well with different theoretical models of environmental sensitivity (Pluess, 2015) according to which a heightened sensitivity is for better and for worse. Applied to the parent-report measure of environmental sensitivity, the total score of the scale may capture such general sensitivity to both negative and positive environments as described in the Differential Susceptibility model combining both sensitivity to adversities, as measured with EOE and LST factors, and sensitivity to positive experiences, as reflected in AES factor. Finally, important to mention, while temperament explained only a third of the variance of the sensitivity measure, and this was true both when considering the summary score and the EOE and AES factors, the LST variance explained by temperament was even lower (about half), suggesting that LST captures specific aspects of sensitivity, not reflected in currently available temperament questionnaires.

Empirical evidence for the moderating effects of the HSC-PR

Results from multiple regression models testing the interplay between sensitivity and the environment showed the parent-rated questionnaire for children’s sensitivity moderated the associations between parenting stress and children’s competence in emotion regulation. According to follow-up analyses with simple slopes, children scoring high in sensitivity were more strongly affected by parenting stress compared to children scoring low. More specifically, highly sensitive children compared to their low sensitive peers showed lower emotion regulation competences when parenting stress was higher, and better emotional competences when

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parenting stress was low. We can hypothesize that the stronger emotional reactivity found in highly sensitive individuals (Aron et al., 2012; Lionetti et al., 2018; Pluess et al., 2020) might lead to difficulties in regulating emotions when the environment is not positive enough. Similar findings have been found with observational studies, providing evidence that regulatory competences in highly sensitive children are hampered by low parenting quality (Lionetti et al., 2021). Importantly, at the same time, children high in sensitivity were more positively influenced by low levels of parenting stress. Though low levels of stress in caregiving do not necessarily fully capture an enriched positive environment, results suggest that children with high environmental sensitivity were particularly able to benefit from environments characterized by lower levels of negativity, with applied implications for informing parenting programs. For example, as we provided evidence that sensitivity can be easily and reliably investigated via a parent-report measure, parents can be further sensitized on the relevance of considering differences in children's sensitivity levels, and familiarized with what sensitivity is by referring to contents as captured by the HSC-PR scale's items. Importantly, though the parent-report version of the HSC scale appears to be a promising and psychometrically sound psychological marker of environmental sensitivity, future studies should continue investigating whether the HSC-PR does predict individual differences (i.e., children social competence, behavioral problems) in response to other environmental influences, such as parenting quality, education, and peer influence, as theory and several empirical studies featuring the self-report measure and the rating system suggest.

Strengths and Limitations

The current multistudy paper is composed of three studies, with a large sample size in Study 1. Our sample was a normative, low-risk sample. We collected data involving families living in no particularly risky areas of central Italy and recruited from schools located in typical neighborhoods. Findings provide empirical evidence in support of the HSC-PR as a psychometrically robust measure, that captures parent-reported environmental sensitivity in children as an individual trait that correlates to some extent with other temperament traits while also do not completely overlapping with any of these, nor with their combination. Importantly, findings also suggest the need of some rewording or editing for the use of the scale with preschoolers. However, the findings should also be considered in light of some limitations. Most importantly, the samples included parents residing in one single country and all data were based exclusively on the single-informant perspective of the mothers. Future research should consider the inclusion of other informants (e.g., fathers), and explore whether findings are stable depending on the eyes of the observer. We invited mothers to compile the questionnaire as in Italy the primary caregiving figure, spending more time with children, is the mother (ISTAT, 2016, 2019). Hence, we hypothesised mothers to have a broader access to child's behaviors to code for sensitivity levels, but future studies should consider if differences exist between caregivers when rating their children's sensitivity levels. Furthermore, our study lacks some forms of reliability (e.g., test–retest reliability) and validity (e.g., testing for convergent validity with the self-report scale or with an observational measure) which should be considered in future studies. In addition, while we were able to count on a large sample size for Study 1, the sample in Study 3 was relatively small. Further research should consider the inclusion of observational measures for both the quality of the environment (i.e., parenting quality, parenting stress) and children's developmental outcomes as well as a larger sample size. Finally, we tested the HSC-PR scale measurement invariance across developmental periods. We considered preschoolers and school-age children up to pre-adolescence for theoretical reasons (as the parent-report format was firstly adopted with preschoolers in Slagt et al., 2018, but the same items were used in a self-report format up to adolescence in Pluess et al., 2018), and for practical reasons, that is, for reaching as many families as possible. However, future studies should consider comparing groups of a narrower age-range (e.g., preschool period, vs. middle childhood and preadolescence).

Conclusion

Theoretical models and empirical studies (Aron & Aron, 1997; Belsky et al., 1998; Belsky & Pluess, 2009; Boyce & Ellis, 2005; Del Giudice et al., 2011; Obradović & Boyce, 2009; Pluess & Belsky, 2010; Pluess, 2015; Slagt et al., 2016) suggest that children differ in the degree they react to environmental quality, with some more vulnerable when facing adversities but also more likely to flourish when exposed to positive experiences, as a function of individual differences in sensitivity. Such differences in sensitivity can be measured in children and adults with questionnaires. Findings from this paper provide evidence for the good psychometric properties of the parent-report version of HSC scale, which can be potentially adopted by parents to deepen their understanding on their children's sensitivity levels, and by practitioners working in the field, to better tailor support and intervention programs. Moreover, our findings suggest that a revision of the item 7 of the HSC-PR scale may be a better option for younger ones. Importantly, the observed associations among the HSC-PR and established temperament dimensions (i.e., negative affect and effortful control) confirm sensitivity as largely distinct from other temperament traits (Lionetti et al., 2018; Lionetti, Pastore, et al., 2019; Pluess et al., 2018). In relation to the measure's ability to capture environmental sensitivity in response to the environment, findings suggest that children scoring high in sensitivity were more negatively influenced by a rearing environment characterized by high levels of parenting stress but, though to a slightly less extent, they also benefited more from low levels of parenting stress. This result is coherent with the literature reporting parenting stress to negatively impact on children's emotional development (Mathis & Bierman, 2015; Spinelli et al., 2021), and it add to these showing that highly sensitive children are more vulnerable in this regard. In relation to the bright side of sensitivity, though we did not consider differences in outcomes for different levels of positive parenting (as low levels of parenting stress do not necessarily capture a highly positive rearing environment), for low levels of parenting stress an advantage (even if comparatively minor) was present, in line with a Differential Susceptibility pattern.

In conclusion, the current paper suggests that it is possible to measure environmental sensitivity reliably in children through the Highly Sensitive Child scale parent-report version. The availability of validated measures covering different age ranges may further contribute to the study of the stability of individual difference in sensitivity across the life span. As a partly heritable individual trait with a genetic basis (Assary et al., 2020; Keers et al., 2016), we assume environmental sensitivity to be stable across the life span, but very little is known in this regard at this stage. A parent-report and reliable scale may represent an additional tool through which further explore this developmental, longitudinal perspective in empirical studies.

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Conflicts of interest. None.

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