

UNIVERSITY OF PAVIA – IUSS SCHOOL FOR ADVANCED STUDIES PAVIA

Department of Brain and Behavioral Sciences (DBBS)
MSc in Psychology, Neuroscience and Human Sciences



**UNIVERSITÀ
DI PAVIA**



IUSS

SENSORY PROCESSING SENSITIVITY AND EMOTIONAL AND PHYSIOLOGICAL REACTIVITY TO CRYING INFANTS

Supervisors:

Prof. Francesca Lionetti

Dr. Alessandra Peluzzi

Thesis written by:

Vita Jamila Keil

Academic year 2025/2026

Index

Index.....	2
Abstract.....	5
1. Introduction and background	7
1.1. Sensory processing sensitivity.....	7
1.1.1. Introduction	7
1.1.2. Environmental sensitivity and SPS	9
1.1.3. Assessment and subdimensions of SPS	10
1.1.4. SPS in relation to other traits.....	12
1.1.5. Heritability and etiology of SPS.....	14
1.1.6. The impact of rearing environments	16
1.1.7. Interoception and SPS.....	18
1.1.8.1. Emotional reactivity and SPS	19
1.1.8.2. Contradicting results of physiological and emotional reactivity	21
1.1.9. Highly sensitive parents	23
1.2. Other sensory processing theories	25
1.3. Theory of mind	26
1.4. Skin conductance	27
1.5. Habituation to sensory stimuli.....	28
1.6. Aims.....	29

2. Research hypothesis	31
3. Method.....	34
3.1. Participants	34
3.2. Procedure.....	35
3.3.1. Tools	36
3.3.2. Additional tools	38
3.4. Coding the answers/data	39
3.5. Analysis of data	40
4. Results	42
4.1. Self-reported physiological and emotional reactivity	42
4.2. Skin conductance responses	44
4.3. The moderating role of the rearing environment.....	44
4.4. Alignment between physiological and self-reported arousal	45
4.5. Types of emotional responses (irritation/concern)	46
4.6. Stability of findings across HSP-12 and HSP-R	48
4.7. Correlations between questionnaires.....	49
5. Discussion.....	50
5.1. Self-reported physiological and emotional reactivity	50
5.2.1. Skin conductance responses	51
5.2.2. Can the rearing environment be an explanation?	52
5.2.3. Can interoception be an explanation?	53

5.3. Irritation and concern	54
5.4. HSP-R and HSP-12	55
5.5. Other variables to explore	56
5.5.1. Regular exposure to children	56
5.5.2. Neuroticism	57
5.5.3. Sensory perception	57
5.5.4. Sensory habituation	58
5.5.5. Theory of mind	58
5.5.6. HSP-12 and HSP-R factors	59
5.6. Limitations and recommendations for future research.....	59
6. Conclusion	63
References.....	65

Abstract

Sensory processing sensitivity (SPS) is a temperamental trait characterised by deeper processing of environmental and social information, heightened awareness of subtle cues, and stronger emotional responsiveness. Although SPS has often been associated with increased physiological reactivity, empirical findings have been mixed, and recent work suggests that highly sensitive individuals may not consistently show stronger physiological responses, and that developmental context, particularly the quality of the rearing environment, may help to explain this variability.

This study examines how SPS relates to emotional and physiological reactivity to videos presenting two stimulus conditions: infant crying and control videos of construction work. Physiological and emotional reactivity is assessed both through self-reported measures and through skin conductance responses (SCR) within a sample of 42 female adult university students. The study further investigates whether the quality of the rearing environment moderates these associations, meaning that the strength or direction of the relationship between SPS and reactivity may vary depending on the person's rearing environment. Finally, it examines whether SPS is linked to stronger correspondence between self-reported physiological arousal and SCR.

Videos of crying infants evoked overall higher emotional and physiological reactivity than control videos. Even though SPS was associated with moderately elevated self-reported reactivity, especially for control conditions, SCR was not significantly influenced by neither SPS nor stimulus type. The rearing environment did not moderate these associations, although negative rearing environments showed a slight positive association with irritation. SPS was linked to a stronger correspondence between SCR and perceived physiological arousal, suggesting heightened interoceptive atonement.

To conclude, these findings contribute to a more nuanced understanding of SPS and they showcase the value of integrating subjective and physiological measures in SPS research.

1. Introduction and background

1.1. Sensory processing sensitivity

1.1.1. Introduction

Humans are not unique in differing in how strongly they take in and respond to the world around them. Many species show a variety of temperament styles that prove advantageous under different conditions. Zebra finches exemplify this idea. These small, social birds show a range of personalities, from shy to bold. Some individuals approach the world cautiously while others dive straight into new experiences. In a study of wild-breeding finches, David et al. (2011) found that these differences are of big importance. In calm, low-stress environments, the shy, observant birds did very well. They formed more harmonious pair bonds, invested more consistently in parental care, and raised more offspring that survived. The bolder birds gained an advantage when life became more competitive or unpredictable, as their quick exploration and willingness to take risks helped them secure limited resources. As each temperament thrives under different circumstances, both are maintained within this population (David et al., 2011). Although this study does not describe sensitivity as seen in humans, it illustrates how natural variation in responsiveness can be beneficial in various contexts. People also vary in how deeply they process and react to the world around them. One framework used to explain these differences is Sensory Processing Sensitivity (SPS).

SPS is a temperamental or personality trait characterised by heightened awareness of and responsivity to external and internal stimuli (Aron et al., 2012). It was first introduced by Elaine and Arthur Aron in 1997 as a trait describing highly sensitive persons (Aron & Aron, 1997). Individuals high in SPS typically exhibit features including greater sensitivity to environmental stimuli and others' emotions, amplified

depth of processing, and increased tendencies towards self-reflection, creativity, empathy, and intuition. At the same time, they may be more prone to feeling overwhelmed in situations involving excessive demands, high levels of incoming information, competition, or when being observed (Acevedo et al., 2020).

Empirical research generally provides findings consistent with this theory and supports the assumption that individuals scoring high in SPS are more sensitive to environmental influences across different contexts. For instance, brain imaging studies have shown that higher SPS is associated with greater activation in brain regions involved in secondary visual processing (Jagiellowicz et al., 2011) as well as areas related to empathy, attention, and awareness (Acevedo et al., 2014). Other studies suggest that people with higher scores in SPS are more affected by environmental influences, including daily life events (Van Reyn et al., 2023) and parenting quality (Slagt et al., 2018). Several studies illustrate that school-based psychological intervention programmes have stronger effects on individuals high in SPS. These include an anti-bullying intervention by Nocentini et al. (2018), a depression prevention program by Pluess and Boniwell (2015), as well as a more recent intervention program fostering identity exploration in multiethnic classrooms by Creccon et al. (2023).

The tendency to more easily experience stress and overstimulation has also been investigated empirically by linking higher SPS to enhanced work stress (Evers et al., 2008) and more common burnout symptoms (Golonka & Gulla, 2021).

Studies have shown that individuals differ in their levels of sensitivity, with approximately 20-30% of the population estimated to fall within the higher sensitivity range (Acevedo, 2020). A large-scale empirical study by Lionetti et al. (2018) reported that 31% of the participants were highly sensitive, 29% were low in sensitivity, and

40% exhibited medium levels of sensitivity. Researchers have also noted gender differences in the manifestation of the trait. Women tend to score overall higher in SPS than men (Trå et al., 2023), and highly sensitive men tend to face difficulties in relation to traditional masculine socialisation (Miller & Lynch, 2024).

1.1.2. Environmental sensitivity and SPS

Environmental sensitivity (ES) is an umbrella term for a group of theories explaining individual differences in the ability to register and process environmental factors (Pluess, 2015). Since the late 1990s, several theories falling under this umbrella term have examined individual differences in ES with different points of view. SPS is one of these theories, and although it has its own specific focus, it is influenced by and partially overlaps with other approaches to ES.

The *diathesis–stress model* proposes that psychopathology emerges from an interaction between stressful life circumstances and a pre-existing vulnerability, or diathesis. This vulnerability may appear in biological, cognitive, or social fields, and it increases an individual's likelihood of developing a disorder when exposed to significant stress (Monroe & Simons, 1991). In contrast, the theory of *vantage sensitivity*, proposed by Pluess and Belsky (2013), focuses specifically on heightened responsiveness to positive experiences without making assumptions about reactions to adversity. Building on this view, *differential susceptibility theory*, proposed by Jay Belsky (1997), argues that highly sensitive individuals are more responsive to both negative and positive environments. This heightened responsiveness is thought to be an evolutionarily maintained form of developmental plasticity, through which the same individuals who do worse in negative environments may also benefit disproportionately from positive ones (Belsky & Pluess, 2009). According to the *biological sensitivity to*

context model, individuals who grow up in either highly stressful/adverse environments or highly supportive/enriched environments develop heightened physiological reactivity. This elevated reactivity makes them more biologically susceptible to environmental influences, showing worse outcomes in harsh contexts but better-than-average outcomes in supportive ones (Boyce and Ellis, 2005). Finally, *sensory processing sensitivity* sees sensitivity as a measurable temperament trait characterised by deeper processing of information, heightened emotional and empathic responsiveness, increased sensitivity to subtle environmental details, and a lower threshold for overstimulation (Aron et al., 2012).

Taken together, these theories suggest that a minority of individuals are especially responsive to both positive and negative environments. Depending on the context, this sensitivity can be linked to either a greater risk or greater benefit (Pluess, 2015; Greven et al., 2019).

1.1.3. Assessment and subdimensions of SPS

One of the most widely used indicators for SPS is the highly sensitive person scale that consists of 27 items (HSP-27). It is a self-report measurement developed by Aron and Aron (1997). In the creation of this scale, a total of 39 adults, who identified themselves as highly sensitive, easily overwhelmed by stimuli or introverted, were interviewed and their answers were captured in a 60-item questionnaire. Later, the questionnaire was tested on over 900 participants in a series of 6 studies, and so the 27-item questionnaire was created with a high internal consistency reliability (cronbach's $\alpha = .87$), believed to capture a single sensitivity factor.

Subsequently, several studies have demonstrated the validity of a three-factor solution, rather than a one-dimensional characteristic of SPS. These three factors are:

low sensory threshold (LST), that signifies an unpleasant sensory arousal to external stimuli (e.g., item 25: Are you bothered by intense stimuli, like loud noises or chaotic scenes?); ease of excitation (EOE), which is the tendency to easily be overwhelmed by internal and external stimuli (e.g., item 14: Do you get rattled when you have a lot to do in a short amount of time?); and aesthetic sensitivity (AES), which reflects the richness of individuals' inner lives and pleasure felt from positive stimuli (e.g., item 8: Do you have a rich, complex inner life?) (Smolewska et al., 2006).

This finding was further developed, and a bifactor structure was suggested (Pluess et al., 2018; Lionetti et al., 2018). In this model, the general factor of SPS reflects an overall tendency to process environmental stimuli deeply and respond more strongly to both positive and negative experiences, whereas the three specific factors (LST, EOE, and AES) capture more distinct aspects of sensitivity (Pluess et al., 2018; Lionetti et al., 2018).

In 2023, Pluess et al. reviewed the HSP-27 scale and selected items that best represented each of the three factors, with a factor loading coefficient higher than .50, while keeping the proportional representation of each subscale. As a result, a 12-item reliable measure of SPS under the name HSP-12 was created. HSP-12 had similar or better psychometric properties than the original scale and an internal consistency of $\alpha = .84$ (Pluess et al. 2023).

Additionally, several versions to measure SPS in children were developed. Among these are a parent-reported (Slagt et al., 2018; Sperati et al., 2024) and a child-reported (Pluess et al., 2018) questionnaire. Even an observational procedure under the name the highly sensitive child rating system (HSP-RS) was developed for children aged 3-5

(Lionetti et al., 2019). The observed child gets rated on a 10-item rating scale, often measuring the child's cautiousness in a new environment.

As research increasingly showed that SPS is not a single, uniform trait but rather a multidimensional one, the original HSP scale came to be seen as needing revision. (Pluess et al., 2025). Although the three-factor structure is supported by the HSP scales, the original HSP-27 was not designed to reflect this differentiation. The majority of items measuring EOE and LST are negatively worded, while AES items are phrased more positively or neutrally. This imbalance has been suggested to bias total scores toward negative aspects of sensitivity and may partly account for the scale's moderate correlation with neuroticism. To address these limitations, Pluess et al. (2025) revised the measure and created the HSP-R scale, using a large adult sample ($N = 1000$) and factor-analytic procedures. This measurement aims to reflect the core components of sensitivity, to balance positive and negative items and to reduce bias. The scale identifies six distinct dimensions of sensitivity: sensitivity to details, depth of processing, social sensitivity, sensitivity to positive experiences, emotional reactivity, and overstimulation. Moreover, the HSP-R scale correlates highly with both HSP-27 and HSP-12 ($r = .76, p < .001$ for both scales) (Pluess et al., 2025).

1.1.4. SPS in relation to other traits

Many studies have examined how SPS relates to other personality and temperament traits. Because some findings become non-significant after controlling for neuroticism, researchers have debated whether SPS might simply reflect a subtype of neuroticism or a combination of neuroticism and empathy (Schaefer et al., 2022, Buchtova et al., 2025). However, all extensive studies show that SPS is a distinct trait with its unique structure and cannot be completely reduced to or explained by other traits. At the same

time, SPS does show partial overlaps with other traits (Pluess et al., 2018; Lionetti et al., 2019).

A recent meta-analysis by Tang et al. (2025) analysed a total of 81 studies and around 60 000 participants from different cultures to map these overlaps. Tang et al. show that SPS is positively correlated with neuroticism ($r = .46$), has a weak negative correlation to extraversion ($r = -.15$) and shows a small positive link to openness ($r = .12$). At the temperament level, SPS is positively correlated with negative affectivity ($r = .46$) and with the behavioural inhibition system (BIS) ($r = .44$), whereas correlations with the behavioural activation system (BAS) are smaller ($r = .20$) (Tang et al., 2025).

Importantly, these associations differ across the three SPS subdimensions. EOE and LST show particularly strong associations with neuroticism and negative affectivity, indicating a heightened negative emotional reactivity. For example, EOE is strongly correlated with neuroticism in adults ($r = .65$). In contrast, AES demonstrates a distinct pattern, showing a strong positive correlation with openness in adults ($r = .54$) and moderate correlation with BAS (e.g., $r = .43$ in European samples). This differentiation suggests that EOE and LST primarily capture vulnerability to overstimulation and stress, whereas AES reflects heightened responsiveness to positive and aesthetic stimuli (Tang et al. 2025).

Furthermore, the strength of these associations varies across developmental stages and cultural regions. The relation between SPS and neuroticism is stronger in adults ($r = .52$) than in children and adolescents ($r = .35$). Likewise, the correlations between AES and openness are also more pronounced in adulthood ($r = .54$ compared to $r = .22$). Regionally, SPS shows stronger correlation with negative affectivity in European

samples ($r = .50$) compared to Asian samples ($r = .30$), highlighting cultural variability in the expression of sensitivity.

Despite these variations, network analyses once again reveal that SPS forms a distinct, coherent construct that cannot fully be explained by other traits (Tang et al., 2025).

1.1.5. Heritability and etiology of SPS

Research consistently indicates that SPS is an innate, genetically based trait. A large twin study by Assary et al. (2021) shows that SPS is moderately heritable, with genetic factors accounting for approximately 47% of the variation. The remaining variance is explained by non-shared environmental influences, and no evidence of shared environmental influences was found. The twin study found that much of the genetic influence on SPS overlaps with personality traits, particularly neuroticism and extraversion, whereas environmental influences were largely unique to sensitivity (Assary et al. 2021).

Beyond heritability estimates, Keers et al. (2016) applied a genome-wide approach to identify genetic variants associated with differential susceptibility by examining within-pair variability in emotional problems among monozygotic twin pairs. From these findings, they developed a polygenic score, with most loci being novel and not previously linked to emotional sensitivity. The score was then tested as a moderator of environmental influences in two independent child samples. Across both samples, children with higher scores showed greater responsiveness to environmental conditions, displaying both increased vulnerability under adverse circumstances and enhanced benefits under supportive ones. These results suggest that the polygenic score is

associated with heightened susceptibility to environmental influence (Keers et al., 2016).

Other molecular genetic studies have identified biological mechanisms underlying SPS. Naumann et al. (2020) highlight several candidate genes, particularly within the serotonergic and dopaminergic system, including the DRD4 7-repeat allele (Bakermans-Kranenburg & van Ijzendoorn, 2011) and the short allele of the serotonin transporter gene (5-HTTLPR) which was linked to higher SPS, increased emotional reactivity (Licht et al., 2011) and differential susceptibility (Pluess et al., 2010; Van Ijzendoorn et al., 2012). Chen et al. (2011) identified ten polymorphisms across seven dopamine genes associated with SPS, and later work linked these variants to reduced regional homogeneity in the praecuneus, which predicted higher SPS (Chen et al., 2015). Similarly, the Epigenetic findings further suggest that environmental exposures, such as prenatal stress, may shape sensitivity by altering gene expression, as seen in animal studies (Hartman et al., 2018).

In a more recent work, Weyn et al. (2025) examined both a candidate-gene cumulative polygenic score and several genome-wide association study (GWAS) polygenic risk scores in a large sample of preschoolers. These scores estimate how many genetic variants associated with a trait a person carries, based either on a small set of candidate genes or on findings from large genome-wide association studies. The candidate-gene score, based on classic susceptibility variants such as 5-HTTLPR, DRD4, DRD2, DAT1, COMT, and BDNF, did not significantly predict observer-rated sensitivity. Among the GWAS polygenic scores, only the attention deficit hyperactivity disorder (ADHD) polygenic scores showed a significant association, and in the negative direction, indicating that a higher genetic propensity for ADHD was linked to lower

observed sensitivity. All other polygenic scores (e.g., neuroticism, anxiety, depression, cognitive performance, extraversion) showed no significant associations. Weyn et al. (2025) interpret ADHD as reflecting opposite behavioural tendencies to SPS. ADHD is associated with impulsivity and low inhibition, whereas SPS is characterized by carefulness, inhibition, and deeper processing. Overall, these results suggest that current GWAS-based polygenic scores capture only a small parts of the genetic variance underlying the trait (Weyn et al., 2025).

Neurobiological research complements these genetic findings. Functional magnetic resonance imaging (fMRI) show that highly sensitive persons have stronger activation in brain regions involved in attention, awareness, empathy and higher order processing, including the insula, inferior frontal gyrus, cingulate cortex, and parietal areas (Acevedo et al., 2014; Acevedo et al., 2017). Peripheral physiological systems may also be involved in the trait. The hypothalamic-pituitary-adrenal (HPA) axis, regulating stress responses, is a mechanism underlying heightened reactivity (Naumann et al. 2020), and an animal study suggests that alterations in this system may contribute to heightened stress reactivity (van der Doelen et al., 2014). Individuals high in SPS also appear more attuned to physiological signals such as hunger, blood glucose fluctuations, and pain, suggesting that sensitivity may extend to broader physiological processes (Aron et al. 2010; Naumann et al., 2020).

1.1.6. The impact of rearing environments

Since the first construction of the concept SPS, Elaine and Arthur Aron expressed that highly sensitive individuals are not inherently introverted, frazzled, overwhelmed or shy. Rather, these characteristics may appear when sensitive individuals are exposed to overly stimulating situations or if raised in environments that were stressful, harsh,

abusive, or impoverished (Aron & Aron, 1997; Acevedo, 2020). The manifested characteristics are believed to be the outcome of the interaction between sensitivity and environmental context, rather than the trait itself. SPS is often explained with the orchid-dandelion metaphor. Orchids represent the highly sensitive group as they do exceptionally well in ideal conditions and exceptionally poorly in poor ones.

Dandelions represent less sensitive people, having strong resilience and being able to grow anywhere. The third metaphor, tulips, can describe individuals with medium sensitivity (Lionetti et al. 2018).

In a longitudinal study of 292 preschool children, Lionetti et al. (2019) demonstrated that sensitivity significantly moderates the relationship between parenting quality and developmental outcomes. Highly sensitive children were more negatively impacted by authoritarian and permissive parenting styles, assessed at age three, showing greater internalising and externalising behavioural problems even in the follow-up, at age six. The same group of highly sensitive children also benefited disproportionately from authoritative parenting, exhibiting higher levels of social competence. In contrast, children low in sensitivity showed relatively stable developmental outcomes regardless of parenting style. In a follow-up study by Lionetti et al. (2022), highly sensitive children exposed to permissive parenting also showed higher levels of rumination than their peers at age nine.

Animal research also supports the interplay between a sensitive predisposition and rearing environments. In a study by Hartman et al. (2018), pregnant prairie voles were exposed to stressors, inducing heightened ES in their offspring through epigenetic mechanisms. After birth, offspring from stressed mothers and from a control group of ordinary mothers were placed with adoptive parents. These adoptive parents were either

good caregivers or neglected the newborns. Offspring of stressed mothers raised in high-quality caregiving environments exhibited the lowest levels of anxiety-like behaviour and corticosterone reactivity, even outperforming less sensitive voles in the same high-quality environments. In contrast, offspring of stressed mothers raised in low-quality care displayed the highest anxiety and physiological stress responses. Neurobiologically, high-quality caregiving increased vasopressin-1a receptor density in the amygdala in the more sensitive group, whereas no impact was shown in the control group. Vasopressin-1a receptor density in the amygdala is related to social behaviour and anxiety behaviour (Nauman et al., 2020, Hartman et al., 2018, Carter et al., 2008).

1.1.7. Interoception and SPS

Interoception is defined as the perception of internal signals from the body (McDonough, 2024). SPS is considered a trait involving deeper processing of external and internal stimuli and heightened awareness of subtleties (Aron & Aron, 1997). It is therefore often hypothesized that highly sensitive individuals might show heightened interoceptive tendencies. However, research directly examining the connection between interoception and SPS remains very limited. A correlational study by Ujiie and Takahashi (2024) reported a small but significant association ($r = .15$, $p < .01$) between SPS and self-reported interoception, and similar effects were observed for the SPS subcomponents EOE and LST, but no association to AES. Another study by Jakobson et al. (2026) examined how different HSP-12 subscales relate to interoceptive tendencies within alexithymia and discovered that AES predicted more adaptive interoceptive tendencies (e.g., noticing, attention regulation, emotional awareness), whereas LST and EOE were linked to maladaptive interoceptive tendencies such as worrying about or distracting oneself from uncomfortable bodily sensations.

In a sample of adolescences Hochreuter et al. (2025) tested self-reported pain ratings in response to heat and discovered that highly sensitive individuals reported a lower pain tolerance, suggesting a stronger atonement to physical sensations.

However, currently the research still remains limited, as there is very little empirical support for the hypothesis that highly sensitive individuals show heightened interoceptive accuracy, leaving a clear gap in the current literature.

1.1.8.1. Emotional reactivity and SPS

Emotional reactivity is considered a core component of SPS (Aron et al., 2012), and early studies show that the HSP-27 scale has a strong positive correlation ($r = \sim .50$) with emotionality (Aron & Aron, 1997). Highly sensitive individuals tend to engage in more elaborative processing of environmental stimuli, which is linked to heightened emotional responsiveness with stronger affective reactions, both positive and negative. Moreover, this is believed to support learning, memory, and the evaluation of experiences (Aron et al., 2012).

The association between SPS and emotional reactivity, including heightened empathy and attention towards emotional information, has been found in both self-report and neuroimaging studies. Laros-van Gorkom et al. (2024) discovered significant associations between SPS and self-reported overall empathy ($\beta = .43$), affective empathy ($\beta = .51$), cognitive empathy ($\beta = .27$), and less emotional disconnection ($\beta = .23$). Results remained significant, even when controlling for openness to experience (Laros-van Gorkom et al., 2024). In another study by Jagiellowicz et al. (2016) participants reported their emotional arousal to emotional pictures and rated the valence of these pictures. Highly sensitive individuals rated the pictures, especially positive ones, as significantly more valanced, and tended to respond faster to the positive

pictures. Interestingly, not all sensitive individuals reported greater arousal, but only individuals high in SPS, who had also reported having high-quality parenting (Jagiellowicz et al., 2016).

In a neuroimaging study, participants viewed positive, negative and neutral facial expressions of their romantic partners and of strangers (Acevedo et al., 2014). fMRI results show that higher SPS across all conditions was associated with increased brain activation of regions involved in awareness, attention and action planning (cingulate and premotor area). Additional results show stronger activation in the highly sensitive group in areas involved in integration of sensory information, emotional processing, empathy, self-other understanding, and higher-order cognition (e.g., cingulate, insula, inferior frontal gyrus, middle temporal gyrus, and premotor area). Although these responses were observed for both partners and strangers displaying positive, negative, and neutral facial expressions, they showed selectivity for partners and positive emotions. These findings support the research suggesting that SPS is associated with enhanced awareness and behavioural readiness to respond to salient environmental stimuli (Acevedo et al. 2014).

Another neuroimaging study by Schaefer et al. (2022) recorded fMRI data while participants experienced physical touch by the experimenter. The researchers concluded that higher SPS was not associated to a stronger activation of primary or secondary somatosensory responses, but to increased activity on the posterior insular cortex (Schaefer et al., 2022). This brain region is connected to bodily awareness, as well as localization of somatic events, and has a pathway to the amygdala through which it can shift behavioural strategies in response to aversive internal states (Gehrlach et al., 2019; Uddin et al., 2017).

A study by Mutschler et al. (2016) provides further evidence for individual differences in emotional reactivity to salient social stimuli such as infant crying, integrating self-report, physiological, and neural measures. In their experiment, healthy female participants were repeatedly exposed to video clips of crying infants while emotional responses (valence, arousal, irritation), SCR and neural activation (fMRI) were recorded simultaneously. Individual differences in neuroticism were linked to stronger emotional reactivity across all levels of measurement: participants high in neuroticism exhibited greater amygdala and anterior cingulate cortex activation, higher SCR, and reported more irritation and more negative valence in response to infant crying. The authors hypothesised that SPS should have a significant association with emotional reactivity and suggested a replication including HSP measures (Mutschler et al., 2016).

Overall, several studies suggest that highly sensitive individuals show stronger emotional responses, greater empathy and direct more attention towards emotional stimuli. This emotional responsiveness may, on the one hand, facilitate attuned responses to others, as shown for example in parents (Lionetti et al., 2026) and young adults (Mastromatteo et al., 2024), where sensitivity was found to influence how individuals engage in cooperative behaviour depending on their physiological regulation. Emotional responsiveness can, on the other hand, increase susceptibility to overstimulation, distress and emotional problems, including anxiety and depressive symptoms (Assary et al., 2024; Aron & Aron, 1997).

1.1.8.2. Contradicting results of physiological and emotional reactivity

Although emotional reactivity is a central component of SPS, this association has in recent years shown to be more complex. A discrepancy has become increasingly evident

in SPS research, where heightened emotional responsiveness does not reliably translate into stronger physiological activation.

In particular, several studies report weak or inconsistent associations between self-reported SPS and measured physiological responses (Weyn et al., 2022; Weyn et al., 2025). In their 2022 study, Weyn and colleagues examined whether SPS predicted cortisol reactivity in adolescents during the trier social stress test for children (TSST-M), but found no association. In 2025, the researchers again measured cortisol reactivity in response to small stressors, this time in preschoolers, as well as resting-state electroencephalogram (EEG) asymmetry and polygenic scores. Once again, physiological measures, including cortisol reactivity and EEG asymmetry, showed no significant associations with SPS (Weyn et al., 2025).

A recent study by Lionetti and Nava (2025) further supports this view by showing that sensitivity alone does not predict stronger physiological reactivity. Instead, children's stress responses measured through SCR, depend strongly on the interplay between sensitivity and the quality of their attachment relationships, with secure attachment buffering and insecure attachment amplifying reactivity. However, the size of these effects was very small and should be interpreted with caution (Lionetti & Nava, 2025).

These inconsistencies suggest that physiological reactivity may not be a universally defining characteristic of SPS. One possible explanation for this is that physiological reactivity is shaped by rearing environments rather than being a stable indicator of the trait. In line with the biological sensitivity to context model, individual differences in stress responsivity may emerge through adaptive calibration processes across development (Del Giudice, 2017, Boyce and Ellis, 2005). Consistent with this view, the

adaptive calibration model proposes that early environmental conditions shape stress-response systems, resulting in different patterns of physiological reactivity. For example, individuals raised in extreme early environments, both highly stressful and highly supportive, are thought to up-regulate stress responsivity, whereas moderate environments tend to down-regulate it (Del Giudice et al., 2011). This suggests that sensitivity may be better understood as an adaptive capacity that enables flexible responses to environmental conditions, rather than as a fixed tendency toward heightened physiological reactivity (Greven et al., 2019).

Another potential explanation for the discrepancy between self-assessed and physiological assessments relates to interoceptive processes. Highly sensitive individuals may be particularly attentive to their internal bodily states rather than just more physiologically reactive. According to this theory, differences in perceived reactivity may arise from greater attention to physiological signals and interoceptive attention rather than from objectively stronger physiological responses (Murphy et al., 2019; Ujiie & Takahashi, 2024).

1.1.9. Highly sensitive parents

Parents of young children are continuously exposed to intense sensory and emotional stimuli, making individual differences in SPS relevant to understanding parenting. Research on SPS and parenting has been limited, and parenting has mostly been assessed with self-report measures. These studies generally suggest that higher SPS is associated with more perceived parenting difficulties, such as greater stress, inconsistency, and psychological intrusiveness, but also with higher perceived atonement to the child (Aron et al., 2019; Goldberg & Scharf, 2020). However, self-report findings may be influenced by the enhanced awareness of highly sensitive

individuals, who may perceive and report subtle aspects of their parenting more readily (Lionetti et al., 2026).

A study by Lionetti et al. (2026) observed parent-infant interactions at the ages of 3 months and 9 months. The findings were more complex than earlier studies suggested. Higher SPS was associated with more intrusive behaviours when infants were 3 months old, consistent with prior studies' findings. It suggests that higher sensitivity levels may complicate parenting and that noticing subtler details may make parents overrespond to small signals, leading to intrusive behaviours. Interestingly, at 9 months of age, higher SPS was linked to less intrusive parenting. This was explained as highly sensitive parents being more able to leverage their heightened attention to the specific behaviour and characteristics of their child. No consistent associations emerged for other parenting dimensions such as sensitive caregiving or structuring the time together (Lionetti et al., 2026).

In the second part of this study, researchers controlled for respiratory sinus arrhythmia (RSA) and adverse childhood experiences (ACE). RSA is a marker of the parasympathetic nervous system through the vagal nerve, and an indicator of one's regulation competence. High RSA was associated with more positive parenting behaviours among highly sensitive parents, while lower RSA showed a trend toward less adaptive caregiving among this same group. When controlling for ACE, higher SPS was associated with less positive parenting behaviours and greater parenting stress, but only among caregivers who had experienced multiple ACEs. This finding once again highlights the importance of the rearing environment in shaping the manifestation of the trait. Overall, SPS may function as both a risk factor and a resource in parenting, depending on parents' past experiences and regulatory capacities (Lionetti et al., 2026).

1.2. Other sensory processing theories

Sensory functioning has been conceptualised through multiple theoretical frameworks separate from ES, each describing how individuals register, interpret, and respond to environmental stimulation. One influential approach is Dunn's sensory processing theory, developed within occupational therapy. This theory proposes that individuals differ in their neurological thresholds for detecting sensory input and in the behavioural strategies they use to manage stimulation (Dunn, 1997; Dunn, 2001). Based on the interaction of these two continua (high vs. low thresholds and active vs. passive behavioural responses), four processing styles can be distinguished that describe ways to respond to sensory inputs (Dunn, 1997; Dunn, 2001). Behaviours such as avoiding or seeking stimulation are understood as adaptive strategies with their origins in the underlying thresholds, meaning that the sensory processing theory primarily captures behavioural patterns in relation to sensory environments rather than internal emotional or cognitive processing (Levit-Binnun et al., 2014). Turjeman-Levi and Kluger (2022) investigated the relationship between sensory processing theory and SPS in a large sample. Although their measures were moderately associated (e.g., some subscales correlated up to $r = 0.63$), the researchers concluded that the two constructs represent related but distinct dimensions of individual differences.

An additional theoretically distinct perspective is the sensory perception theory, which focuses on basic perceptual thresholds rather than behavioural strategies or depth of processing (Tavassoli et al., 2014). This approach originates primarily from autism research, where atypical sensory reactivity is understood as a function of heightened or reduced detection and discrimination abilities across sensory modalities. Tavassoli et al. (2014) emphasise that existing sensory questionnaires, including the sensory profile,

often merge perception with affective or behavioural reactions, making them unsuitable for measuring basic sensory function. To address this gap, they developed the sensory perception quotient (SPQ), which only investigates basic sensory sensitivity, with no reference to affective response. The SPQ assesses hyper- and hyposensitivity in vision, hearing, touch, smell, and taste.

1.3. Theory of mind

Theory of mind (ToM) refers to the capacity to accurately interpret others' thoughts, intentions, and emotions (Alvi et al., 2020). ToM enables individuals to explain and predict others' behaviour by reasoning about their underlying beliefs, desires, and emotions. Because ToM involves inferring unobservable mental states, it is assessed through behavioural tasks, such as the false-belief task, that reveal how individuals interpret mental states from observable actions (Wellman, 2014). One widely used measure is the triangles task, in which participants view animated geometric shapes whose movements imply intentionality or emotional states (Abell et al., 2000).

Within the broader literature of interpersonal sensitivity, ToM is considered a core component of social cognitive ability (Tabak et al., 2022). In their investigation of the association between SPS and different forms of interpersonal sensitivity, Tabak et al. (2022) distinguished between positive SPS (primarily reflected in AES) and negative SPS (primarily reflected in EOE and LST). Positive SPS showed small but consistent associations with better performance on behavioural ToM measures ($r = .17-.21$), whereas negative SPS showed no reliable relationship. Interestingly, compared with findings for other types of interpersonal sensitivity, including prosocial tendencies and social anxiety, results were less consistent across studies examining the associations between SPS factors and behavioural measures of ToM (Tabak et al., 2022). This

inconsistency was also noted by Hellwig and Roth (2021). Overall, ToM represents a distinct cognitive component of interpersonal sensitivity that is different from but moderately linked to certain components of SPS (Tabak et al., 2022).

1.4. Skin conductance

Electrodermal activity (EDA) is a measure of SCR, a physiological signal commonly used to assess emotional arousal. More specifically, EDA measures the change of SCR, though placing electrodes with a weak voltage onto the skin. The conductance between the electrodes is then measured in micro siemens (μS). Moisture on the skin decreases the resistance and, in this way, increases the conductance of the current. As sweat glands in the skin are controlled by the sympathetic and parasympathetic nervous system, higher EDA is an indicator of the activation of the sympathetic nervous system (Hamilton et al., 2024; Gonzalez-Sanchez et al., 2017). Even though SCR alone does not identify a specific emotion, a relationship has been established between the conductance of the skin and emotional arousal (Li et al 2022; Hovers et al., 2021).

EDA can be divided into tonic and phasic activity. The tonic activity can be seen as the background or baseline EDA. On the contrary, phasic activity is stimulus-dependent, starting one to four seconds after the stimulus with a duration of one to three seconds (Caruelle et al. 2019). Event-related phasic EDA is assessed through the change in amplitude of the conductance, before and after the occurrence of the stimulus (Hovers et al., 2021). SCR indicates a general emotional arousal and activity of the sympathetic nervous system and is often paired with a self-report measure of emotion to identify the emotional valence. SCR in comparison to self-report data is time-sensitive, not impacted by social desirability, and able to capture arousal not reaching our awareness (Caruelle et al. 2019).

There are a couple of limitations associated with the measurement of SCR. Caruelle et al. (2019) emphasise that SCR can be affected by other mental processes beyond just the reaction to the stimulus. They also mention that EDA signals are very sensitive to noise and connectivity issues. Movements or other sources of interference can distort the recording and complicate analysis. Finally, the authors note that individual differences, such as age (Caruelle et al., 2019), or gender, can impact baseline levels and responsiveness, with women showing greater overall changes in SCR than men (Chentsova-Dutton & Tsai, 2007).

1.5. Habituation to sensory stimuli

Habituation refers to the process through which response intensity to a stimulus decreases when that stimulus is repeated or sustained over time, enabling individuals to filter out irrelevant sensory input and reducing interference with ongoing activities (Tarantino et al., 2024). Individual differences in reactions to sensory input depend on factors such as sensory thresholds and habituation levels, making habituation an important component of sensory and cognitive functioning (Tarantino et al., 2024). For this reason, habituation is often examined when using physiological and neuroimaging measures. Studies show that repeated exposure to the same stimulus leads to decreased responses across multiple response systems. For instance, reduced activation in regions involved in emotional processing, such as the amygdala, as well as lower autonomic activity, measured in SCR (Mutschler et al., 2016). These decreases reflect how emotional and physiological reactions change over time and are therefore essential for understanding how individuals adapt to repeated environmental stimulation (Mutschler et al., 2016).

Importantly, individual differences in sensory habituation are closely related to sensory sensitivity. Using the sensory habituation questionnaire (S-Hab-Q), Tarantino et al. (2024) showed that slower habituation, reflected in higher S-Hab-Q scores, is associated with higher sensory sensitivity. This indicates that individuals with slower habituation experience prolonged sensory stimulation and may feel overwhelmed by continued exposure. These findings suggest that the slower habituation processes may contribute to variability in sensory responsiveness (Tarantino et al., 2024). However, it is important to point out that sensory sensitivity was measured in accordance with the sensory perception theory, measured with the SPQ and not HSP measures, and therefore focuses on general sensory sensitivity rather than SPS specifically (Tarantino et al., 2024). Although this relationship has not been directly examined using HSP measures, the observed link between high sensitivity and slower habituation suggests that differences in habituation processes may contribute to broader patterns of ES (Tarantino et al., 2024; Mutschler et al., 2016).

1.6. Aims

The present study aims to expand previous research on SPS and emotional reactivity and to examine whether individual differences in SPS are connected with differences in emotional and physiological responses to infant crying. In particular, the study investigates whether, when exposed to emotionally salient videos of crying infants, individuals high in SPS show stronger self-reported emotional and physiological reactivity and stronger SCR, compared to non-social, acoustically matched control videos displaying construction work, and compared to less sensitive individuals.

A second aim is to examine whether the quality of the rearing environment, assessed through retrospective reports of parental acceptance and rejection, moderates the

association between SPS and physiological responses to infant crying. This study wants to investigate the hypothesis that emotional and physiological responses may not be fixed markers of SPS but may vary depending on developmental conditions.

A third aim is to explore whether SPS is linked to a stronger correspondence between objectively measured physiological activation and subjective reports of physiological arousal. This is to investigate whether highly sensitive individuals may be more attuned to their bodily responses.

A fourth aim is to examine the type of emotional response elicited by the videos, focusing on irritation and concern/care. Specifically, the study assesses whether SPS or the rearing environment are associated with differences in irritation and concern/care following the video clusters.

A fifth aim is to examine whether the results remain robust irrespective of whether SPS is measured with HSP-12 or HSP-R. Because HSP-R is a new measurement and there is less evidence of its robustness, it could be necessary to compare the two measures to see if the results of both assessments correspond with each other.

Finally, a last aim is to examine the correlations between SPS and neuroticism, sensory habituation, and sensory perception. Although these variables are not analysed in relation to reactivity in this thesis, they are included in the procedure because this work is part of a broader research project. Their correlation with SPS provide valuable insight into how these constructs relate and will be examined here as they can help guide future research.

2. Research hypothesis

In line with the first aim, the study hypothesises that all participants will have stronger physiological and emotional reactivity (SCR and self-report) to emotionally salient stimuli than to emotionally neutral stimuli. Additionally, the study predicts that highly sensitive individuals will overall score higher on physiological and emotional reactivity than individuals low in sensitivity across both types of stimuli. Moreover, the research anticipates that an interaction effect will showcase a stronger increase in reactivity among the highly sensitive group in reaction to socially salient stimuli (*Figure 1*). This is connected to the assumption that highly sensitive individuals process stimuli more deeply and are more emotionally reactive.

Regarding aim two, the rearing environment is expected to moderate the relationship between SPS and reactivity. Individuals raised in either highly stressful and adverse environments or in extremely supportive contexts may develop heightened physiological responsiveness in line with the biological sensitivity to context model. This environmental influence is expected to be more pronounced among individuals high in SPS, who are thought to react more strongly to both negative and positive environments.

Connected to aim three, the study predicts that SPS will be associated with stronger correspondence between objectively measured physiological activation and subjective reports of physiological and emotional arousal. Specifically, individuals higher in SPS are expected to show a stronger positive association between SCR and self-reported physiological and emotional reactivity than individuals lower in SPS. This hypothesis is based on the idea that highly sensitive individuals may be more attentive to internal

bodily signals, leading to greater alignment between physiological responses and perceived bodily arousal.

Regarding aim four, the rearing environment is expected to influence the qualitative nature of the emotional response to infant crying, with more adverse rearing environments being associated with higher irritation and lower concern/care, and more supportive rearing environments being associated with lower irritation and higher concern/care. In contrast, SPS is not expected to influence the type of emotional reaction, but rather to be associated with an overall increase in emotional reactivity.

Concerning aim five, the research expects the results to be robust, regardless of the scale used to measure SPS (HSP-R or HSP-12), as the two scales have previously shown to be highly correlated.

Finally, considering aim six, neuroticism is expected to correlate moderately with SPS, as consistently shown in previous research, with a stronger association observed for the HSP-12 compared to the HSP-R. Sensory habituation is also expected to show a positive correlation to SPS, in line with literature suggesting that sensitive individuals may habituate more slowly to repeated stimuli. Sensory perception is anticipated to correlate partially with SPS, reflecting shared aspects while still remaining conceptually distinct, as the two constructs capture different aspects of sensory processing.

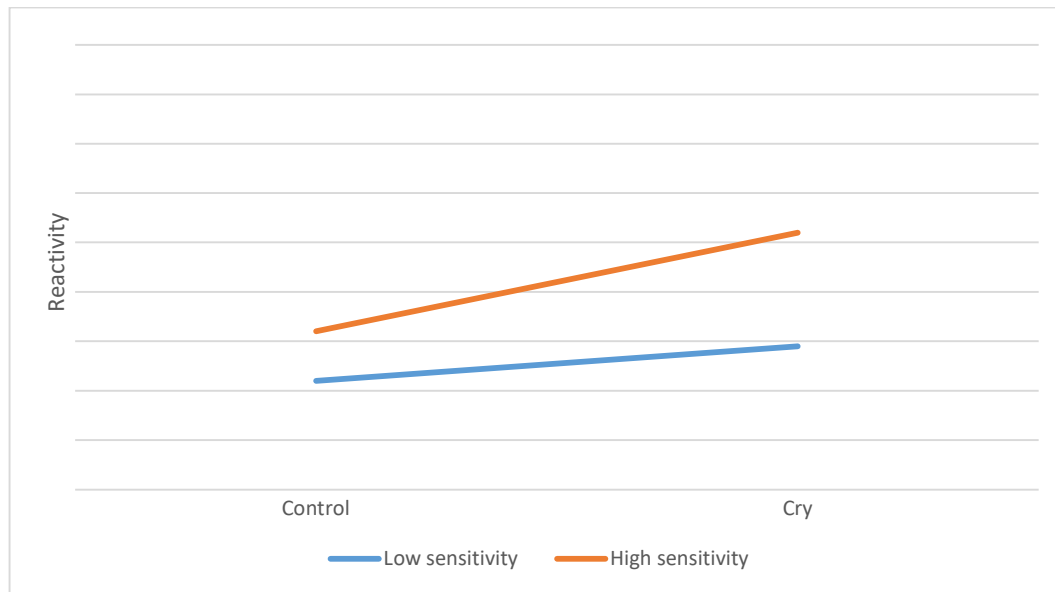


Figure 1: Hypothesis: Emotional reactivity to emotionally salient stimuli of crying infants and control stimuli for individuals low and high in SPS. Reactivity is in this hypothesis generalised as a combination of self-reported physiological and emotional arousal, as well as SCR scores.

3. Method

3.1. Participants

The sample consisted of $N = 42$ female adults, mainly recruited from the University of Pavia through flyers, posters, newsletters and in person recruitments during lectures (*Table 1*). All participants were fluent in Italian. Participants were rewarded with one quarter university educational credit.

Age	25.3 (SD 7.1)
Main occupation	
Student (of psychology)	64.3% (27)
Student (other)	11.9% (5)
PhD student	11.9% (5)
Working professional	11.9% (5)
Country of upbringing	
Italy	90.5% (38)
Other	9.5% (4)
Cultural impact	
Italian	81.0% (34)
Mixed/other	19.0% (8)
Younger siblings	
Yes	50.0% (21)
No	50.0% (21)
Regular contact with children	
As parents	7.1% (3)
Through work	31.0% (13)
Through close family	35.7% (15)
Through another context	2.4% (1)
None	33.3% (14)

Table 1: Participant Demographic Information

The study was approved by the ethics committee of the department of brain and behavioural sciences of the University of Pavia and was conducted in accordance with institutional and international ethical guidelines.

3.2. Procedure

After informed consent, participants completed the following questionnaires: the highly sensitive person 12-item scale, the big five inventory neuroticism subscale and the adult parental acceptance-rejection questionnaire.

Participants were then exposed to two categories of videos with both image and sound, edited to have the same mean sound intensity (-12.4 dBFS) and peak intensity (-1.2 dBFS). The videos were shown on a computer screen with noise-cancelling headphones at a volume of 30. Participants were instructed to take off jewellery, keep their eyes on the screen and not to move during the videos. The two categories were composed of (1) 10 social and emotional videos of crying infants. No other noises or objects were present in the videos (e.g., no intervening parents). (2) 10 control videos of emotionally neutral construction work (no faces or social interactions were shown). The videos were all seven seconds long and were presented in four clusters, each cluster consisting of five videos of either the experimental or control condition. Videos within clusters were randomised, and the order of the clusters was counterbalanced across participants. SCR was recorded continuously on the non-dominant hand.

After each video, participants self-evaluated experienced physiological arousal and emotional arousal. After each cluster, participants self-evaluated the valence of their emotions, indicating the level of concern and irritation. For concern, the Italian word “premuroso/a” was used, which translates into both care and concern. In order to minimise the participants’ movements, it was the examiner who started the videos and turned the pages of the questionnaires.

Additionally, participants completed the animated triangles task and finally filled out the sensory perception short form questionnaire, the sensory habituation questionnaire and the highly sensitive person revised scale.

Participants were tested one at the time, and the total duration of the study was one hour.

3.3.1. Tools

This thesis is part of a broader research project, and the present thesis focuses on a selected subset of variables that are directly relevant to its aims. These primary measures are described below, while additional measures collected as part of the wider project are presented separately in Section 3.3.2.

Demographic data, including age, occupation, cultural impact, and regular exposure to children, were measured with a 7-item demographic questionnaire.

SPS was evaluated with two self-reported questionnaires: (1) The *Highly Sensitive Person Scale* (HSP-12, Pluess et al., 2023), a 12-item questionnaire with a 7-point Likert scale, validated in an adult sample in Italy (Lionetti et al., 2024). The HSP-12 captures the three factors of SPS: low sensory threshold, ease of excitation, and aesthetic sensitivity. (2) The *Highly Sensitive Person Revised Scale* (HSP-R, Pluess et al., 2025), a new questionnaire with the validation for the Italian population not yet published. HSP-R consists of 18 items, rated on a 7-item Likert scale, and assesses six dimensions of sensitivity: sensitivity to details, depth of processing, social sensitivity, sensitivity to positive experiences, emotional reactivity, and overstimulation. SPS was considered as a continuous score in line with the empirical literature.

Characteristics of the rearing environment were recorded with the *Parental Acceptance-Rejection Questionnaire* (Adult-PARQ, Rohner et al., 2005), a 48-item self-

report and retrospective questionnaire, assessing characteristics of the rearing environment. The questionnaire assesses the characteristics of one's rearing environment and the relationship between child and caregiver one/mother (24 questions) and caregiver two/father (24 questions). Adult-PARQ assesses four factors: (a) warmth and affection, (b) hostility and aggression, (c) indifference and neglect, and (d) undifferentiated rejection. The Italian version by Sense et al. (2016) was used, and the original 4-point Likert scale was changed to a 7-point Likert scale ranging from 1 = not true at all/per niente vero to 7 = very true/molto vero. Items concerning mother/caregiver 1 were only provided when participants responded yes to: When you were between the ages of 7 and 12, were you in regular contact with your mother or a similar caregiver (e.g., an aunt who may have raised you)?/Quando eri in un'età compresa fra i 7-12 anni, eri in contatto regolare con tua madre o una figura di riferimento paragonabile (es. una zia che potrebbe averti cresciuto)? Items concerning father/caregiver 2 were only provided when participants responded yes to: When you were between the ages of 7 and 12, were you in regular contact with your father or a similar figure (e.g., a grandparent who may have raised you)?/Quando eri in un'età compresa fra i 7-12 anni, eri in contatto regolare con tuo padre o una figura di riferimento paragonabile (es. un nonno che potrebbe averti cresciuto)?

SCR was acquired using a Biopac MP150 System Inc. and the AcqKnowledge software (AcqKnowledge 5.0, Biopac Systems Inc.). The electrodes were filled with gel 101A, an isotonic electrode gel for EDA. They were then placed on the fingertips of the index finger and ring finger of the non-dominant hand, and a reference electrode was placed on the lower arm. To synchronise each video stimulus with the autonomic signal,

digital triggers were sent and stored in the recording system representing the start of every video.

Subjective physiological and emotional reactivity were measured with two self-reported items after each video on a paper-based 10 cm long visual analogue scale (VAS) (*Indicate your emotional arousal on a scale of 0 to 100/indica il tuo livello di attivazione emotiva da 0 a 100; Rate your physical arousal on a scale of 0 to 100/indica il tuo livello di attivazione fisica da 0 a 100*). Emotional valence was measured with two self-reported items on a 10 cm long VAS after each cluster of videos (*Indicate how irritated you felt on a scale of 0 to 100/indica quanto ti sei sentito irritato/a da 0 a 100; Indicate how concerned you felt on a scale of 0 to 100/indica quanto ti sei sentito premuroso/a da 0 a 100*), as similarly used in previous research (Hiraoka & Nomura, 2016; Riem et al., 2012; Mutschler et al., 2016).

All questionnaires used an informal Italian language, and the questionnaires originally addressed the participant with the formal “lei” were changed to use the informal “tu”.

3.3.2. Additional tools

The following measures were also administered as part of the broader research project. They are not included in the analyses in relation to reactivity of the present thesis but explored in relation to SPS to direct future research.

Neuroticism was rated with the neuroticism subscale of the *Big Five Inventory* (BFI, John et al., 1991), and was included as it correlates with SPS to some extent. This is an 8-item, self-report questionnaire with a 5-point Likert scale, validated in an Italian adult population (Ubbiali et al., 2013). In order to increase continuity, we used a 7-point Likert scale ranging from 1 = not at all/per nulla to 7 = completely/completamente.

Sensory perception was measured with the *Sensory Perception Quotient Short Forms* (SPQ SF 35, Tavassoli et al., 2014). This self-report questionnaire consists of 35 items rated on a 4-point Likert scale and assesses sensory perception across vision, hearing, touch, smell and taste. The Italian translation by Keller and Brighenti was used. With the aim to increase coherence between the questionnaires, the order of the Likert scale was reversed, and ranged from 1 = strongly disagree/*fortemente in disaccordo*; 4 = strongly agree/*fortemente d'accordo*, instead of 1 = strongly agree/*fortemente d'accordo*; 4 = strongly disagree/*fortemente in disaccordo*.

Sensory habituation was self-reported with the *Sensory Habituation Questionnaire* (S-Hab-Q, Podoly & Ben Sasson, 2020). The questionnaire comprises 25 items assessing the adaptation time to sensory stimuli. Specifically, participants were asked to estimate the time they usually need for habituation on a 4-point Likert across two factors: vision and hearing, as well as touch, smell and taste. The questionnaire was validated in Italy with a sample of healthy adults (Tarantino et al., 2024).

ToM was measured with the *Animated Triangles Task* (AT, Abell et al., 2000). In this task, participants watch five short and salient animations of a large red triangle and a small blue triangle and attribute mental states to these animated geometric shapes. The order of the animations was randomised, and scores range from zero to five for each video, measuring accuracy and mentalizing capacity.

3.4. Coding the answers/data

Participants were given a personal code that was used to link all data recorded across different questionnaires. The code consisted of a combination of a randomised letter and a number. To associate the responses with the participants in case they wished to

withdraw from the study, all personal codes and names were kept on the informed consent and stored in a safe place.

SCR data were processed using a high-pass infinite impulse response digital filter with a cut-off frequency fixed at 0.05 Hz. This filtering step was applied to centre the signal and reduce slow, low-frequency tonic variation while retaining the phasic SCR activity relevant to responses to the video stimuli. A peak-to-peak epoch analysis was then conducted using a 7-second epoch width, corresponding to the duration of each video stimulus. The SCR data were visually inspected and cleaned, and responses occurring in combination with disturbances or artefacts were removed from the dataset.

All data were linked through an excel query, allowing responses from the same participant to be matched across questionnaire data, self-report paper-based ratings, behavioural task scores, and SCR recordings. Within this query, reverse-scored items were recoded, and total scores for each scale and subscale were calculated.

3.5. Analysis of data

Models were estimated within a Bayesian generalized linear mixed modelling (GLMM) framework. GLMMs are useful in repeated measure designs, taking to account both within-person and across-person variability. A Bayesian approach was selected for its ability to estimate uncertainty directly and to produce stable results in smaller samples. Weakly informative priors were used to stabilise estimation and constrain model parameters to plausible ranges without strongly determining the results. VAS scores were converted from the original 0–10 cm range to the unit interval [0,1] and analysed with beta regression so the model respects the bounded scale and allows coherent priors and stable estimation. For SCR, a log transformation was applied to reduce skewness. Results are reported as estimates with 95% credible intervals (CI).

Lastly, a Pearson correlation was computed to examine the correlation between HSP-12, HSP-R, BFI-N, S-Hab and SPQ-SF-35.

4. Results

4.1. Self-reported physiological and emotional reactivity

The first model examined self-reported emotional reactivity across HSP-12 scores and conditions (crying infants or control videos) (*Figure 2*). Across participants, infant crying videos elicited higher emotional reactivity than control videos ($\beta = 1.52$, 95% CI = [1.19, 1.83]). The main effect of SPS, measured with HSP-12, on emotional reactivity was positive but not fully credible ($\beta = 0.31$, 95% CI [-0.02, 0.64]), as the credible interval bordered zero. This means that even though the estimate points toward a positive effect, the credible interval shows that the true value could lie close to zero, implying only modest evidence that individuals higher in SPS experienced stronger emotional reactions across both conditions.

When exploring interaction effects, a credible negative interaction occurred between SPS and condition ($\beta = -0.34$, 95% CI = [-0.61, -0.05]) as the difference in emotional reactivity between crying and control videos became slightly smaller at higher SPS levels. Contrary to our hypothesis, the findings suggest that highly sensitive individuals showed overall stronger reactions irrespective to the type of stimuli, meaning that they tended to report somewhat elevated emotional reactivity during the neutral construction videos in comparison to less sensitive individuals.

Regarding self-reported physiological reactivity, the research showed a similar pattern (*Figure 3*). SPS was credibly associated with higher perceived physiological activation across conditions ($\beta = 0.74$, 95% CI = [0.18, 1.28]) and infant crying videos again elicited higher overall physiological reactivity than control videos ($\beta = 1.43$, 95% CI = [0.92, 1.94]). The interaction between SPS and condition was not credible ($\beta = -0.12$, 95% CI = [-0.60, 0.35]), but it pointed in the same direction as the

emotional-reactivity model. Individuals higher in SPS tended to report slightly elevated physiological arousal even in response to emotionally neutral stimuli.

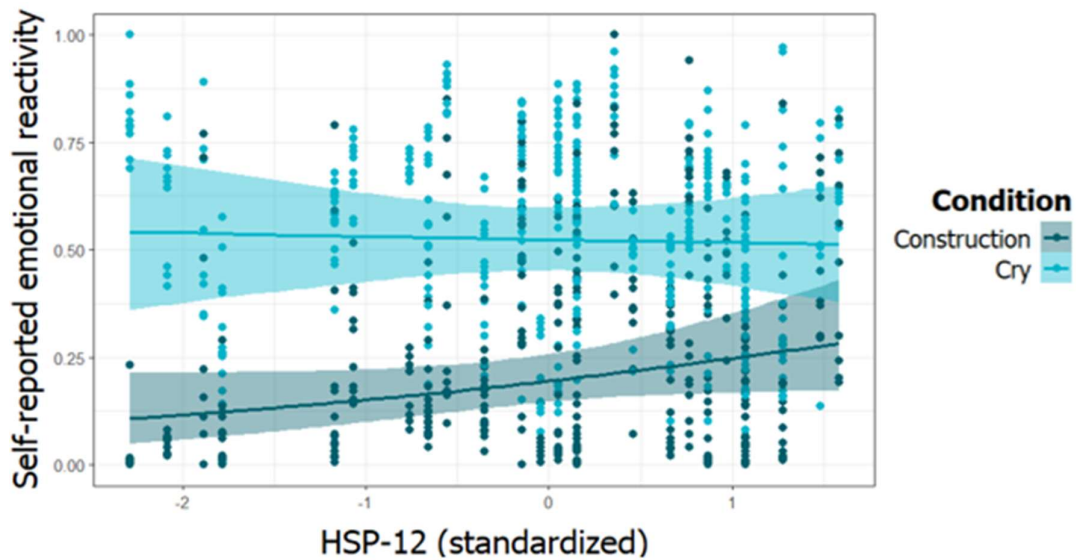


Figure 2: Scatterplot showing the association between HSP-12 (z-scored) and self-reported emotional reactivity (scaled 0–1), with observed data points and GLMM-estimated regression lines for the control and infant crying conditions.

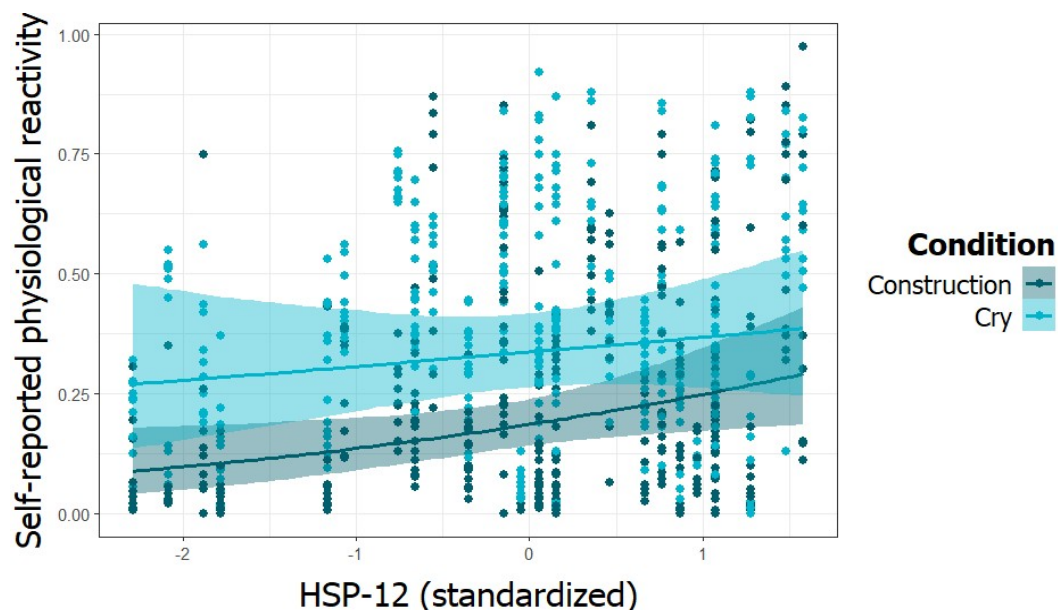


Figure 3: Scatterplot showing the association between HSP-12 (z-scored) and self-reported physiological reactivity (scaled 0–1), with observed data points and GLMM-estimated regression lines for the construction and infant crying conditions.

4.2. Skin conductance responses

In contrast, physiological reactivity measured through SCR did not show meaningful variation across SPS levels or conditions (*Figure 4*). SCR was not credibly associated with SPS ($\beta = -0.07$, 95% CI = $[-0.34, 0.21]$), and infant crying videos did not elicit reliably stronger SCR responses than control videos ($\beta = 0.06$, 95% CI = $[-0.13, 0.26]$), indicating that SCR responses did not reliably differ between the infant crying and control conditions.

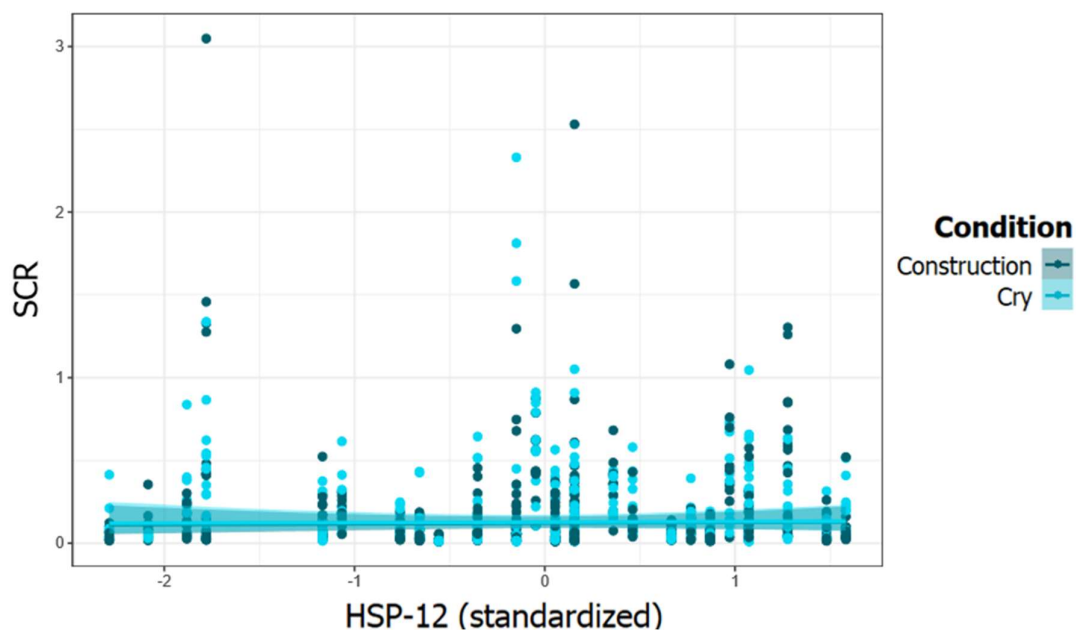


Figure 4: Scatterplot showing the association between HSP-12 (z-scored) and SCR, with observed data points and a GLMM-estimated regression line.

4.3. The moderating role of the rearing environment

Another research question examined whether the rearing environment moderated the association between SPS and physiological reactivity to the stimuli. Adult-PARQ scores did not credibly predict SCR responses ($\beta = 0.08$, 95% CI = $[-0.23, 0.38]$). Moreover, the interaction between adult-PARQ and HSP-12 was also not credible a credible

predictor ($\beta = -0.11$, 95% CI = $[-0.36, 0.14]$), indicating that the relationship between SPS and SCR did not change depending on the quality of the rearing environment.

4.4. Alignment between physiological and self-reported arousal

The third research question examined whether individuals higher in SPS showed a stronger correspondence between physiological activation, measured with SCR, and self-reported physiological reactivity. The GLMM revealed a credible interaction between HSP-12 scores and SCR in predicting self-reported physiological reactivity ($\beta = 0.16$, 95% CI = $[0.05, 0.27]$) (Figure 5). This suggests that the association between SCR and perceived physiological arousal became stronger as SPS increased. For self-reported emotional reactivity, the SCR and HSP-12 interaction was not credible ($\beta = 0.07$, 95% CI = $[-0.06, 0.19]$).

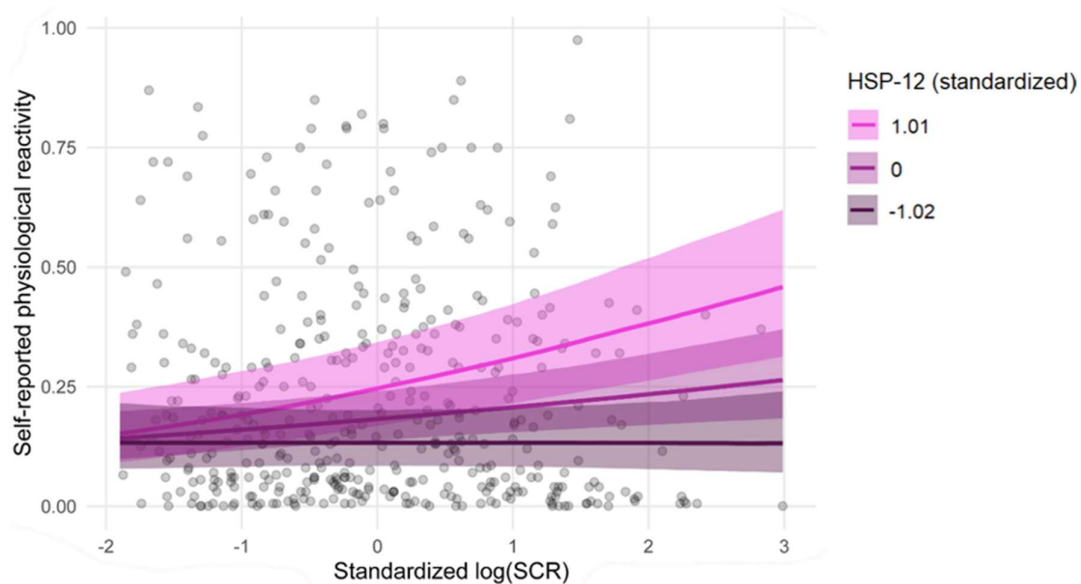


Figure 5: Scatterplot showing the association between log-transformed SCR and self-reported physiological reactivity (scaled 0–1), with observed data points and GLMM-estimated regression lines at low, medium and high levels of HSP-12. Low HSP corresponds to 1 SD below the mean, medium HSP to the mean, and high HSP to 1 SD above the mean.

Simple slope estimates (*Table 2*) further clarify this pattern. SCR was not associated with self-reported physiological reactivity at low levels of SPS ($\beta = 0.02$, 95% CI = [-0.13, 0.10]), but the association became evident at moderate levels ($\beta = 0.11$, 95% CI = [0.03, 0.19]) and was strongest at high levels of SPS ($\beta = 0.23$, 95% CI = [0.12, 0.34]), when considering both the crying and construction conditions together.

This pattern was most distinct concerning the construction condition, whereas the association was weaker and less certain concerning the infant crying condition.

Condition	HSP level	Estimate	95% CI	Interpretation
Cry	Low HSP	-0.033	[-0.17, 0.10]	No effect
	Mid HSP	0.054	[-0.05, 0.16]	Uncertain, not credible
	High HSP	0.140	[-0.01, 0.29]	Weak, borderline credible
Construction	Low HSP	0.000	[-0.16, 0.16]	No effect
	Mid HSP	0.159	[0.05, 0.27]	Credible effect
	High HSP	0.317	[0.17, 0.46]	Strong, credible effect
Both conditions	Low HSP	-0.017	[-0.13, 0.10]	No effect
	Mid HSP	0.106	[0.03, 0.19]	Credible effect
	High HSP	0.229	[0.12, 0.34]	Strong, credible effect

Table 2: Simple estimates and credible intervals of SCR predicting self-reported physiological reactivity at low, medium, and high levels of HSP-12. Low HSP corresponds to 1 SD below the mean, medium HSP to the mean, and high HSP to 1 SD above the mean.

4.5. Types of emotional responses (irritation/concern)

The next research question examined whether SPS, rearing environment, or their interaction predicted the valence of participants' emotional responses to the infant crying videos, measured as irritation and concern.

For irritation, HSP-12 scores were not a credible predictor and did not display any reliable evidence that higher SPS was associated with greater or lesser irritation in response to infant crying ($\beta = -0.11$, 95% CI = [-0.58, 0.34]). Whereas adult-PARQ

showed a positive association with irritation (*Figure 6*), that was almost credible ($\beta = 0.46$, 95% CI = [-0.01, 0.92]), with the lower bound of the interval falling only slightly below zero. This suggests that higher perceived parental rejection may be associated to greater irritation towards the cry stimuli, although this effect should still be interpreted cautiously. Finally, the interaction between HSP-12 and adult-PARQ was not credible in predicting SCR towards infant crying ($\beta = -0.26$, 95% CI = [-0.70, 0.16]). This showcase that there is no reliable evidence that rearing environment moderated the relation between SPS and irritation.

The effects connected to concern were overall weaker. HSP-12 scores showed a positive but non-credible association with concern ($\beta = 0.19$, 95% CI = [-0.15, 0.53]), while adult-PARQ showed a negative but also non-credible association ($\beta = -0.26$, 95% CI = [-0.61, 0.09]). Finally, the HSP-12 and adult-PARQ interaction was likewise not credible ($\beta = 0.24$, 95% CI = [-0.08, 0.58]).

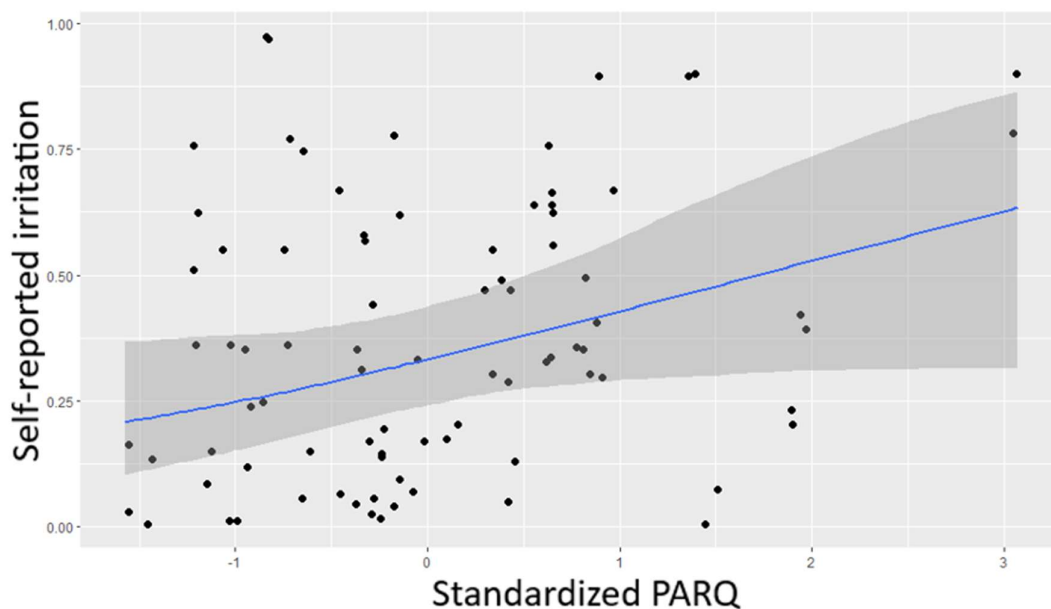


Figure 6: Scatterplot showing the association between adult-PARQ (z-scored) and self-reported irritation (scaled 0–1) in response to infant crying videos, with observed data points and a GLMM-estimated regression line.

4.6. Stability of findings across HSP-12 and HSP-R

Overall, HSP-12 and HSP-R showed a strong positive correlation ($r = 0.87$, $p < .001$, *Table 4*) and the results obtained were very consistent across the two measures.

When HSP-R was used as the indicator of SPS, the observed findings remained stable, with only minor shifts in effect magnitude (*Table 3*). The main effect of SPS on emotional reactivity became somewhat stronger ($\beta = 0.43$, 95% CI [0.12, 0.74], compared to $\beta = 0.31$, 95% CI [-0.02, 0.64] with HSP-12), whereas the main effect of SPS on physiological reactivity was slightly weaker ($\beta = 0.47$, 95% CI [0.17, 0.78], compared to $\beta = 0.74$, 95% CI [0.18, 1.28]). The interaction between condition and SPS predicting physiological reactivity also increased slightly in magnitude but remained non-credible ($\beta = -0.16$, 95% CI [-0.39, 0.06], compared to $\beta = -0.12$, 95% CI [-0.60, 0.35]). Finally, the interaction between SCR and SPS predicting physiological reactivity remained credible, although became a bit weaker when using HSP-R ($\beta = 0.12$, 95% CI [0.00, 0.23], compared to $\beta = 0.16$, 95% CI [0.05, 0.27]).

	HSP-12	HSP-R
SPS→ emotional reactivity	$\beta = 0.31$, CI = [-0.02, 0.64]	$\beta = 0.43$, CI = [0.12, 0.74]*
condition × SPS→ emotional reactivity	$\beta = -0.34$, CI = [-0.61, -0.05]	$\beta = -0.31$, CI = [-0.60, -0.01]
SPS→ physiological reactivity	$\beta = 0.74$, CI = [0.18, 1.28]*	$\beta = 0.47$, CI = [0.17, 0.78]*
condition × SPS→ physiological reactivity	$\beta = -0.12$, CI = [-0.60, 0.35]	$\beta = -0.16$, CI = [-0.39, 0.06]
SPS→ SCR	$\beta = -0.07$, CI = [-0.34, 0.21]	$\beta = -0.02$, CI = [-0.18, 0.14]
SCR × SPS→ emotional reactivity	$\beta = 0.07$, CI = [-0.06, 0.19]	$\beta = 0.11$, CI = [-0.01, 0.24]
SCR × SPS→ physiological reactivity	$\beta = 0.16$, CI = [0.05, 0.27]*	$\beta = 0.12$, CI = [0.00, 0.23]*

*Table 4: Summary of regression estimates for SCR, emotional and physiological reactivity using HSP-12 and HSP-R as indicators of SPS. *Credible effects whose 95% credible intervals do not include zero.*

4.7. Correlations between questionnaires

BFI-N, S-Hab and SPQ-SF-35 are part of a broader project, and these variables are not considered in the interaction to emotional and physiological reactivity. The Pearson's Correlation of the questionnaires still give us valuable insights to direct future research (*Table 3*). The correlation analysis shows that HSP-12 and HSP-R correlate strongly to one another ($r = 0.87$, $p < .001$). BFI-N shows a stronger correlation to HSP-12 ($r = 0.46$, $p = .001$) than to HSP-R ($r = 0.35$, $p = .016$). SPQ-SF-35 is moderately correlated to SPS with stronger correlations to HSP-R ($r = 0.44$, $p = .002$). S-Hab was strongly correlated with both SPS scales ($r = 0.71$ and $r = 0.67$, $p < .001$)

Variable		HSP-12	HSP-R	BFI-N	S-Hab	SPQ-SF-35
1. HSP-12	Pearson's r	—				
	p-value	—				
2. HSP-R	Pearson's r	0.866***	—			
	p-value	< .001	—			
3. BFI-N	Pearson's r	0.457**	0.354*	—		
	p-value	0.001	0.016	—		
4. S-Hab	Pearson's r	0.708***	0.674***	0.267	—	
	p-value	< .001	< .001	0.076	—	
5. SPQ-SF-35	Pearson's r	0.356*	0.437**	0.138	0.384**	—
	p-value	0.015	0.002	0.360	0.009	—

*Table 3: Pearson's Correlation HSP-12, HSP-R, BFI-N, Adult-PARQ, S-Hab, SPQ-SF-35. * $p < .05$,*

*** $p < .01$, *** $p < .001$*

5. Discussion

This study examined whether individual differences in SPS influenced emotional and physiological responses to infant crying, whether these associations were moderated by rearing environment, and whether higher SPS was linked to higher alignment between objectively measured physiological activation and subjective reports of reactivity. Despite the modest sample size, the study yielded several meaningful findings. The most important finding is, that individuals higher in SPS showed a stronger alignment between SCR and self-reported physiological arousal. This shows the first direct evidence of an objectively measured interoception in highly sensitive individuals, with strong and consistent psychometric support across both SPS measures. This finding is an important contribution to the literature as it supports the view that SPS may involve heightened attention to internal bodily signals rather than uniformly stronger physiological activation.

Moreover, the research highlighted that SPS was more consistently associated with higher self-reported reactivity than with SCR. In contrast, the expected moderating role of rearing environment was not clearly supported, although adult-PARQ showed a borderline association with irritation.

5.1. Self-reported physiological and emotional reactivity

The first aim was to test whether participants, and especially individuals higher in SPS, would show stronger emotional and physiological reactivity to infant crying videos than to control videos. As expected, crying-infant videos elicited higher self-reported emotional and physiological reactivity than control videos. This confirms that the infant-crying stimuli were perceived as more emotionally salient and arousing than the construction videos.

Consistent with the hypothesis, highly sensitive individuals self-reported higher overall emotional and physiological reactivity, although the evidence for emotional reactivity was weaker. On the contrary, the expected interaction between SPS and stimulus type was not supported in the predicted direction. For emotional reactivity, the interaction was credible but negative, highlighting that SPS modulated the emotional responses to the control videos slightly more than to the infant cry. As a result, the difference between crying and control videos was smaller among individuals with higher SPS. For self-reported physiological reactivity, the result indicates a similar direction, although with lower certainty.

One possible interpretation is that the emotionally salient stimuli caused uniformly high reactions across participants, potentially creating a ceiling effect. In contrast, the construction-work videos may have allowed more room for individual differences to emerge even though they were intended to evoke minimal emotional responses. Individuals higher in SPS may have engaged in deeper processing of these more ambiguous stimuli which resulted in slightly elevated self-reported reactivity even in the control condition. This interpretation aligns with the wider idea that SPS may amplify processing of subtle cues.

5.2.1. Skin conductance responses

Contrary to the initial hypothesis, SCR were not affected by stimuli condition nor by HSP-12 scores. These results contradict the expectations derived from Mutschler et al. (2016), who reported higher SCR among individuals high in neuroticism when viewing crying infants and proposed that SPS might show a similar pattern. The findings also stand in contrast to earlier work indicating that highly sensitive individuals display

heightened bodily activation in response to emotional or affective stimuli. (Acevedo et al., 2014; Schaefer et al., 2022).

The findings of this research instead suggest that highly sensitive individuals do not exhibit stronger physiological activations, neither to emotional nor to unemotional stimuli compared to less sensitive individuals. This is consistent with recent research that suggests that SPS is not associated with heightened physiological responses in a uniform matter (Weyn et al., 2022; Weyn et al., 2025; Lionetti & Nava, 2025) and proposes that SPS may be more strongly reflected in subjective experience than in autonomic arousal.

It is also paramount to consider methodological factors. SCR amplitudes are often very low, and the viewing of videos may not have been sufficiently intense to evoke strong responses. Although Acevedo et al. (2014) found stronger emotional activation among highly sensitive individuals across all their conditions, their effects were stronger for positive emotions and familiar stimuli (partners in comparison to strangers). This raises the possibility that the stimuli of sad videos of unfamiliar infants may have elicited weaker physiological reactions overall.

5.2.2. Can the rearing environment be an explanation?

The literature suggests that physiological reactivity may be shaped by the rearing environment (Del Giudice et al., 2011; Greven et al., 2019, Lionetti & Nava, 2025).

However, this study did not support the hypothesis. The research observed that adult-PARQ scores did not moderate the association between SPS and SCR, and adult-PARQ alone was also not a credible predictor of SCR. Thus, the current data do not provide evidence that the relationship between SPS and physiological reactivity is dependent on the perceived parental acceptance or rejection.

At the same time, the absence of a credible moderation effect should be interpreted with caution as the sample size was modest, and moderation effects require larger samples to be estimated reliably. Moreover, adult-PARQ captures only one aspect of the rearing environment, focusing primarily on negative experiences and relying on retrospective self-report, which may not fully capture the developmental experiences. Therefore, while the present findings do not support the hypothesis, they also do not completely rule out the possibility that rearing environments shape physiological responses in highly sensitive individuals.

Future analyses could examine whether adult-PARQ predicts stronger reactivity in highly sensitive individuals when focusing specifically on the crying infant condition. Additionally, it would be valuable to test whether the rearing environment moderates the relationship between SPS and self-reported physiological or emotional reactivity. As the self-report measures yielded overall more credible effects, it is a possibility that environmental influences may be more identifiable in subjective responses than in the physiological measures.

5.2.3. Can interoception be an explanation?

The literature proposes interoceptive processes as another potential explanation for the absence of uniformly elevated physiological assessments. According to this theory, differences in perceived reactivity may arise from greater attention to physiological signals rather than from objectively stronger physiological responses (Murphy, 2019, Ujiie & Takahashi, 2024).

The findings of this research greatly correspond with this hypothesis. At low levels of SPS, SCR was not related to self-reported physiological arousal, whereas at medium and high levels of SPS this relation became credible and increasingly stronger.

Individuals scoring high on the high on SPS, irrespective of scale, showed a strong correlation between SCR and self-reported physiological reactivity.

This finding is important as it suggests that higher SPS may not necessarily involve stronger physiological activation, but rather a tighter alignment between physiological activation and perceived bodily arousal. This implies that highly sensitive individuals may be more attentive to, or aware of, internal bodily signals. This interpretation is supported by the theory by Aron and Aron (1997) that SPS involves deeper processing of internal stimuli and heightened recognition of subtleties.

For self-reported emotional reactivity, the SCR and SPS interaction was not credible although it pointed in a similar direction. This suggests that the correspondence between objective and subjective activation was more specific to perceived bodily arousal than to emotional arousal in general. Emotional reactivity is more complex concept as it is made of additional processes, such as empathy, cognitive appraisal and interpretation of the stimuli. As a result, it might be less directly coupled with SCR than ratings of physical arousal.

5.3. Irritation and concern

As SCR is solely focused on the intensity of emotional arousal, self-reported irritation and concern/care were examined additionally to gain a better understanding of the quality of participants' emotional responses. Irritation was meant to reflect a more negative, withdrawal-oriented reaction, whereas concern was meant to reflect a more positive, engagement-oriented response towards the crying infant.

SPS did not credibly predict either irritation or concern, suggesting that higher sensitivity was not clearly associated with feeling more caring or more irritated in response to the infant-crying stimuli. Overall, the literature focuses on SPS as a

predictor of general arousal, rather than on whether highly sensitive individuals respond more positively or negatively. One exception is constituted by Jagiellowicz et al. (2016), who reported stronger valence ratings among highly sensitive individuals when viewing emotional pictures. Because the stimuli used in this study consisted of seven-second videos of unfamiliar infants and construction scenes, it may have not been sufficiently evocative to induce strong feelings of concern or irritation in general.

On the other hand, the rearing environment showed a more suggestive pattern. Although adult-PARQ was not a fully credible predictor, it showed a borderline positive association with irritation. This may indicate that individuals who retrospectively perceived more parental rejection tended to report more irritation in response to the cry videos. This pattern is consistent with the idea that early interpersonal experiences may shape how the reaction to emotionally demanding social signals, such as infant crying.

On the contrary, adult-PARQ scores were no predictors of self-reported concern. A likely explanation is given by the nature of the questionnaire. Adult-PARQ assesses negative rearing experiences more strongly than positive ones, and high scores indicate parental rejection. In contrast, low scores do not necessarily indicate exceptionally positive rearing environments, but rather the absence of negative ones. It is plausible that exceptionally positive rearing environments might be more relevant for predicting heightened concern or empathic responses among persons high in SPS.

5.4. HSP-R and HSP-12

The study shows that HSP-12 and HSP-R are strongly correlated, supporting previous findings by Pluess et al. (2025). This suggests that both measurements assess a common underlying sensitivity construct, while still allowing the HSP-R to capture more differentiated subdimensions of sensitivity. Although small differences emerged

when using HSP-R, the overall pattern and directions of effects remained stable, showing robustness of the findings. The minor variations between the two sets of analysis did not follow any trend, and given the sample size, no conclusion can be drawn about whether one scale predicts reactivity more effectively than the other.

5.5. Other variables to explore

Additional measures to assess neuroticism, sensory perception, sensory habituation, and theory of mind were completed by the participants. However, these variables were not included in the statistical models in relation to reactivity. Due to the modest sample size, adding further predictors or moderators would have increased the model complexity and reduced the reliability of the estimate's parameters. These constructs are therefore considered theoretically in the discussion.

5.5.1. Regular exposure to children

A factor that could have influenced participants' responses is their regular exposure to children. This was assessed in the demographic questionnaire. Notably, a large proportion of the sample reported regular contact with children: 7.1% as parents, 31.0% through work, and 35.7% through close family, while only 33.3% reported no regular contact. Although this variable was not included in the statistical models, informal comments made during testing suggested that prior experience with infants or young children may shape how individuals perceive and react to infant crying.

Participants who frequently interact with children, may be more accustomed to the sensory and emotional qualities of crying, potentially leading to reduced perceived intensity, less worry and more efficient regulatory responses. On the other hand, participants with little or no exposure may experience infant crying as more novel, salient, or demanding, which could amplify both subjective reactivity and physiological

arousal. Controlling for regular exposure to children would decrease confounding variables and potentially strengthen the relationship between SPS and physiological and emotional reactivity.

5.5.2. Neuroticism

Moreover, it would have been informative to test whether the higher self-reported reactivity observed among highly sensitive individuals would remain constant after controlling for neuroticism. As the results of this study once again confirm that SPS and neuroticism are moderately correlated (HSP-12: $r = 0.46$, $p = .001$, HSP-R: $r = 0.35$, $p = .016$), such an analysis would help clarify whether the heightened reactivity, especially the emotional component, reflects a distinct sensitivity-related mechanism rather than a by-product of broader negative affectivity.

5.5.3. Sensory perception

Future analysis should aim to incorporate sensory perception, measured with the SPQ-SF-35 in the analysis predicting reactivity. Including this factor could provide a more detailed understanding of individual differences in physiological responses, considering that the present study confirmed that sensory perception is partially related to SPS while remaining conceptually distinct (HSP-12: $r = 0.36$, $p = .015$, HSP-R: $r = 0.44$, $p = .002$). Individuals scoring high on the visual and auditory scales of the SPQ-SF-35 may more intensively experience the sensory features of the videos. This could translate into stronger self-reported physiological arousal or more pronounced SCR responses, independent of SPS. Examining these perceptual thresholds would help to clarify whether reactivity to infant crying and construction work is better explained by SPS or by specific sensory processing mechanisms, as captured by the SPQ-SF-35.

5.5.4. Sensory habituation

A further aspect that could have been important to examine is sensory habituation to the repeated video stimuli. Participants viewed 20 short clips in total, and several informally reported that they “got used to” the crying and construction work overtime. SCR amplitudes also showed a downward trend across repeated videos, suggesting that habituation processes were indeed occurring. In the correlational analysis, S-Hab showed a strong and significant correlation with both HSP-12 and HSP-R ($r = 0.71$ and $r = 0.67$, $p < .001$), supporting previous research (Tarantino et al., 2024; Mutschler et al., 2016). Including S-Hab in the models could have clarified whether slower habituation partly explains stronger self-reported reactivity in individuals high in SPS.

The results highlight important directions for future analyses. One is to assess whether the observed effects are unique to SPS or also characterises S-Hab, given their strong correlation. Another is to examine whether S-Hab may act as a mediating mechanism linking SPS to heightened reactivity. It would be valuable to determine whether the heightened self-reported reactivity reflects reduced habituation across repeated exposures or whether it is already present during the initial stimuli, before habituation processes emerge. This would help clarify whether SPS is associated with prolonged responsiveness rather than merely stronger initial reactions.

5.5.5. Theory of mind

ToM assessed with AT could potentially have been expected to be relevant for the interpretation distress evoked by crying babies. Individuals with stronger mentalising abilities may have interpreted the infant crying as a more socially meaningful signal, potentially eliciting higher concern and lower irritation. In this sense, ToM could help to

explain individual differences in the emotional response to infant crying, especially whether the cry is experienced as a signal requiring care.

5.5.6. HSP-12 and HSP-R subscales

Finally, analysis of the HSP-12 and HSP-R subscales would have been useful to distinguish between the impact of different SPS factors on the reactivity. It would have been particularly informative to examine how the less explored factors of the HSP-R differ in their association with reactivity to the stimuli. In particular, the emotional reactivity factor of the HSP-R is less covered by the HSP-12 and may play an important role in shaping emotional responses to social stimuli. This should be investigated in future analyses.

Regarding interoception, previous findings have shown that the HSP-12 subscales differ both in their strength of their associations with interoceptive processes and the types of interoceptive tendencies they predict (Ujiie & Takahashi, 2024; Jakobson et al., 2026). To better understand these relationships, it would be useful to examine each SPS factor separately when predicting the degree of SCR–self-report correspondence.

5.6. Limitations and recommendations for future research

The most substantial limitation of the present study is the small sample size. With 42 participants, statistical power was limited, which likely contributed to weaker and less stable associations. Therefore, the measures of BFI-N, SPQ-SF-35, S-Hab-Q, AT, HSP-12 subscales, HSP-R subscales, and additional analyses involving adult-PARQ were not taken into consideration for the analysis. To strengthen the reliability of the findings, data collection for this study should continue until the sample reaches approximately 100 participants.

A second limitation is related to the homogeneity of the sample. All participants were female adults, and 37 of the 42 were university students (of which 27 were psychology students). Over 90% were raised in Italy. Although this homogeneity helped reduce confounding variables, it also limits the generalisability of the findings. This is particularly relevant for physiological measures, as males differ from females in SCR responses (Chentsova-Dutton & Tsai, 2007). Therefore, the present results cannot be assumed to generalise across genders or cultural backgrounds. Future studies should include more diverse and balanced samples to examine whether the observed patterns are constant across different groups.

A further limitation concerns the SCR measure. Although SCR is a widely used indicator of sympathetic arousal, the magnitude of SCR changes is often small and can be influenced by factors unrelated to the stimulus, such as movement, attention, temperature, deep breaths, or individual differences in sweating. Future studies could include additional physiological measures, such as heart rate variability or respiratory sinus arrhythmia, to obtain a more complete picture of emotional and physiological regulation.

The use of video stimuli also limits ecological validity. Even though videos of crying infants and construction work allowed the stimuli to be standardised across participants, watching videos in a laboratory setting may not evoke the same emotional, physiological, or caregiving responses as direct interaction with a real crying infant. Although the seven-second duration was appropriate for SCR measurement, it may have been too brief to elicit stronger feelings of irritation or concern. Results should be interpreted as responses to controlled audiovisual stimuli rather than direct evidence of real-life caregiving behaviour. Moreover, future research should increase ecological

validity by examining responses to more naturalistic infant-related situations. This would help determine whether laboratory-based responses translate into real-world caregiving contexts.

Another limitation concerns the appropriateness of the stimuli in relation to the sample selected. Students might generally be in a life-stage in which they feel less emotional reactivity towards crying infants compared to parents.

Additionally, potential confusion regarding the VAS scale may represent a limitation. After completing several Likert scale questionnaires (HSP-12, BFI-N and adult-PARQ), participants may have been primed to interpret the centre of the scale as “neutral”. On the VAS, however, feeling completely neutral or indifferent towards the stimuli corresponds to the left end of the line, described as zero reactivity. Nevertheless, every participant reported at least one activation rating close to the left end (1.4 cm or less on a 10 cm line), suggesting that major misinterpretation was unlikely. Future research could try to find a way to limit potential confusion. Another potential issue of the VAS scale concerns the ambiguity of the emotional-reactivity question for the emotionally neutral construction-work videos. This question may have been confusing for participants and more open for interpretations.

Despite these limitations, the study provides novel insights and represents the first direct evidence of an objectively measured interoceptive correspondence among highly sensitive individuals. It also contributes to an expanding body of work that questions the assumption that highly sensitive individuals exhibit uniformly stronger physiological responses to emotional stimuli. Future research should continue to investigate this topic using targeted interoception questionnaires and including additional objective measures. Such work would increase the understanding of this trait and may shift theoretical

perspectives from an emphasis on uniformly heightened physiological activation toward a more nuanced view of increased awareness of internal signals.

6. Conclusion

The present study examined how individual differences in SPS relate to self-reported emotional and physiological responses and SCR to videos of infant crying and construction work, and whether these associations are shaped by the rearing environment. The findings showed that crying-infant videos elicited higher self-reported emotional and physiological reactivity than control videos, and that individuals higher in SPS generally report higher emotional and physiological activation, with an interaction effect showing especially heightened reactivity towards the more ambiguous control stimulus.

Physiological activation measured through SCR did not differ across SPS levels or conditions, and the rearing environment did not moderate these associations. Similarly, irritation and concern were not credibly predicted by SPS or rearing environment, even though parental rejection showed a slight positive association with irritation.

Besides these patterns, the study highlighted that individuals higher in SPS showed a credible correlation between SCR and self-reported physiological arousal, suggesting that sensitivity may be linked to greater awareness of internal bodily signals rather than to stronger autonomic responses. This correlation was not shown in individuals with lower levels of SPS. The results remained consistent regardless of whether HSP-12 or HSP-R was used to measure SPS, indicating the robustness of the findings.

While the small and homogeneous sample limits the generalisability of the findings, the study demonstrates the value of integrating subjective and physiological measures to examine sensitivity-related mechanisms. Continuing data collection for this study until reaching a higher number of participants will allow for more reliable estimates and the inclusion of additional variables such as sensory perception, ToM, sensory habituation,

and neuroticism. Future research should also incorporate more diverse samples and more ecologically valid designs to determine whether the observed patterns extend to real-life caregiving contexts.

References

- Abell, F., Happé, F., Frith, U. (2000). Do triangles play tricks? Attribution of mental states to animated shapes in normal and abnormal development. *Cognitive development* 15, 1-16. [https://doi.org/10.1016/S0885-2014\(00\)00014-9](https://doi.org/10.1016/S0885-2014(00)00014-9)
- Acevedo, B. P., Aron, E. N., Aron, A., Sangster, M., Collins, N., Brown, L. (2014). The highly sensitive brain: An fMRI study of sensory processing sensitivity. *Brain and Behavior*, 4, 580–594. <https://doi.org/10.1002/brb3.242>
- Acevedo, B. P., Jagiellowicz, J., Aron, E., Marhenke, R., Aron, A. (2017). Sensory processing sensitivity and childhood quality's effects on neural responses to emotional stimuli. *Clinical Neuropsychiatry: Journal of Treatment Evaluation*, 14(6), 359–373.
- Acevedo, B. A. (2020). The basics of sensory processing sensitivity. *The highly sensitive brain*, 1-16. <https://doi.org/10.1002/brb3.242>
- Alvi, T., Kouros, C. D., Lee, J., Fulford, D., Tabak, B. A. (2020). Social anxiety is negatively associated with theory of mind and empathic accuracy. *Journal of Abnormal Psychology*, 129(1), 108–113. <https://doi.org/10.1037/abn0000493>
- Aron, E. N., Aron, A. (1997). Sensory-processing sensitivity and its relation to introversion and emotionality. *Journal of Personality and Social Psychology*, 73(2), 345–368. <https://doi.org/10.1037//0022-3514.73.2.345>
- Aron, E. N., Aron, A., Jagiellowicz, J. (2012). Sensory processing sensitivity: A review in the light of the evolution of biological responsivity. *Personality and Social Psychology Review*, 16(3), 262–282. <https://doi.org/10.1177/1088868311434213>
- Aron, A., Ketay, S., Hedden, T., Aron, E. N., Rose Markus, H., Gabrieli, J. D. (2010). Temperament trait of sensory processing sensitivity moderates cultural differences in

neural response. *Social Cognitive and Affective Neuroscience*, 5(2–3), 219–226.

<https://doi.org/10.1093/scan/nsq028>

Aron, E. N., Aron, A., Nardone, N., Zhou, S. (2019). Sensory processing sensitivity and the subjective experience of parenting: An exploratory study. *Family Relations*, 68(4), 420–435. <https://doi.org/10.1111/fare.12370>

Assary, E., Oginni, O. A., Morneau-Vaillancourt, G., Krebs, G., Peel, A. J., Palaiologou, E., Lockhart, C., Ronald, A., Eley, T. C. (2024). Genetics of environmental sensitivity and its association with variations in emotional problems, autistic traits, and wellbeing. *Molecular Psychiatry*, 29(8), 2438–2446. <https://doi.org/10.1038/s41380-024-02508-6>

Assary, E., Zavos, H. M. S., Krapohl, E., Keers, R., Pluess, M. (2021). Genetic architecture of Environmental Sensitivity reflects multiple heritable components: a twin study with adolescents. *Molecular Psychiatry* 26, 4896–4904. <https://doi.org/10.1038/s41380-020-0783-8>

Bakermans-Kranenburg, M. J., van Ijzendoorn, M. H. (2011). Differential susceptibility to rearing environment depending on dopamine-related genes: New evidence and a meta-analysis. *Development and Psychopathology*, 23(1), 39–52. <https://doi.org/10.1017/S0954579410000635>

Belsky, J. (1997). Variation in susceptibility to environmental influence: An evolutionary argument. *Psychological Inquiry*, 8(3), 182–186. https://doi.org/10.1207/s15327965pli0803_3

Belsky, J., Pluess, M. (2009). Beyond diathesis stress: differential susceptibility to environmental influences. *Psychological Bulletin*, 135(6), 885–908. <https://doi.org/10.1037/a0017376>

- Boyce, W. T., Ellis, B. J. (2005). Biological sensitivity to context: I. An evolutionary-developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology*, 17(2), 271-301. <https://doi.org/10.1017/s0954579405050145>
- Buchtova, M., Malinakova, K., Benitan, M. C., Husek, V., Tavel, P. (2025). Sensory processing sensitivity and its associations with guilt, shame, self-esteem, and neuroticism. *BMC Psychology*, 13(1). <https://doi.org/10.1186/s40359-025-03530-1>
- Caruelle, D., Gustafsson, A., Shams, P., Lervik-Olsen, L. (2019). The use of electrodermal activity (EDA) measurement to understand consumer emotions – A literature review and a call for action. *Journal of Business Research*, 104, 146-160. <https://doi.org/10.1016/j.jbusres.2019.06.041>
- Carter, C. S., Grippo, A. J., Pournajafi-Nazarloo, H., Ruscio, M. G., Porges, S. W. (2008). Oxytocin, vasopressin and sociality. *Progress in Brain Research*, 170, 331–336. [https://doi.org/10.1016/S0079-6123\(08\)00427-5](https://doi.org/10.1016/S0079-6123(08)00427-5)
- Chen, C. H., Chen, C. S., Moyzis, R., Stern, H., He, Q. H., Li, H., Li, J., Zhy, B., Dong, Q. (2011). Contributions of dopamine-related genes and environmental factors to highly sensitive personality: A multi-step neuronal system-level approach. *PLoS One*, 6(7), 9. <https://doi.org/10.1371/journal.pone.0021636>
- Chen, C., Xiu, D., Chen, C., Moyzis, R., Xia, M., He, Y., Xue, G., Li, J., He, Q., Lei, X., Wang, Y., Liu, B., Chen, W., Zhu, B., Dong, Q. (2015). Regional homogeneity of resting-state brain activity suppresses the effect of dopamine-related genes on sensory processing sensitivity. *PLoS One*, 10(8), e0133143. <https://doi.org/10.1371/journal.pone.0133143>

- Chentsova-Dutton, Y. E., & Tsai, J. L. (2007). Gender differences in emotional response among European Americans and Hmong Americans. *Cognition and Emotion*, 21(1), 162–181. <https://doi.org/10.1080/02699930600911333>
- Ceccon, C., Schachner, M. K., Lionetti, F., Pastore, M., Umaña-Taylor, A. J., Moscardino, U. (2023). Efficacy of a cultural adaptation of the Identity Project intervention among adolescents attending multiethnic classrooms in Italy: A randomized controlled trial. *Child Development*, 94, 1162–1180. <https://doi.org/10.1111/cdev.13944>
- David, M., Auclair, Y., Cézilly, F. (2011). Personality predicts social dominance in female zebra finches, *Taeniopygia guttata*, in a feeding context. *Animal Behaviour*, 81, 219–224. <http://dx.doi.org/10.1016/j.anbehav.2010.10.008>
- Del Giudice, M. (2017). The evolution of interaction shape in differential susceptibility. *Child Development*, 88(6), 1897–1912. <https://doi.org/10.1111/cdev.12710>
- Del Giudice, M., Ellis, B. J., Shirtcliff, E. A. (2011). The Adaptive Calibration Model of stress responsivity. *Neuroscience and biobehavioral reviews*, 35(7), 1562–1592. <https://doi.org/10.1016/j.neubiorev.2010.11.007>
- Dunn, W. (1997). The impact of sensory processing abilities on the daily lives of young children and their families: a conceptual model. *Infants and Young Children*, 9, 23–35. <https://doi.org/10.1097/00001163-199704000-00005>
- Dunn, W. (2001). The sensations of everyday life: empirical, theoretical, and pragmatic considerations. *American Journal of Occupational Therapy*, 55, 608–620. <https://doi.org/10.5014/ajot.55.6.608>

- Evers, A., Rasche, J., Schabracq, M. J. (2008). High sensory-processing sensitivity at work. *International Journal of Stress Management*, 15(2), 189-198.
<https://doi.org/10.1037/1072-5245.15.2.189>
- Gehrlach, D. A., Dolensek, N., Klein, A. S., Chowdhury, R. R., Matthys, A., Junghänel, M., Gaitanos, T. N., Podgornik, A., Black, T. D., Vaka, N. R., Conzelmann, K., Gogolla, N. (2019). Aversive state processing in the posterior insular cortex. *Nature Neuroscience*, 22, 1424–1437. <https://doi.org/10.1038/s41593-019-0469-1>
- Goldberg, A., Scharf, M. (2020). How do highly sensitive persons parent their adolescent children? The role of sensory processing sensitivity in parenting practices. *Journal of Social and Personal Relationships*, 37(6), 1825–1842.
<https://doi.org/10.1177/0265407520911101>
- Golonka, K., Gulla, B. (2021). Individual Differences and Susceptibility to Burnout Syndrome: Sensory Processing Sensitivity and Its Relation to Exhaustion and Disengagement. *Frontiers in Psychology*, 12, 751350.
<https://doi.org/10.3389/fpsyg.2021.751350>
- Gonzalez-Sanchez, J., Baydogan, M., Chavez-Echeagary, M. E., Atkinson, R. K., Burleson, W. (2017). Chapter 11 - Affect Measurement: A Roadmap Through Approaches, Technologies, and Data Analysis. *Emotions and Affect in Human Factors and Human-Computer Interactions*, 255-288. <https://doi.org/10.1016/B978-0-12-801851-4.00011-2>
- Greven, C. U., Lionetti, F., Booth, C., Aron, E. N., Fox, E., Schendan, H. E., Pluess, M., Bruining, H., Acevedo, B., Bijttebier, P., Homberg, J. (2019). Sensory Processing Sensitivity in the context of Environmental Sensitivity: A critical review and

- development of research agenda. *Neuroscience & Biobehavioral Reviews*, 98, 287-305.
<https://doi.org/10.1016/j.neubiorev.2019.01.009>
- Hamilton, R. I., Garcia, A. A., Bowd, J., Hamilton, D., Mason, D., Elliott, M., Holt, C. (2024). Utilising electrodermal activity sensor signals to quantify nociceptive response during movement activities. *BMC Research Notes*, 17(36).
<https://doi.org/10.1186/s13104-024-06689-9>
- Hartman, S., Freeman, S. M., Bales, K. L., Belsky, J. (2018). Prenatal stress as a risk- and an opportunity-factor. *Psychological Science*, 29(4), 572–580.
<https://doi.org/10.1177/0956797617739983>
- Hellwig, S., Roth, M. (2021). Conceptual ambiguities and measurement issues in sensory processing sensitivity. *Journal of Research in Personality*, 93, 104130.
<https://doi.org/10.1016/J.JRP.2021.104130>
- Hiraoka, D., Nomura, M. (2016). The Influence of Cognitive Load on Empathy and Intention in Response to Infant Crying. *Scientific Reports*, 6, 28247.
<https://doi.org/10.1038/srep28247>
- Hovers, A., Tombeng, N., Bosse, T., Lazonder, A. W., Molenaar, I. (2021). Detecting Emotions through Electrodermal Activity in Learning Contexts: A Systematic Review. *Sensors*, 21, 7869. <https://doi.org/10.3390/s21237869>
- Jagiellowicz, J., Aron, A., Aron, E. N. (2016). Relationship between the temperament trait of sensory processing sensitivity and emotional reactivity. *Social Behavior and Personality*, 44(2), 185–200. <https://psycnet.apa.org/doi/10.2224/sbp.2016.44.2.185>
- Jagiellowicz, J., Xu, X., Aron, A., Aron, E., Cao, G., Feng, T., Weng, X. (2011). The trait of sensory processing sensitivity and neural responses to changes in visual scenes.

Social Cognitive and Affective Neuroscience, 6(1), 38-47.

<https://doi.org/10.1093/scan/nsq001>

Jakobson, L. S., Pearson, P. M., Rigby, S. N. (2026). Links between facets of alexithymia, self-rated interoception, and social perception. *Frontiers in Psychology*, 16, 1669056.

<https://doi.org/10.3389/fpsyg.2025.1669056>

John, O. P., Donahue, E. M., Kentle, R. L. (1991). *Big Five Inventory (BFI)* [Database record]. APA PsycTests. <https://doi.org/10.1037/t07550-000>

Keers, R., Coleman, J. R., Lester, K. J., Roberts, S., Breen, G., Thastum, M., Bögels, S., Schneider, S., Heiervang, E., Meiser-Stedman, R., Nauta, M., Creswell, C., Thirlwall, K., Rapee, R. M., Hudson, J. L., Lewis, C., Plomin, R., Eley, T. C. (2016). A Genome-Wide Test of the Differential Susceptibility Hypothesis Reveals a Genetic Predictor of Differential Response to Psychological Treatments for Child Anxiety Disorders.

Psychotherapy and Psychosomatics, 85(3), 146-58. <https://doi.org/10.1159/000444023>

Keller, R., Brighenti, S. (????). SPQ SF-35. *University of Cambridge Autism research centre database*. <https://www.autismresearchcentre.com/>

Laros-van Gorkom, B. A. P., Damatac, C. G., Stevelmans, I., Greven, C. U. (2024).

Relationships of sensory processing sensitivity with creativity and empathy in an adult sample. *Frontiers in Psychology*, 15,

1465407. <https://doi.org/10.3389/fpsyg.2024.1465407>

Levit-Binnun, N., Szepsenwol, O., Stern-Ellran, K., and Engel-Yeger, B. (2014). The relationship between sensory responsiveness profiles, attachment orientations, and anxiety symptoms. *Australian Journal of Psychology*, 66, 233–240.

<https://doi.org/10.1111/ajpy.12064>

- Li, S., Sung, B., Lin, Y., Mitas, O. (2022). Electrodermal activity measure: A methodological review. *Annals of Tourism Research*, 96, 103460.
<https://doi.org/10.1016/j.annals.2022.103460>
- Licht, C. L., Mortensen, E. L., Knudsen, G. M. (2011). Association between sensory processing sensitivity and the serotonin transporter polymorphism 5-HTTLPR short/short genotype. *Biological Psychiatry*, 69(9), 152S–153S.
<https://doi.org/10.1016/j.biopsych.2011.03.031>
- Lionetti, F., Aron, A., Aron, E. N., Burns, L., Jagiellowicz, J., Pluess, M. (2018). Dandelions, tulips and orchids: evidence for the existence of low-sensitive, medium-sensitive and high-sensitive individuals. *Translational Psychiatry*, 8, 24.
<https://doi.org/10.1038/s41398-017-0090-6>
- Lionetti, F., Aron, E. N., Aron, A., Klein, D. N., Pluess, M. (2019). Observer-rated environmental sensitivity moderates children's response to parenting quality in early childhood. *Developmental Psychology*, 55(11), 2389-2402.
<https://doi.org/10.1037/dev0000795>
- Lionetti, F., Dumpfrey, R. S. C., Richetin, J., Fasolo, M., Nocentini, A., Penolazzi B., Pluess, M., Santona, A., Spinelli, M., Preti, E. (2024). Is environmental sensitivity a unique trait? A multi-sample study on the association between sensitivity, personality, and psychological adjustment. *Personality and Individual Differences*, 217, 112463.
<https://doi.org/10.1016/j.paid.2023.112463>
- Lionetti, F., Klein, D. N., Pastore, M., Aron, E. N., Aron, A., Pluess, M. (2022). The role of environmental sensitivity in the development of rumination and depressive symptoms in childhood: a longitudinal study. *European Child Adolescent Psychiatry*, 31(11), 1815-1825. <https://doi.org/10.1007/s00787-021-01830-6>

- Lionetti, F., Nava, E. (2025). The contribution of environmental sensitivity and attachment on physiological emotional reactivity and regulation in children. *Personality and Individual Differences*, 246, 113345. <https://doi.org/10.1016/j.paid.2025.113345>
- Lionetti, F., Pastore, M., Moscardino, U., Nocentini, A., Pluess, K., Pluess, M. (2019). Sensory Processing Sensitivity and its association with personality traits and affect: A meta-analysis. *Journal of Research in Personality*, 81, 138-152. <https://doi.org/10.1016/j.jrp.2019.05.013>
- Lionetti, F., Spinelli, M., Bosmans, G., D'Urso, G., Fasolo, M., Pluess, M. (2026). Is environmental sensitivity relevant to understand parenting? Observational studies with mothers of young children. *Journal of Family Psychology*, 40(1), 12-24. <https://doi.org/10.1037/fam0001329>
- Mastromatteo, L. Y., Lionetti, F., Pluess, M., Scrimin, S. (2024). Moderate cardiac vagal tone predicts more cooperation in highly sensitive individuals. *Psychophysiology*, 61(10), e14638. <https://doi.org/10.1111/psyp.14638>
- McDonough, M. (2024). Making sense of interoception. *Harvard Medicine Magazine*. <https://magazine.hms.harvard.edu/articles/making-sense-interoception>
- Miller, D. C., Lynch, M. F. (2024). The Gender Socialization Experiences of Highly Sensitive Men. *Psychology of Men & Masculinities*, 25(2), 203-212. <https://doi.org/10.1037/men0000463>
- Monroe, S. M., Simons, A. D. (1991). Diathesis-stress theories in the context of life stress research: Implications for the depressive disorders. *Psychological Bulletin*, 110(3), 406–425. <https://doi.org/10.1037/0033-2909.110.3.406>
- Murphy, J., Catmur, C., Bird, G. (2019). Classifying individual differences in interoception: Implications for the measurement of interoceptive

- awareness. *Psychonomic Bulletin & Review*, 26, 1467–1471 (2019).
<https://doi.org/10.3758/s13423-019-01632-7>
- Mutschler, I., Ball, T., Kirmse, U., Wieckhorst, B., Pluess, M., Klarhöfer, M., Meyer, A. H., Wilhelm, F. H., Seifritz, E. (2016). The Role of the Subgenual Anterior Cingulate Cortex and Amygdala in Environmental Sensitivity to Infant Crying. *PLoS ONE*, 11(8), e0161181. <http://dx.doi.org/10.1371/journal.pone.0161181>
- Naumann, F. V., Acevedo, B. P., Jagiellowicz, J., Greven, C. U., Homberg, J. R. (2020). Etiology of sensory processing sensitivity: Neurobiology, genes, and evolution. *The highly sensitive brain*, 109-134. <https://doi.org/10.1016/B978-0-12-818251-2.00005-9>
- Nocentini, A., Menesini, E., Pluess, M. (2018). The personality trait of environmental sensitivity predicts children’s positive response to school-based antibullying intervention. *Clinical Psychological Science*, 6(6), 848-859.
<https://doi.org/10.1177/2167702618782194>
- Pluess, M. (2015). Individual Differences in Environmental Sensitivity, *Child Development Perspectives*, 9(3), 138–143. <https://doi.org/10.1111/cdep.12120>
- Pluess, M., Aron, E. N., Kähkönen, J.E., Lionetti, F., Huang, Y., Tillmann, T., Greven, C.U., Aron, A. (2026). Evolution of the Concept of Sensitivity and its Measurement: The Highly Sensitive Person Scale-Revised, *Personality and Individual Difference* 257, 113782. <https://doi.org/10.1016/j.paid.2026.113782>
- Pluess, M., Assary, E., Lionetti, F., Lester, K. J., Krapohl, E., Aron, E. N., Aron, A. (2018). Environmental sensitivity in children: Development of the Highly Sensitive Child Scale and identification of sensitivity groups. *Developmental Psychology*, 54(1), 51-70. <https://doi.org/10.1037/dev0000406>

- Pluess, M., Belsky, J. (2013). Vantage sensitivity: individual differences in response to positive experiences. *Psychological Bulletin*, 139(4), 901-916.
<https://doi.org/10.1037/a0030196>
- Pluess, M., Belsky, J., Way, B. M., Taylor, S. E. (2010). 5-HTTLPR moderates effects of current life events on neuroticism: Differential susceptibility to environmental influences. *Progress in Neuro-Psychopharmacology & Biological Psychiatry*, 34(6), 1070–1074. <https://doi.org/10.1016/j.pnpbp.2010.05.028>
- Pluess, M., Boniwell, I. (2015). Sensory-Processing Sensitivity predicts response to school-based depression prevention program: Evidence of Vantage Sensitivity. *Personality and Individual Differences*, 82, 40-45.
<https://doi.org/10.1016/j.paid.2015.03.011>
- Pluess, M., Lionetti, F., Aron, N. E., Aron, A. (2023). People differ in their sensitivity to the environment: An integrated theory, measurement and empirical evidence. *Journal of Research in Personality*, 104, 104377. <https://doi.org/10.1016/j.jrp.2023.104377>
- Podoly, T. Y., Ben Sasson, A. (2020). When It's Impossible to Ignore: Development and Validation of the Sensory Habituation Questionnaire. *The American Journal of Occupational Therapy*, 74(3), 7403205040. <https://doi.org/10.5014/ajot.2020.033878>
- Riem, M. M., Bakermans-Kranenburg, M. J., van IJzendoorn, M. H., Out, D., Rombouts, S. A. (2012). Attachment in the brain: adult attachment representations predict amygdala and behavioral responses to infant crying. *Attachment & Human Development*, 14(6), 533-5. <https://doi.org/10.1080/14616734.2012.727252>
- Rohner, R. P., Saavedra, J. M., Granum, E. O. (1978). Development and Validation of the Parental Acceptance and Rejection Questionnaire: Test Manual. *JSAS Catalog of Selected Documents in Psychology*, 8, 7-8.

- Schaefer, M., Kühnel, A., Gärtner, M. (2022). Sensory processing sensitivity and somatosensory brain activation when feeling touch. *Scientific Reports*, 12(1), 12024. <https://doi.org/10.1038/s41598-022-15497-9>
- Slagt, M., Dubas, J. S., van Aken, M. A. G., Ellis, B. J., Deković, M. (2018). Sensory processing sensitivity as a marker of differential susceptibility to parenting. *Developmental Psychology*, 54(3), 543-558. <https://doi.org/10.1037/dev0000431>
- Smolewska, K. A., McCabe, S. B., Woody, E. Z. (2006). A psychometric evaluation of the Highly Sensitive Person Scale: The components of sensory-processing sensitivity and their relation to the BIS/BAS and “Big Five”. *Personality and Individual Differences*, 40(6), 1269-1279. <https://doi.org/10.1016/j.paid.2005.09.022>
- Sperati, A., Spinelli, M., Fasolo, M., Pastore, M., Pluess, M., Lionetti, F. (2024). Investigating sensitivity through the lens of parents: validation of the parent-report version of the Highly Sensitive Child scale. *Development and Psychopathology*, 36(1), 415-428. <https://doi.org/10.1017/s0954579422001298>
- Tabak, B. A., Gupta, D., Sunahara, C. C., Alvi, T., Wallmark, Z., Lee, J., Fulford, D., Hudson, N. W., Chmielewski, M. (2022). Environmental sensitivity predicts interpersonal sensitivity above and beyond Big Five personality traits. *Journal of Research in Personality*, 98, 104210. <https://doi.org/10.1016/j.jrp.2022.104210>
- Tang, R., Dai, X., Greven, C. U., Li, Z., Zhu, C., Yan, N. (2025). Network-based meta-analysis of sensory processing sensitivity: Exploring its relations with personality and temperament traits. *Personality and Individual Differences*, 247, 113435. <https://doi.org/10.1016/j.paid.2025.113435>
- Tarantino, V., Passerello, N., Ben-Sasson, A., Podoly, T. Y., Santostefano, A., Oliveri, M., Mandolesi, L., Turriziani, P. (2024). Measuring habituation to stimuli: The Italian

- version of the Sensory Habituation Questionnaire. *PLoS ONE* 19(12): e0309030.
<https://doi.org/10.1371/journal.pone.0309030>
- Tavassoli, T., Hoekstra, R. A., Baron-Cohen, S. (2014). The Sensory Perception Quotient (SPQ): development and validation of a new sensory questionnaire for adults with and without autism. *Molecular Autism*, 5(29). <https://doi.org/10.1186/2040-2392-5-29>
- Turjeman-Levi, Y., Kluger, A. N. (2022). Sensory-processing sensitivity versus the sensory-processing theory: Convergence and divergence. *Frontiers in Psychology*, 13, 1010836. <https://doi.org/10.3389/fpsyg.2022.1010836>
- Trå, H. V., Volden, F., Watten, R. G., (2023). High Sensitivity: Factor structure of the highly sensitive person scale and personality traits in a high and low sensitivity group. Two gender—matched studies. *Nordic Psychology*, 75(4), 328-350.
<https://doi.org/10.1080/19012276.2022.2093778>
- Ubbiali, A., Chiorri, C., Hampton, P., Donati, D. (2013). Psychometric properties of the Italian adaptation of the Big Five Inventory (BFI). *Applied Psychology Bulletin*, 266(59), 37-48.
- Uddin, L. Q., Nomi, J. S., Hébert-Seropian, B., Ghaziri, J., Boucher, O. (2017). Structure and Function of the Human Insula. *Journal of Clinical Neurophysiology*, 34(4), 300-306. <https://doi.org/10.1097/wnp.0000000000000377>
- Ujiie, Y., & Takahashi, K. (2024). Subjective Sensitivity to Exteroceptive and Interoceptive processing in Highly Sensitive Person. *Psychological Reports*, 127(1), 142–158. <https://doi.org/10.1177/00332941221119403>
- Van der Doelen, R. H., Deschamps, W., D’Annibale, C., Peeters, D., Wevers, R. A., Zelena, D., Homberg, J. R., Kozicz, T. (2014). Early life adversity and serotonin transporter gene variation interact at the level of the adrenal gland to affect the adult

hypothalamo-pituitary-adrenal axis. *Translational Psychiatry*, 4, e409.

<https://doi.org/10.1038/tp.2014.57>

Van Ijzendoorn, M. H., Belsky, J., Bakermans-Kranenburg, M. J. (2012). Serotonin transporter genotype 5HTTLPR as a marker of differential susceptibility? A meta-analysis of child and adolescent gene-by-environment studies. *Translational Psychiatry*, 2, e147. <https://doi.org/10.1038/tp.2012.73>

Van Reyn, C., Koval, P., Bastian, B. (2023). Sensory Processing Sensitivity and Reactivity to Daily Events. *Social Psychological and Personality Science*, 14(6), 772-783.

<https://doi.org/10.1177/19485506221119357>

Wellman, H. M. (2014). Chapter 1 – Developing a Theory of Mind – initial overview. *Making Minds – How theory of mind develops*. 15-31.

Weyn, S., Lionetti, F., Klein, D. N., Aron, E., Aron, A., Hayden, E. P., Dougherty, L. R., Singh, S., Waszczuk, M., Kotov, R., Docherty, A., Shabalin, A., Pluess, M. (2025). Observer-rated environmental sensitivity and its characterization at behavioral, genetic, and physiological levels. *Development and Psychopathology*, 1–15.

<https://doi.org/10.1017/s0954579424001883>

Weyn, S., Van Leeuwen, K., Pluess, M., Goossens, L., Claes, S., Bosmans, G., Van Den Noortgate, W., Lutin, E., Bröhl, A. S., Chubar, V., Geukens, F., Bijttebier, P. (2022). Individual differences in environmental sensitivity at physiological and phenotypic level: Two sides of the same coin?. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology*, 176, 36–53.

<https://doi.org/10.1016/j.ijpsycho.2022.02.010>