Open University of Cyprus

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Faculty of Pure and Applied Sciences

Postgraduate (Master's) Program of *Cognitive Systems*

Postgraduate (Master's) Dissertation

Sensory Processing Sensitivity and its Association to Autistic Traits in General Population.

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Supervisor
Univ.- Prof. Dr. Konstantinos Tsagkaridis

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Summary

Sensory processing sensitivity (SPS) constitutes a genetically based phenotypic trait involving heightened emotional responsivity and empathy, greater awareness of environmental subtleties, deeper cognitive processing, and ease of overstimulation. The first part of the present dissertation explores in depth the theoretical framework of SPS, the distinct constructs of sensitivity, and the evidence of SPS as an indicator of environmental sensitivity, which constitutes the most recent meta-framework on sensitivity. Furthermore, the assessment of SPS involving behavioral measurements is investigated in terms of validity and reliability across the lifespan. The neurobiological basis of highly sensitivity is examined primarily in relation to other clinical disorders through most recent innovative behavioral, genetic, and electrophysiological studies. Thereafter, the association between SPS and psychopathology as well as the risk factors of high SPS are explored. The second part of the dissertation examines for the first time the association between SPS and autistic traits in the general population. Our sample (N = 132) was recruited through advertisement in social media. Participants followed the given link and completed the study comprised of the informed consent, demographic data, and the Highly Sensitive Person scale (HSP) as well as the Autism Spectrum Quotient test (AQ). Primary results demonstrated a positive association of SPS with autistic traits ($r = .18$, $p = .03$), confirming the hypothesis of the study.

Keywords: Autistic Traits, Cognitive Neuroscience, Environmental Sensitivity, Highly Sensitive Person, Sensory Processing Sensitivity

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GLOSSARY

ABBREVIATION/TERM	DEFINITION
ACTH	Adrenocorticotropic Hormone
ADHD	Attention-Deficit Hyperactivity Disorder
AES	Aesthetic Sensitivity
ASD	Autism Spectrum Disorder
AQ	Autism-Spectrum Quotient
AT	Autistic Traits
BAS	Behavioral Activation System
BIS	Behavioral Inhibition System
BSC(T)	Biological Sensitivity to Context (Theory)
CRF	Corticotrophin Releasing Factor
DLPFC	Dorsolateral Prefrontal Cortex
DSM-5	Diagnostic and Statistical Manual of Mental Disorders 5th edition
DS(T)	Differential Susceptibility (Theory)
DZ	Dizygotic
EOE	Ease of Excitation
FMRI	Functional Magnetic Resonance Imaging
GABA	Gamma-aminobutyric Acid
GWAS	Genome Wide Association Studies
HPA-AXIS	Hypothalamus-Pituitary-Adrenal-axis
HSC	Highly Sensitive Child
HSC-RS	Highly Sensitive Child-Rating System
HSC(S)	Highly Sensitive Child Scale
HSP	Highly Sensitive Person
HSP(S)	Highly Sensitive Person (Scale)
IAPS	International Affective Picture System
IFG	Inferior Frontal Gyrus
LST	Low Sensory Threshold
MTG	Middle Temporal Gyrus

MZ	Monozygotic
PFC	Prefrontal Cortex
PMA	Premotor Area
PVN	Paraventricular Nucleus
PTSD	Post-Traumatic Stress Disorder
QCP	Quality of Childhood Parenting
RS	Resting state
SNP	Single Nucleotide Polymorphism
SPS	Sensory Processing Sensitivity
SZ	Schizophrenia
VS(T)	Vantage Sensitivity (Theory)
5-HTT	Serotonin Transporter
5-HTTLPR	Serotonin-Transporter-Linked Promoter Region

Chapter 1

Introduction

All species of organisms arise and develop through the natural selection of small, inherited variations that increase individual's ability to compete, survive, and reproduce through time. Humans, animals, and certain plant diversities share the ability of perceiving, processing, reacting, and adapting to positive and negative new environments allowing not only their self-preservation, but also the species' survival (El-Nabi & Sobhy, 2020). Significant inter-individuals variations in sensitivity and responsivity to the environment suggest a continuum personality trait from low to high sensitivity.

The last two decades, different models have been developed to investigate these differences in sensitivity. Of interest, the model of *sensory processing sensitivity (SPS)* (Aron & Aron, 1997) which, most recently, has flourished attracting sundry researchers among different fields comprising of cognitive science, neuroscience, and biology. SPS constitutes the earliest theoretical framework and the only one, thus far, that can capture the temperament trait through questionnaire-based and behavioral / observational assessment. The theory of SPS hypothesizes sensitivity as a global, heritable phenotype reflecting a deeper cognitive processing of sensory stimuli, increased perception of environmental subtleties, ease of overstimulation, and emotional responsivity. Although high sensitivity and clinical disorders, including autism spectrum disorder (ASD), share activation in similar brain regions entangled in memory, reward processing, and physiological homeostasis, neurobiological studies have confirmed unique neural circuits among them (Acevedo, Aron, Pospos, Jessen, 2018). Positive and negative environments as well as personal experiences contribute to a typical or atypical development of individuals.

The present dissertation aims initially, in a comprehensive and holistic literature review of the theory on the personality trait of SPS, as research on SPS is still in its early development. Additionally, the dissertation includes a small-scale empirical research exploring, for the first time a possible association between SPS and autistic traits in the general population. It needs to be noted that due to time constraints, unexpected difficulties, and the innovative nature of the subject, the research is limited to an exploratory investigation of the relationship of SPS with autistic characteristics. These constraints have, consequently resulted in a special form of dissertation, a hybrid form between a bibliographic review and a typical empirical research dissertation.

Chapter 2

Fundamentals of Sensory Processing Sensitivity

This chapter presents the theoretical background of SPS. First, preceding theories on sensitivity will be presented and evaluated. Second, the theory of SPS as well as an overview of the phenotypic trait will be introduced. Lastly, a most recent meta-framework on sensitivity regarding SPS will be reviewed. Data supporting SPS as an indicator of sensitivity will be further discussed.

2.1 Theoretical Background on SPS

More recently, inter-individual differences in sensitivity regained the interest of the academia and the public. However, the subject of sensitivity and susceptibility to environmental stressors was first studied through two vulnerability models i.e., the *dual-risk* model (Sameroff & Seifer, 1983) and the *diathesis-stress* model (Monroe & Simons, 1991). At present, the most prevalent theories on sensitivity consist of *differential susceptibility (DS)* (Belsky, 1997; Belsky & Pluess, 2009), *biological sensitivity to context (BSC)* (Boyce & Ellis, 2005), and sensory processing sensitivity (SPS) (Aron & Aron, 1997).

The first models of sensitivity were established to better comprehend the underlying mechanisms of sensitive individuals affected by the sensation and perception of environmental stimuli. First, the dual-risk model was proposed by the developmental researchers Sameroff and Seifer (1983) to originally study the risk factors of children with mentally ill mothers. Second, the diathesis-stress model developed by researchers in psychopathology (Monroe & Simons, 1991), whereas the model was later revisited by

Zuckerman (1999) to investigate social processes that generate penalties. Both paradigms propose that certain individuals share traits that result in environmental stressors making them overly susceptible, plausibly resulting in psychopathology (Monroe & Simons, 1991). Such susceptibilities (i.e., diatheses) can be considered as behavioral (i.e., personality trait), endophenotypic or genetic attributes.

The diathesis-stress model (also denoted as vulnerability-stress model in literature) postulates that individuals with increased risk factors as specific genes or complicated temperament to stimuli and environments, are inclined to a pre-dispositional vulnerability to penalties of environmental intricacies in comparison to control individuals (Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011; Metalsky, Halberstadt, & Abramson, 1987). Evidence in developmental and psychiatric research has indicated strong interactions between temperament and parenting as well as gene and environment. Both the diathesis-stress and the dual-risk models share the perception that certain individuals are overly prone to be adversely affected by environmental stressors due to a particular "vulnerability" that could be behavioral (e.g., complicated temperament), physiological or endophenotypic (e.g., increased biological reactivity to stress), or genetic (e.g., serotonin linked polymorphic region [5-HTTLPR] short alleles), where individuals with a negatively emotional temperament, specific "vulnerability" genes or "high risk" alleles are more susceptible to exhibit psychopathological conditions, when exposed to adversity (Ellis Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011). The primary restriction of the diathesis-stress model lies in the complex and extensive range of environments or behavioral functioning usually defined in terms of their presence or absence (e.g., maltreatment vs. no maltreatment, anxious vs. not anxious).

On the contrary, the vantage sensitivity framework defines individual differences in response to positive experiences and stimuli, such as supportive psychological interventions (de Villiers, Lionetti, & Pluess, 2018; Pluess & Belsky, 2015). Previous studies have suggested three endogenous markers of vantage sensitivity consisting of genetic, physiological, and psychological factors (Pluess & Belsky, 2011), whilst most recently, evidence of environmental factors have emerged as well (Iimura & Kibe, 2020). More precisely, genetic research indicates the short variant of the 5-HTTLPR gene (Morgan, Kumsta, Fearon, Moser, Skeen, Cooper, ... & Tomlinson, 2017) and the A-allele of the single-nucleotide polymorphism (SNP) rs10482672 (Albert, Belsky, Crowley, Latendresse, Aliev, Riley, ... & Dodge, 2015) to signify increased vantage sensitivity to the positive effects of psychological intervention, functioning as an indicator of positive response to treatment. Research on multiple genes into polygenic scores has suggested a positive correlation between genetic sensitivity scores and treatment quality, where individuals with increased genetic sensitivity score profited more from the higher quality treatment (Keers, Coleman, Lester, Roberts, Breen, Thastum, ... & Eley, 2016).

Research on the physiological attributes functioning as indicators of sensitivity (e.g., hypothalamus– pituitary– adrenal [HPA]-axis, cortisol levels) in relation to the model of vantage sensitivity has suggested an association among cortisol levels during exposure, cortisol awaking responses, and results of recovery regarding panic disorder and agoraphobia (Meuret, Trueba, Abelson, Liberzon, Auchus, Bhaskara, ... & Rosenfield, 2015) as well as awakening cortisol levels and trauma-focused therapy[1], explaining 10% of the variance (Rapcencu, Gorter, Kennis, van Rooij, & Geuze, 2017). Such findings though, could not be verified in a meta-analysis on the association between pre-treatment cortisol and psychotherapy for anxiety disorders (Fisher & Cleare, 2017), possibly signifying cortisol reactivity rather than basal cortisol in revealing sensitivity to the environment.

Studies in psychology employed personality and temperament traits to investigate whether vantage sensitivity can reflect and predict treatment response by moderating intervention effects. Findings revealed increased sensitivity of highly irritable children to the positive outcomes of a psychological treatment (Cassidy, Woodhouse, Sherman, Stupica, & Lejuez, 2011), a positive correlation between higher conscientiousness and agreeableness and a positive response to multi-systemic therapy (MST)[2] for severe and persistent delinquents (Asscher, Deković, Van Den Akker, Manders, Prins, Van Der Laan, & Prinzie, 2016), as well as increased anxiety as a plausible measure of vantage sensitivity (Tanofsky-Kraff, Shomaker, Wilfley, Young, Sbrocco, Stephens, ... & Yanovski, 2017).

[1] Trauma- focused therapy constitutes a form of psychotherapy integrating cognitive behavioral therapy with eye movement desensitization and processing (Cohen & Mannarino, 2015).
[2] Multi- systemic therapy (MST) refers to intensive home and community intervention. MST involves two to four therapists and a therapist supervisor utilizing practices from cognitive behavioral therapy, strategic family therapy, and structural family therapy for juvenile offenders addressing violent and/or sex offending as well as substance abuse (Weis, 2020).

Most recently, research on adolescents explored a plausible interaction between individual variability in sensitivity and environmental factors (i.e., individual differences in socio-emotional well-being changes assessed before and after the transition from junior to high school) (Iimura & Kibe, 2020). Results confirmed that individual susceptibilities can moderate external influences in a "for better or for worse" manner with highly sensitive adolescents demonstrating greater benefits from a positive school transition in comparison to lower susceptible adolescents. Such findings thus, indicate not only the importance of individual's sensitivity to environmental factors, but also the significance of considering its moderation as an additional marker of vantage sensitivity (Iimura & Kibe, 2020).

Even though research on genetic factors in vantage sensitivity structure has identified specific genes as indicators of sensitivity, research on physiological measures - whether there is an association between cortisol levels and treatment response - has not been verified. Evidence on psychological factors suggests that certain individuals appear to benefit greatly from positive experiences such as encouraging parenting, supportive relationships, and psychological therapy, whereas others seem to benefit less. On the other hand, findings on environmental factors indicate a possible moderating role for vantage sensitivity. Although the model of vantage sensitivity constitutes a rather novel framework, with a growing number of studies supporting the theory, the main limitation persists, as the theory focuses solely on positive experiences. Therefore, predictions regarding the response of highly sensitive individuals to negative experiences cannot be made.

To include both positive and negative experiences, two distinct evolutionary models of sensitivity were developed, the differential susceptibility theory (DST) (Belsky, 1997; 2005; Belsky & Pluess, 2009a; 2013; Belsky, Vandell, Burchinal, Clarke-Stewart, McCartney, Owen, & NICHD, 2007) and the biological sensitivity to context theory (BSCT) (Boyce, Chesney, Alkon, Tschann, Adams, Chesterman, ... Wara, 1995; Boyce & Ellis, 2005). The interactions between individuals and their environment (Person x Environment) are central for both models. Also, organismic attributes are hypothesized to moderate the effects of both negative and positive environments on individuals' development (Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van IJzendoorn, 2011). Furthermore, both models postulate individual differences in sensitivity to environmental stimuli and presume that individuals most likely to be adversely affected by unfavorable environments are similarly most likely to benefit from favorable ones (Ellis et al., 2011).

The model of differential susceptibility, which was first developed by Belsky (1997), has been based on the premise of adaptive individual variations in neurobiological susceptibility to the environment (Ellis et al., 2011). The structures of vantage sensitivity and diathesis-stress constructs are smoothly integrated in the theory of differential susceptibility, through the idea of responsivity to both positive and negative environments (Belsky & Pluess, 2009a). The paradigm thus has foundations in developmental psychology and proposes that individual differences in sensitivity are genetically determined. Highly sensitive individuals share a higher susceptibility to environmental conditions in comparison to individuals less susceptible to environmental changes (Pluess, 2015).

The differential susceptibility theory is supported by two evolutionary mechanisms i.e., conditional adaptation[3] and diversified bet-hedging[4] (Belsky, Hsieh, & Crnic, 1998). Significant individual differences in susceptibility might arise from two alternative developmental strategies: the plastic and fixed strategy. Both strategies have been preserved as a result of natural selection, in the form of bet-hedging which promotes variability and suitability of the species (Belsky & Pluess, 2009b). The plastic strategy reflects adaptation to the environment (implying high susceptibility), whilst the fixed strategy reveals relative apathy to environmental conditions (implying low susceptibility) (Ellis et al., 2011; Pluess, 2015). In terms of predictability, both models of conditional adaptation and differentiated bet-hedging propose hypotheses that require further research for improvement and testing (Ellis et al., 2011).

The DS model initially indicated that variations in susceptibility are genetically influenced and unveiled in the sensitivity of the central nervous system, though recent studies associate high susceptibility with a response to prenatal and early postnatal factors (Pluess, 2015; Pluess & Belsky, 2011). The framework of differential susceptibility accentuates on both phenotypic and endophenotypic attributes as well as genetic variations that could be

[3] Evolutionary developmental psychology defines conditional adaptation as a special type of adaptation to facilitate adaptive developmental plasticity. These adaptations allow organisms to implement alternative and contingent life history strategies, depending on environmental factors (Boyce and Ellis, 2005).
[4] Bet- hedging refers to the biological concept where suffering organisms decrease fitness in their typical conditions in response to increased fitness in stressful conditions (Stearns, 1976).

considered plasticity factors making certain individuals more pliable to different environmental conditions (Belsky & Pluess, 2009b). Nonetheless, implications of the DS model involve the primary mechanisms of children's development and potential responsivity.

More recently, research from Van Ijzendoorn and Bakermans-Kranenburg (2015) shifted the interest from inherent "risk factors" such as reactive temperament and "risk genotypes" to the intervention efficiency, investigating both the positive and the negative moderating role of genotypes. Results from 22 randomized experiments on the interaction between genetic and environmental factors (G x E) as well as meta-analytic evidence for the differential susceptibility model demonstrated that intervention effects are more efficient in the susceptible genotypes than in the non-susceptible genotypes. Such findings are valuable, as they create a new path of addressing the enduring issue of personalized therapy.

Similar to the DS theory, the BSC model, proposed by Boyce and colleagues (1995), involved two studies exploring whether environmental detriments and biological responsivity could function as indicators of respiratory diseases in young children. Findings showed no significant differences between low and high adversity environmental conditions in children with low cardiovascular or immune reactivity to stressors resulting to almost equivalent rates of respiratory diseases in both groups. In line with the diathesis-stress model though, highly biologically reactive children in highly adverse environments or child-care experienced illness incidents at a much higher rate in comparison to all other groups. A new discovery of BSC was the reflection that highly reactive children in lower adverse environmental or child-care conditions had the lowest disease rates, whilst those rates were found to be substantially lower even in comparison to low reactivity children in analogous conditions (Boyce et al., 1995). These findings were later incorporated into the differential susceptibility theory, according to which children differ in their susceptibility to environmental conditions in a "for better or worse" manner, where worse is defined in terms of psychopathological and physiological conditions (Pluess & Belsky, 2011).

Hence, the theory of BSC provides an evolutionary functional analysis advancing the hypothesis that developmental variances in biological sensitivity to context is sustained by natural selection, as biological sensitivity to context differences consistently generate diverse fitness products in distinct childhood environmental conditions coming across evolutionary history (Ellis et al., 2011). Boyce and Ellis (2005) posited that children exposed to highly stressful environments upregulates biological sensitivity to context, resulting in increased ability of individuals to perceive and respond to environmental risks. Similarly, exposure of children to positive environments upregulates biological sensitivity to context, resulting in increased vulnerability to support. Lastly, exposure of children to typical environments (i.e., environments neither adverse nor supportive) down-regulates biological sensitivity to context, plausibly protecting individuals against long-lasting stressors. The hypothesis of BSC has been confirmed in two exploratory analyses by Ellis and colleagues (2005), demonstrating that the lowest predominance of high responsivity phenotypes was established in environments of moderate stress, whilst both extremes of the support-adversity distribution were related to higher percentages of reactive children (Ellis, Essex, & Boyce, 2005).

The DS theory perceives inter-individual differences in sensitivity as genetically determined due to bet-hedging against uncertain future conditions (Ellis & Boyce, 2011). Conversely, the BSC theory focuses on early environmental difficulties that form sensitivity based on conditional adaptation to different environments (Del Giudice, Ellis, & Shirtcliff, 2011). Albeit the theoretical framework of DS points out responsivity and the BSC accentuates in reactivity, both concepts have originated from the evolutionary theory describing analogous developmental dynamics in extreme environmental conditions (adverse or supportive) rather than in typical. Nonetheless, neither can provide a systematic explanation of such variation, whereas the integration of the two models has been also proposed by few researchers (Ellis et al., 2011).

All the aforementioned models have offered valuable evidence on the subject of sensitivity, including genetic, behavioral, and environmental factors (particularly in extreme environments). However, sensory processing sensitivity is the first evolutionary theory perceiving sensitivity as a distinct phenotypic trait investigating individual's patterns of cognition, feelings, and behaviors to both typical and atypical environmental conditions, whilst it further suggests a strong link between those factors and inter-individual sensitivity differences. Lastly, SPS constitutes the only theory capturing this inter-individual variance through validated behavioral and observational psychometric tools among the lifespan that assess typical behaviors and experiences reflecting the fundamental attributes of sensitivity, specifically perception and processing. For these reasons, we perceive the theory of SPS as the most complete and accurate for the investigation of highly sensitivity as a newly discovered personality trait.

2.2 Sensory Processing Sensitivity

The theory of sensory processing sensitivity[5], developed by Aron and Aron (1997; see also Aron, 1996) constitutes the earliest theoretical framework perceiving sensitivity as a distinct biobehavioral trait present in both humans and animals. Through an extensive literature review (including animal literature) conducted by Aron and colleagues (2012), SPS is now identified as a significant genetically determined temperamental (personality) trait, reflecting an increased sensitivity of the central nervous system as well as increased depth of processing regarding physical, emotional, and social stimuli (Aron, 2002; Aron, Aron, & Jagiellowicz, 2012). Moreover, SPS remains the only theoretical framework of capturing inter-individual variations through validated psychometric tools among lifespan (e.g., the highly sensitive person [HSP] scale and the highly sensitive child Rating-System [HSC-RS]). Most recently, and due to societal interest, the terms of "hypersensitivity", "highly sensory processing sensitivity" (HSPS), or "highly sensitive person" (HSP) are considered universal synonyms for the scientific concept of SPS as they are widely utilized in psychological practice with adults and children (Aron et al., 2012).

Research on evolutionary biology has further revealed that the personality trait of SPS can be detected in the minority of over 100 nonhuman species (including animals and certain plant diversities) in terms of sensitivity, responsiveness, plasticity, and flexibility to environmental stimuli (Wolf, Van Doorn, & Weissing, 2008; Wolf & Weissing, 2010). Even though sensitivity was initially perceived as a feature of weakness, research reflects sensitivity as an advantageous feature of social animals (including humans) for their species survival (Aron & Aron, 1997). To further elaborate, increased sensitivity and consequently, responsivity to environmental stimuli by a minority provide evolutionary

[5] The term Sensory Processing Sensitivity (SPS) defines both the theory and the personality trait, though its different purpose will be sufficiently clarified across the dissertation.

advantages to their species, as highly sensitive organisms are inclined to a deeper cognitive processing of environmental elements resulting in ameliorated preparation for similar future situations. The biological cost of increased responsivity (i.e., being overwhelmed by intense stimuli) is thus, advantageous in a minority but disadvantageous in a majority, whereas it remains unclear whether this responsive strategy is expressed in genotype of phenotype in distinct species.

Highly sensitive individuals are thought to process stimuli at an increased cognitive depth and be easily overstimulated by environmental stimuli as a result of a lower perceptual threshold (Boterberg & Warreyn, 2016). According to the response strategy (Aron & Aron, 1997; Aron et al., 2012), HSPs react more to environmental cues by associating them to prior experiences with similar cues. This may precede individuals to dawdle more to observe and respond slower, whilst HSPs are also observed to be less susceptible to act when faced with new encounters and experience more aversion to risk-taking.

Research of Aron and Aron (1997) proposes that individual variances in SPS are partially regulated by the responsiveness of the operating parameters of the Behavioral Inhibition System (BIS), whereas additional studies of Aron and colleagues (2012) suggest that the personality traits of introversion (implying the inhibition of social behaviors) and neuroticism (the disposition of intense negative emotions) could, at least theoretically, be two aspects of a broader sensitivity. Systematic statistical studies of Smolewska and colleagues (2006) were the first to examine the psychometric properties of the Highly Sensitive Person scale (HSPS), and its association with the BIS / BAS approach (Gray, 1982; 1991; Carver & White, 1994), as well as the “Big Five” framework (Costa & McCrae, 1992), confirming not only the BIS function in HSPs, but also a positive correlation between high SPS and neuroticism (Smolewska, McCabe, & Woody, 2006).

The BIS / BAS approach (Gray, 1991) suggests three important distinct brain systems (Behavioral Inhibition System [BIS], Behavioral Activation System [BAS], and Fight / Flight / Freeze System [FFFS]) that regulate human behavior and establish the neurological basis for personality. The BIS, associated to the septo-hippocampal system, regulates aversive motives and being more sensitive to punishment, non-reward, and novelty. The BAS controls goal-directed behavior as well as positive feelings and responses. Lastly, the FFFS responds to immediate punishment or threat of harm (Corr & Perkins, 2006; Gray & McNaughton, 2003). During the BIS activation, one must pause, observe, and prepare for action. SPS theory (Aron & Aron, 1997) hypothesizes that BIS functioning is highly related to SPS, if we consider the "pause-to-check" function of the system as the default response strategy of highly sensitive individuals (Aron et al., 2012). Research of Smolewska and colleagues (2006) confirmed this assumption; namely, they reported a positive association between SPS and BIS activity ($r[821] = .32$, $p < .01$), whereas no significant association of BAS sensitivity and SPS was found. A similar study by Pluess and colleagues (2018) on a sample of 334 children of age 11 through 14 years recently reported a positive correlation not only between high sensitivity and BIS ($r[332] = .55$, $p < .01$), but also with BAS ($r[332] = .41$, $p < .01$).

Furthermore, the "Big Five" framework, developed by Costa and McCrae (1992) includes five broad personality domains. These domains were discovered by the researchers through studies of natural language using a lexicographic approach. The domains consist of Extraversion, Neuroticism, Openness to Experience, as well as Agreeableness and Conscientiousness; each domain is further analyzed in other particular facets. Thus far, studies investigating the associations between facets of SPS and personality domains have shown a moderate effect size of positive association with neuroticism and a negative association with extraversion. Research of Smolewska and colleagues (2006) found SPS to have a moderate positive association to neuroticism ($r(821) = .45$, $p < .01$) and an insignificant association to extraversion ($r[821] = .09$, $p > .05$). Similarly, Pluess and colleagues (2018) reported a moderate positive correlation between SPS and neuroticism ($r(1,172) = .31$, $p < .01$) and an insignificant correlation with extraversion ($r(1,172) = .18$, $p < .0.1$) was reported. On the other hand, Grimen and Diseth (2016) and Lionetti and colleagues (2018) reported a positive correlation of SPS and neuroticism (respectively $r(165) = .41$, $p < .0.1$ and $r(1,134) = .56$, $p < .01$), but also a negative correlation of SPS and extraversion (respectively $r(165) = -.33$, $p < .0.1$ and $r(1,1342) = -.24$, $p < .0.1$). The correlations of SPS to the other traits in the "Big Five", namely openness to experience (Grimen & Diseth, 2016; Lionetti, Aron, Aron, Burns, Jagiellowicz, & Pluess, 2018; Pluess et al., 2018; Smolewska et al. 2006), agreeableness and conscientiousness (Lionetti et al., 2018; Smolewska et al. 2006) were found to be non-significant.

A significant characteristic of high SPS is the low sensory threshold. This is similarly present in sensory processing disorders, where patients demonstrate distinct patterns (Boterberg & Warreyn, 2016). The theoretical overlap between the personality trait of SPS and clinical or developmental disorders has created extensive interest attracting academics from various disciplines such as biology, neuroscience, and psychiatry (Acevedo et al., 2018; Acevedo, Jagiellowicz, Aron, Marhenke, & Aron, 2017) and highlighted the importance for further interdisciplinary research. High SPS has been found to associate with higher levels of stress, alexithymia, anxiety, depression, and attention deficit hyperactivity disorder (ADHD) traits (Benham, 2006; Liss, Mailloux, & Erchull, 2008; Liss, Timmel, Baxley, & Killingsworth, 2005; Panagiotidi, Overton, & Stafford, 2020). Moreover, highly sensitive individuals raised in adverse environments are linked to negative affectivity and shyness (Aron, Aron, & Davies, 2005). Recent neuroscientific findings also demonstrate unique neural circuits including the prefrontal cortex (PFC), insula, and amygdala, which differentiate SPS from clinical disorders such as autism spectrum disorder, post-traumatic stress disorder, and schizophrenia (Acevedo et al., 2018). Likewise, brain regions involved in awareness, memory, and reward processing are affected in different ways among individuals with high SPS and clinical disorders.

Lastly, another unique feature of SPS involves the strong association between a wide variety of internal and external environments and levels of sensitivity. Even though all aforementioned constructs on sensitivity (VS, DS, BSC) have ambiguously indicated behavioral, environmental, and genetic factors, SPS further suggests a strong link between those factors and inter-individual sensitivity variations. Thus, SPS theory defines both conditioned and unconditioned environments comprising of physical, sensory, social, and emotional stimuli (Aron et al., 2012; Greven et al., 2019). These environments refer to physical stimuli (such as caffeine and sugar intake), sensory stimuli [visual (e.g., art, bright lights), auditory (e.g., loud noises), olfactory (e.g., smells), and tactile (e.g., textures)], social experiences (such as other people's intentions) as well as internal experiences (such as feelings and bodily sensations, e.g., pain, hunger) (Rappaport & Corbally, 2018). Overall, processing sensory events and stimuli substantially affects human experiences and behavior. The heightened depth of processing of stimuli in such environments demonstrated by highly sensitive individuals can result in overstimulation and higher responsiveness to distress.

2.2.1 Operational Definitions / Measurement of SPS

Alongside the theoretical framework of SPS, Aron and Aron (1997) developed the first scale for assessing individual differences in sensitivity, the Highly Sensitive Person scale (HSP scale). It was intended to be used for exploratory and empirical studies investigating how sensitivity is perceived among clinicians and society. The HSP scale was the first attempt to assess sensitivity in adults, and the scale is based on the theory of individual differences in sensitivity as a wider sensory processing of both internal and external stimuli, rather than sensitivity solely to sensory stimuli. A very good internal consistency was reported ($\alpha = 0.87$) and afterwards cross-validated ($\alpha = 0.85$). The HSPS has been additionally validated on a larger heterogeneous sample (Aron & Aron, 1997), whereas further studies cross-validated the unidimensionality of the scale (in terms of internal structure) resulting in three different levels of sensitivity (low, moderate, high) (Lionetti et al., 2018).

More recently, a shorter version of the HSP scale, consisting of a 12-item questionnaire, was developed by Pluess (2013) and has been thereafter utilized and validated in a series of studies with alphas of 0.71–0.75 (Lionetti et al., 2018; Pluess et al., 2018; Rubaltelli et al., 2018). The Highly Sensitive Child scale (HSC) was later also developed as a 12-item self-report assessment of SPS in children and adolescents between 8 and 13 years of age (Pluess et al., 2018), whereas additional studies showed decent psychometric properties and sufficient internal consistency in early and late adolescents (9-17 years of age) as well with Cronbach's α ranging from 0.67-0.78 (Iimura et al., 2020; Pluess et al., 2018; Weyn, Van Leeuwen, Pluess, Lionetti, Greven, Goossens, ... & Bijttebier, 2021). Lastly, the HSC self-report measurement was utilized to further construct a novel parent-report scale to measure sensitivity in kindergarten children (Mage = 4.77) with satisfactory internal consistency ($\alpha = 0.77$) (Slagt et al., 2017).

The HSP / HSC scales have been widely translated into several languages establishing both criterion validity and cross-cultural validity. More precisely, HSP scale is available in German (Konrad & Herzberg, 2017), Icelandic (Þórarinsdóttir, 2018), Spanish (Pérez Chacón, Pérez Chacón, Borda Mas, Avargues Navarro, & López Jiménez, 2021), Swedish (Ferré Hernandez, 2019), and Turkish (Şengül-İnal & Sümer, 2020), while HSC scale is available in Dutch (Weyn et al., 2021), German (Tillmann, El Matany, & Duttweiler, 2018), Italian (Nocentini, Menesini, Lionetti, & Pluess, 2017), and Japanese (Kibe, Suzuki, & Hirano, 2018; Iimura et al., 2020).

Initially, the HSP scale viewed SPS as a unidimensional construct, a subtype of social anxiety. Subsequent factor analyses though on the HSP scale have indicated a three-factor structure comprising of aesthetic sensitivity (AES), low sensory threshold (LST), and ease of excitation (EOE) (Grimen & Diseth, 2016; Smolewska et al., 2006). To further elaborate, the AES factor captures aesthetic awareness (i.e., openness to art and positive stimuli), LST reflects deep sensory arousal to external influences such as bright lights and loud noises, whereas EOE describes being easily negatively affected by both internal and external stimuli (e.g., negative response to abrupt awakening or to being hungry) (Pluess et al., 2018). All three components are found to represent distinctive associations for various aspects of sensitivity. LST has been suggested to associate with self-reported sensory distress (Weyn et al., 2021), whilst both the components of EOE and LST were positively correlated to a moderate extent with self-rated negative emotionality, depression, and anxiety (Liss et al., 2005). On the contrary, AES has been found to be related only with positive emotionality in adulthood as well as in childhood (Pluess et al., 2018; Sobocko & Zelenski, 2015).

Whether SPS ought to be classified as a dimensional or taxonomic trait constitutes an important dispute amongst academics. Early studies indicated two levels of sensitivity (high and moderate), where roughly the 20% of the population is considered highly sensitive and the remaining 80% less sensitive (Aron et al., 2012). Consistent with these findings, several studies have found clear divisions into distinct levels, with highly sensitive individuals being those scoring in the top 15 to 35% (Aron & Aron, 1997; Belsky & Pluess, 2009; Jagiellowicz et al., 2011; Kagan, 2022; Lionetti et al., 2018; Pluess et al., 2018). More recently, two distinct series of studies have identified three distinct SPS levels, a low sensitive group of approximately 25-35%, a medium group of roughly 40-47%, and a high group of 20-35% (Lionetti et al., 2018; Pluess et al., 2018). In such conceptualizations, SPS is perceived as a continuum trait that could be parsed in those three main groups, often likened to the sensitivity of different flowers (i.e., orchids, tulips, and dandelions, respectively) (Boyce & Ellis, 2005; Lionetti et al., 2018; Pluess et al., 2018).

In summary, a final answer on the establishment of SPS as a continuous or a categorical trait cannot yet be provided. Dimensionality proposes that individuals in the population vary only quantitatively (i.e., the degree of sensitivity), whereas categorization suggests that individuals can be qualitatively classified into distinct sensitivity groups (i.e., types of sensitivity) (Greven et al., 2019). In what manner SPS is investigated, depends on the research hypotheses and design. Similarly, some researchers point out the shortcomings of labelling in the diagnosis of mental disorders[6]. In this dissertation, we consider the phenotypic trait of SPS to fall into a continuum and operationalize both SPS and autistic traits scores as continuous variables with regard to our study's goals.

2.3 The Meta-framework of Environmental Sensitivity

Intrinsically, the theoretical frameworks of DS, BSC, and SPS all share the concept of sensitivity to both advantageous and adverse environments, whereas VS emphasizes on the positive end of sensitivity. Most recently, Pluess (2015) developed the meta-framework of environmental sensitivity built on the aforementioned models to describe each construct elucidating individual differences in perceiving and processing environmental stimuli (see **Figure 1** for a detailed schematic). Though prior concepts have insinuated that individuals with higher sensitivity are susceptible to experience stronger responsivity to both advantageous and adverse environmental stimuli and conditions, the model of environmental sensitivity further proposes that individuals may be more sensitive to negative and / or positive experiences as well (Pluess, 2015). Thus, whilst certain individuals scoring high in SPS may be particularly susceptible to adverse experiences (in contrast to positive ones), other may be specifically responsive to positive exposure (but not vulnerable to negative ones).

[6] For example, a recent study argued against the classification of psychiatric diagnoses, treating psychiatric categories as a scientifically insignificant, considering the high degree of comorbidity among mental disorders (Allsopp, Read, Corcoran, & Kinderman, 2019).

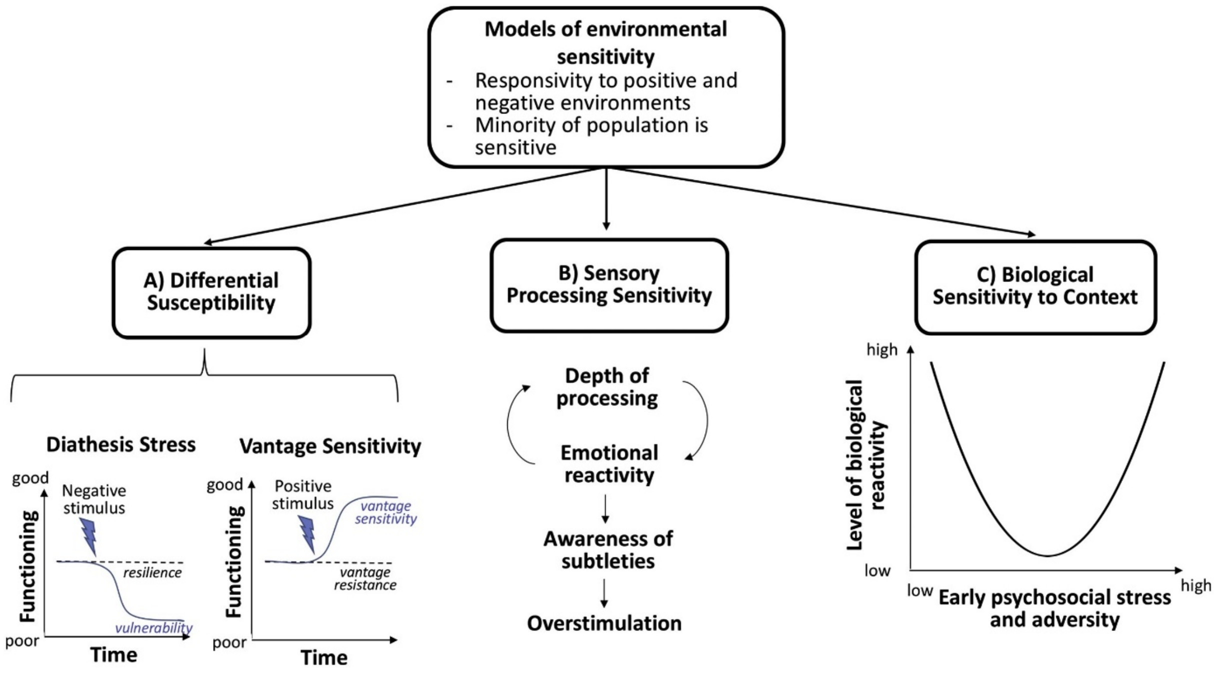

Figure 1: The meta-framework of environmental sensitivity

This graph presents all theories of sensitivity integrated under the meta-framework of environmental sensitivity including the differential susceptibility structure (A) comprised of the vulnerability models of diathesis-stress and vantage sensitivity; the structure of sensory processing sensitivity (B); and the structure of biological sensitivity to context (C). Source: Greven et al. (2019).

Consequently, the meta-framework of environmental sensitivity is perceived as an umbrella term comprising of distinct models of sensitivity, while at the same embracing additional standpoints. Namely, ES includes the theory of DS, comprised of the vulnerability models of diathesis-stress and vantage sensitivity suggesting vulnerability or resilience in response to both positive and negative environments due to genetic, temperamental and endophenotype influences. The SPS theory views sensitivity as a behavioral (personal) trait regarding exhibiting greater awareness of environmental subtleties, deeper cognitive processing, ease of overstimulation, and emotional reactivity and empathy. Furthermore, it posits that the interaction between greater depth of processing and emotional reactivity constitutes the fundamental cause of increased responsiveness to subtleties and ease of overstimulation. Finally, the BSC theory focuses on the biological basis of sensitivity, viewing it as a result of increased reactivity of the stress response system as a result of extremely stressful social environments at an early age.

Novel conceptualizations of environmental sensitivity concern the distinction between the notions of sensitivity and responsivity, as well as the denotation of developmental processes. Despite a significant correlation between sensitivity and responsivity, sensitivity implies facets of perception and processing of external stimuli, whilst responsivity implies the behavioral result of the processing, which can be influenced by various factors. Environmental sensitivity further illustrates developmental processes including phenotypic plasticity (i.e., the organism's ability to adapt its phenotype according to particular environmental conditions) and immediate reactivity presuming a moderately constant attribute of sensitivity across lifespan and distinct conditions (Pluess, 2015). In the following sections, relevant studies and evidence will be thus discussed in relation to both the framework of SPS and the meta-framework of environmental sensitivity.

2.4 Empirical Evidence of SPS as an Indicator of Environmental Sensitivity

Observational, experimental, and intervention-based research among different theoretical frameworks has been conducted to investigate the attribute of SPS in depth and assess its effects on highly sensitive individuals. Thus far, observational studies show consistency with the theories of SPS and diathesis-stress, as well as with the construct of environmental sensitivity as a marker of susceptibility, whereas no strong evidence are reported for differential susceptibility. Experimental studies demonstrate an association between high SPS and environmental sensitivity, while intervention studies seem to be more in line with the theory of vantage sensitivity.

Initial research on SPS and environmental conditions demonstrated a positive correlation between parenting quality and SPS, where highly sensitive individuals raised in a poor childhood environment indicated higher scores both on negative emotionality and social introversion, compared to highly sensitive individuals raised in a supportive environment, who received scores akin to the typical population (Aron & Aron, 1997). Another study exploring the association between parenting quality (measured by the parental bonding scale) and the externalization of depression symptoms, indicated a similar positive correlation; HSPs who reported low parenting quality showed higher levels of depression, suggesting that SPS could function as an independent risk factor for the externalization of distress symptoms in addition to parental experiences (Liss, Timmel, Baxley, & Killingsworth, 2005). More recently, research on life satisfaction and levels of SPS suggested reduced happiness in HSPs with adverse childhood conditions, whereas children raised in positive environments did not show any difference to controls in either SPS scores or life satisfaction (Booth, Standage, & Fox, 2015).

Research findings consistent with the DS theory revealed crossover interactions between SPS and positive experiences. Aron and colleagues (2005) reported a crossover interaction amongst SPS level, negative affect measures, and childhood conditions. Namely, their findings indicated that highly sensitive individuals with disturbed childhood demonstrated increased negative affectivity, whilst similarly sensitive individuals with a healthier childhood demonstrated less negative affectivity. These were the first obtained data consistent with the construct of DS, and its assumptions on a positive association between high sensitivity and supportive environments regarding the advancement of an individual. Recently, a study utilizing micro level observation data, in addition to longitudinal questionnaire data, investigated the association of differential reactivity and differential susceptibility in Dutch preschool children (Slagt, Dubas, van Aken, Ellis, & Deković, 2017). Results revealed an emotionally reactive "for better and for worse" group of children, where SPS was found to interact with differences in parenting quality (low vs. high), suggesting the accurate prediction of externalized behavioral problems based on the two factors of SPS and parental care (Slagt et al., 2017). More precisely, highly sensitive children were found to be most responsive to changes in parenting behavior in both forms of parenting. This model verified the prediction of increased externalization of problems when parenting became more adverse, and decreased externalization when parenting improved, thus supporting the paradigm of differential susceptibility.

In line with the meta-framework of environmental sensitivity, a recent study explored the moderating effects of environmental influences in the sensitivity of young children (3-5 years of age) (Lionetti, Aron, Aron, Klein, & Pluess, 2019). Findings validated the scale's efficacy on capturing inter-individual differences in children's sensitivity and revealed that highly sensitive children at ages three and six showed higher sensitivity to both low and high parental care, on both negative and positive developmental effects.

Furthermore, experimental studies verified the association between highly sensitive individuals and amplified responsivity to both negative and positive experiences. Research of Lionetti and colleagues (2018) explored the effects of high sensitivity utilizing a mood induction task, in which participants (N = 230) evaluated their mood prior to and after being exposed to a happy and sad video clip. Findings confirmed that HSPs are inclined to be more responsive to both positive and negative experiences, whilst less sensitive individuals are equally less responsive to both beneficial and detrimental exposures. Another research involving undergraduate students (N = 95) explored the interaction between SPS and the response to terrorism-related and neutral pictures, and found that individuals high in SPS and stress reactivity were affected the most by terrorism-related images. They were also more likely to accept shrinking privacy for improving national security, compared to individuals with lower SPS (Rubaltelli, Scrimin, Moscardino, Priolo, & Buodo, 2018). These findings, consistent with the theory of SPS, suggest that HSPs may be more sensitive to negative media, as a result of the increased depth of processing sensory information and the heightened emotional and behavioral responsiveness generated by such exposure in terrorism (Rubaltelli et al., 2018).

An intervention study in adolescent females investigated treatment response in a school-based depression prevention program constructed by principles of cognitive behavioral therapy (CBT) combined with positive psychology techniques (Pluess & Boniwell, 2015). Results indicated that different levels of SPS could accurately predict the treatment response to the program as females with high SPS responded more positively to the resiliency program compared to females with low SPS. More precisely, adolescent females with high SPS demonstrated a significant reduction in depression symptoms, where at the 12-months follow-up evaluation the highly sensitive group demonstrated substantially lower depression scores compared to the control group (though both low and high SPS groups started with comparable depression scores at baseline), whilst no significant difference was identified between the low SPS and the control group (Pluess & Boniwell, 2015).

A larger study (N = 2,024) in a randomized controlled trial explored whether individual differences in sensitivity could predict children's responsiveness to an antibullying intervention treatment (Nocentini, Menesini, & Pluess, 2018). Results confirmed previous findings with highly sensitive children to be more responsive to the treatment for internalizing behaviors, whereas children with lower SPS appeared rather resilient to the program's effects concerning victimization (Nocentine et al., 2018). Both studies provided empirical evidence consistent with the model of vantage sensitivity demonstrating that SPS variations could predict treatment response, where certain individuals are more responsive than others due to differences in sensitivity.

A most recent cross-sectional study investigated the moderating effects of SPS on the association between life skills and depressive tendencies in Japanese university students (Yano, Kase, & Oishi, 2021). A sample of undergraduate students (N = 868) completed a behavioral questionnaire to assess levels of SPS, and a number of variables such as depressive tendencies, emotional coping skills, decision-making, and interpersonal relationships. Results suggested a positive association between SPS and depressive predispositions, whereas emotional coping skills were observed to reduce depressive tendencies only in highly sensitive individuals. Furthermore, decision-making skills indicated a negative association to depressive tendencies only to low sensitive individuals, whilst interpersonal relationships were equally negatively associated to depressive tendencies, independent of variations in SPS (Yano et al., 2021).

Chapter 3

Neurobiology of SPS

Although SPS is established as a genetically based phenotypic trait associated with increased sensitivity and responsivity to internal and external stimuli, greater awareness of environmental subtleties, and ease of overstimulation, it remains uncertain how it differentiates from seemingly related behavioral or clinical disorders sharing comorbid symptoms, such as overstimulation by environmental stimuli. At present, advanced technologies in biology and neuroscience have been designed and utilized to explore the genetic and environmental aetiologies of SPS, as well as neural and neurocognitive mechanisms observed in humans and other primates. Thus, in this chapter, innovative research and findings on the neurobiological basis of SPS (including both humans and animals) will be presented and evaluated.

3.1 Genetic Basis and Environmental Factors of SPS

For a better understanding of the genetic and environmental mechanisms underlying SPS, we need more molecular genetics studies and large-scale research on genetic databases. Thus, candidate gene studies have been recently implemented to examine plausible links with certain genetic variants, known for their biological function to test the possibility of significant genetic influence on SPS. Much recent research includes genome wide association studies (GWAS) examining relations across the entire genome, in an attempt to unravel genetic aetiologies of a trait in a hypothesis-free manner. The main disadvantage of such an approach is cost and time inefficiency, given that such studies require a large sample to reliably detect genetic variances (Greven et al., 2019). Moreover, in an effort to create large-scale databases, twin data research is required, where correlations between monozygotic (MZ) and dizygotic (DZ) twins[7] can provide evidence on the heritability of a trait. Such twin designs are used to approximate the proportion of variance in a genetically based trait including shared and non-shared environmental factors (Boomsma, Busjahn, & Peltonen, 2002). Nonetheless, even if recent genetic studies attempt to unravel underlying personality traits, including SPS, the obtained evidence remain inconclusive. Consequently, research on animals is expected to further advance our knowledge on the neural structures of behavior as well as the mechanistic understanding of complex biologically based traits by providing a better control over environmental factors, in comparison to human studies. (Robbins, 2018).

Two molecular genetic studies have been conducted to investigate plausible associations among SPS, the s-allele, and various candidate genes in the dopaminergic system, such as the serotonin transporter-linked polymorphic region (5-HTTLPR - also containing the single nucleotide polymorphism [SNP] rs25531), whose significance is also highlighted in the vantage sensitivity model. Research on both humans (Beevers Marti, Lee, Stote, Ferrell, Hariri, & Telch, 2011) and animals (Homberg & Lesch, 2011; Homberg, Schubert, Asan, & Aron, 2016) has established the association of the 5-HTTLPR and increased sensitivity to positive and negative stimuli, based on the variation of the gene (Pearson, McGeary, Maddox, & Beevers, 2016). Results from one of the initial studies (N = 169) which tested this hypothesis suggested a small-scale association of SPS and s-allele, indicating an association with homozygosity in the serotonin system (Licht, Mortensen, Knudsen, 2011).

A later molecular genetic study included 480 college students and aimed to explore the relation of SPS to various candidate genes in the dopaminergic system (Chen, Chen, Moyzis, Stern, He, Li ..., & Dong, 2011). Data indicated ten polymorphisms which were reported to show significant associations with SPS. Subsequent regression analyses revealed that a model with all ten polymorphisms as predictors could explain approximately 15% of the variance in SPS, with an additional 2% explained by stressful life events (Chen et al. , 2011). These findings have demonstrated significant primary results of plausible underlying genetic aetiologies of SPS and should therefore be treated with caution, as additional,

[7] Monozygotic twins (also referred to as identical twins) share 100% of their genetic complexion, whilst dizygotic twins (acknowledged as fraternal twins as well) share approximately 50% of their additive genes (Boomsma, Busjahn, & Peltonen, 2002).

larger-scale molecular genetic research is necessary for both replication and validation of the results.

These results are in line with animal studies focusing on the role of serotonin in SPS. To further elaborate, the knockout animals[8] (i.e., rodents) exhibiting the 5-HTTLPR s-allele demonstrated strong behavioral similarities with individuals scoring high on SPS (Caspi, Hariri, Holmes, Uher, & Moffitt, 2010; Homberg et al., 2016). Functional and structural imaging studies have also confirmed differences in their neural activity in the PFC, insula, amygdala, hippocampus, and nucleus accumbens (Bearer, Zhang, Janvelyan, Boulat, & Jacobs, 2009; Pang, Wang, Klosinski, Guo, Herman, Celikel, … & Holschneider, 2011; Van der Marel, Homberg, Otte, & Dijkhuizen, 2013). Moreover, the knockout animals show faster sensory processing (Miceli, Nadif Kasri, Joosten, Huang, Kepser, Proville, ... & Schubert, 2017) and reduced latent inhibition (Nonkes, van de Vondervoort, de Leeuw, Wijlaars, Maes, & Homberg, 2012), indicators of augmented openness to extraneous environmental subtleties (Carson, Peterson, & Higgins, 2003). The animals further appear to adapt well to environmental changes, where the "pause to check" attribute suggests a highly adaptive behavior for processing information in a given situation before making the best plausible response (Nonkes, Maes, & Homberg, 2013), whilst they demonstrate increased responsivity to rewarding agents and better memory for emotionally arousing events (Homberg, De Boer, Raasø, Olivier, Verheul, Ronken, … & Vanderschuren, 2008; Nonces et al., 2012; Nonces et al., 2013). However, they also seem to be more susceptible to increased anxiety- and depression-related phenotypes when exposed to emotionally conflicting situations (Kalueff, Olivier, Nonkes, & Homberg, 2010).

Moreover, behavioral and electrophysiological research on rodents regarding the excitation-inhibition (E/I) balance resulting from the perception of environmental stimuli has indicated that such imbalance may be one of the underlying neural mechanisms of increased sensitivity to environments. Namely, a decrease of the inhibitory control results in hyperexcitability of the glutamatergic excitatory neurons (Miceli, Nadif Kasri, Joosten, Huang, Kepser, Proville, ... & Schubert, 2017). These findings were consistent with previous

[8] Knockout animals lack of a target gene, obtained by disrupting a specific gene. The technology for creating knockout animals is triggered by the discovery of embryonic stem cells (ES cells) that have totipotency (the ability to differentiate into all cells; that is, the ability to create whole individuals) (Hall, Limaye, & Kulkarni, 2009).

research (Pang et al., 2011) and the hypothesis of a mechanism which contributes to increased excitability of the somatosensory cortex. Furthermore, additional research has suggested that such increased excitability might extend to other brain areas as well, considering that receptors of the GABA structure are decreased in the PFC, somatosensory cortex, and hippocampus (Guidotti, Calabrese, Auletta, Olivier, Racagni, Homberg, & Riva, 2012; Luoni, Hulsken, Cazzaniga, Racagni, Homberg, & Riva).

At the present time, only two twin studies have been conducted. The first evaluated the heritability of SPS, whilst the second explored the genetic and environmental influences on ASD and sensory processing alterations. In the first study, SPS was measured in a representative sample of British adolescents approximately 16-17 years of age (N = 2,868) with the goal of investigating its association to probable genetic causes (Assary, Zavos, Krapohl, Keers, & Pluess, 2021). Data demonstrated that genetic factors could explain 47% of the variation in sensitivity, whereas non-shared environmental factors could account for the remaining 53% of the variance. Nevertheless, this finding supports the idea of the heritability of SPS.

Furthermore, multivariate analyses indicated significant distinctions in genetic and environmental aetiologies regarding variance in the ease of excitation (EOE) and low sensory threshold (LST), but not aesthetic sensitivity (AES) (see **Figure 2** for a detailed graph of shared and non-shared genetic and environmental factors on the three main factors of sensitivity). This evidence could be accounted for by a multi-dimensional genetic model of sensitivity, where genetic factors might differentially influence the development of highly sensitive individuals, particularly those scoring high on either AES or EOE / LST. As mentioned earlier, SPS was substantially correlated with two of the five factors of the five-factor model of personality, neuroticism (r = 0.34) and extraversion (r = -0.18). These correlations could be explained by shared genetic influences (see **Figure 3** for a detailed schematic representation of shared and specific genetic and environmental factors on both personality and sensitivity). It is, therefore suggested that phenotypic similarities between sensitivity, extraversion and neuroticism are a byproduct of an underlying shared genetic base, while variations among these attributes affected by environmental influences (Assary e al., 2021).

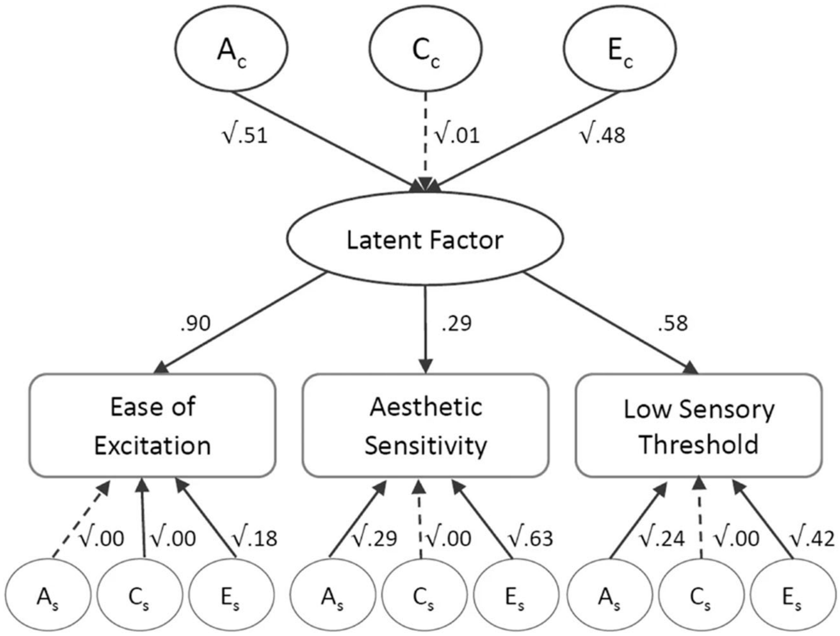

Figure 2: Common pathway representation of shared and non-shared genetic and environmental factors on key components of sensitivity (ease of excitation [EOE], aesthetic sensitivity [AES], and low sensory threshold [LST]).

This graph illustrates the standardized estimations for the latent factor of sensitivity and the percentage of variance explicated in each component by the latent factor (A[c,s], common and specific additive genetic factors, C[c,s], common and specific shared environmental factors, E[c,s], common and specific non-shared environmental factors). Source: Assary et al. (2021).

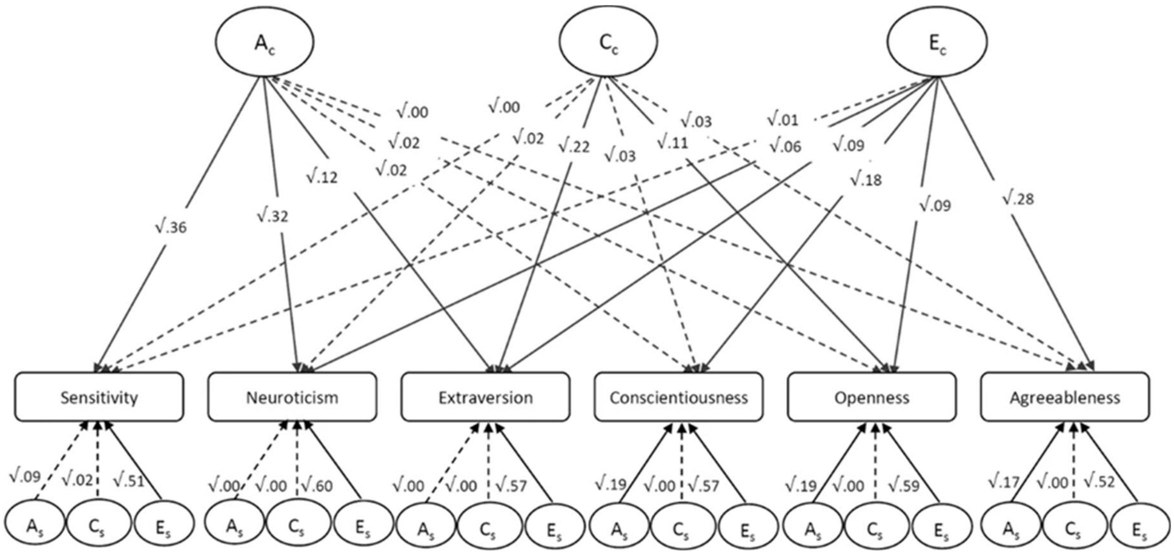

Figure 3: Independent Pathway representation of shared and specific genetic and environmental factors on both personality and sensitivity.

This graph presents the standardized variance facets explained by common ACE factors in each trait as well as the standardized ACE estimations specific to each facet. Source: Assary et al. (2021).

The second twin study (N = 269) investigated the genetic and environmental associations between autistic traits (ATs) / ASD diagnosis and sensory processing alterations (Neufeld, Taylor, Lundin Remnélius, Isaksson, Lichtenstein, & Bölte, 2021). For this study, the Adolescent / Adult Sensory Profile[9] was used. This is a scale measuring sensory processing alterations among sensory modalities and differentiating it in subdomains of low registration, sensory sensitivity, sensation seeking, and sensation avoiding. Results indicate an association of sensory sensitivity and ATs only in DZ twins, suggesting a genetic influence, whilst the association between ASD and the subdomains of low registration and sensation avoiding demonstrate non-shared environmental factors (see **Figure 4** for an elaborated illustration of the results of ATs and the four subdomains of sensory alterations). These findings suggest that altered sensory processing is not particular to ASD, whilst ASD could function as an indicator of certain sensory processing alterations, even in cases of other diagnoses of comorbid neurodevelopmental / psychiatric disorders (Neufeld et al., 2021).

[9] The Adolescent / Adult Sensory Profile, based on the Sensory profile (Dunn, 1999), is designed for self-evaluation of behavioral responses to every day sensory experiences, allowing professionals and individuals to measure and to profile the effect of sensory processing on functional performance.

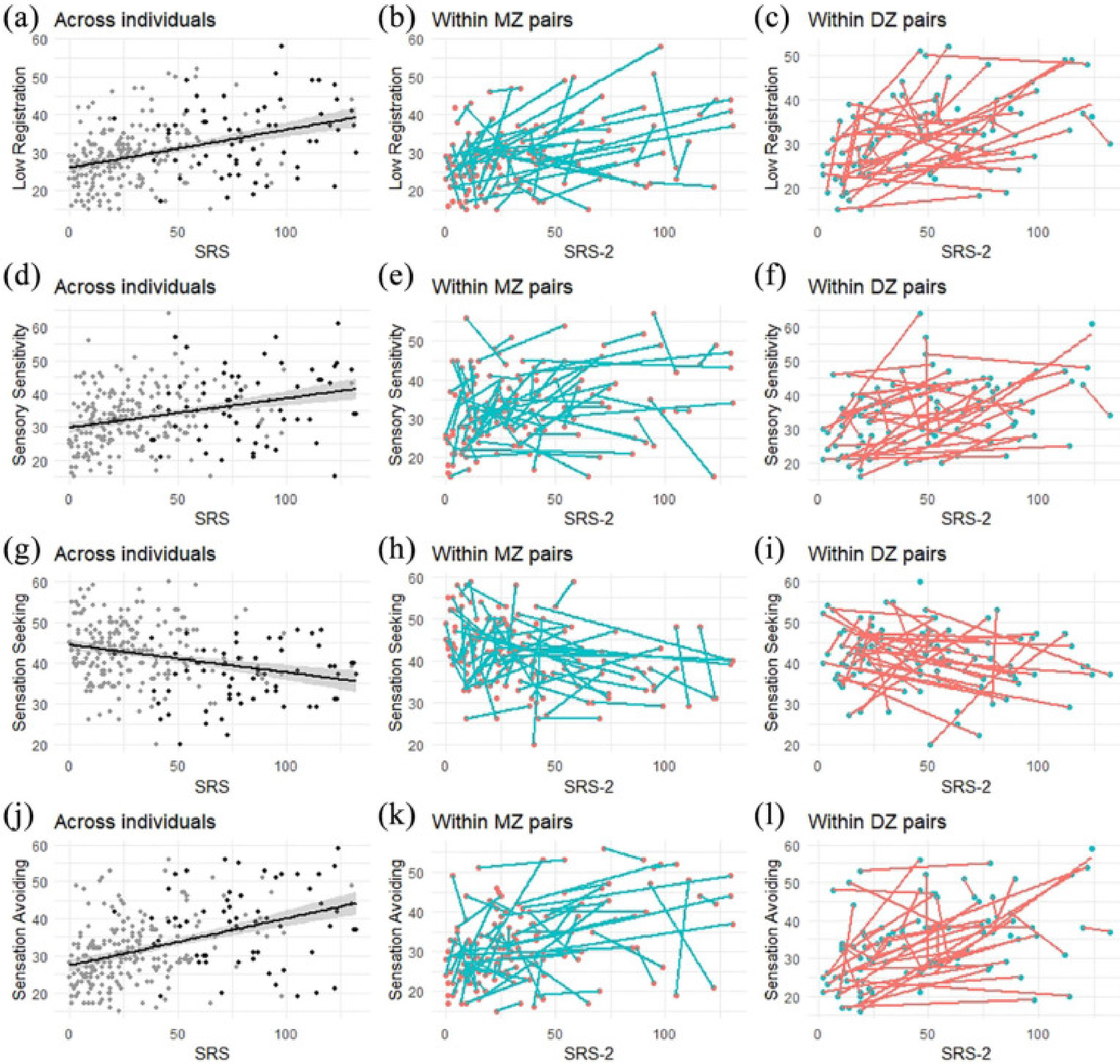

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Figure 4: Plots visualizing unadjusted regression results of autistic traits and low registration, sensation seeking, sensory sensitivity, and sensation avoiding in individuals, monozygotic, and dizygotic twins.

This graph denotes the four subdomains of the Sensory Profile in quadrants mapped as a function of autistic traits. Quadrants a, d, g, and j demonstrate the unadjusted models across individuals with ASD (black dots) and those without (gray dots). Quadrants b, e, h, and k represent the associations within MZ twins (each pair of twins is connected with blue lines), whilst c, f, i, and l the associations within DZ twins (each pair is connected with a red line). Source: Neufeld et al. (2021).

3.2 Neural Structures

Thus far, there have been only six functional magnetic resonance imaging (fMRI) studies conducted in adult humans, investigating the neural basis of SPS. All studies utilized the

HSP scale to assess SPS. Among them, two studies explored brain responses to perceptual tasks, two examined SPS responsivity to emotional stimuli, and two investigated differences between resting-state (RS) brain activity and SPS. In addition to the associated neuroimaging findings, supplementary behavioral studies suggesting enhanced awareness of environmental influences and emotional reactivity in SPS will be presented here. Albeit findings from the aforementioned studies indicate additional differences in depth of processing, empathy, and overstimulation, up to date studies have yet not directly focused on such associations rather pointed towards this direction for future research.

First, a cross-cultural fMRI research investigated the perceptual aspects of SPS in Asians and Americans (N = 20) using numerous visuospatial tasks (Aron, Ketay, Hedden, Aron, Rose Markus, & Gabrieli, 2010). As brain activation increases in arduous tasks, Asian and American individuals completed visuospatial tasks involving context-independent (generally easier for the American population) or context-dependent (generally easier for the Asian population) judgements to investigate the association between SPS and cultural-related differences. Results showed a positive correlation, suggesting that SPS may be related with perceptual judgments rather than with cultural, where highly sensitive individuals process all stimuli intensely, independent of social and cultural norms, a finding which indicates reduced influence of culturally induced biases (Aron et al., 2010). Findings also exhibited increased brain activity in both the frontal and parietal lobes during the more demanding task in both Asian and American individuals, whereas no similar association was observed between them in high SPS individuals. A subsequent behavioral study on 89 undergraduate psychology students (Gerstenberg, 2012) confirmed these results and also reported a significant positive correlation between SPS and enhanced performance in a visual detection task, though high SPS additionally resulted in increased reported stress after the test.

A second fMRI research investigating the neural basis of SPS focused on perceptual responsivity as a function of SPS . 18 participants were scanned while performing a task where they were asked to observe subtle differences between landscape photographs. Results revealed a positive correlation between SPS and reaction times. They also reported increased activation of brain regions involved in both high-order visual processing and attention (including the right claustrum, left occipito-temporal, bilateral temporal and medial and posterior parietal regions) following minor (versus major) changes in stimuli (Jagiellowicz, Xu, Aron, Aron, Cao, Feng, & Weng, 2011). A more recent behavioral study (N = 97) has similarly confirmed that HSPs show increased reaction times in perceiving subtle changes of a stimulus in photographs (e.g., color or size), but not in response to more apparent (e.g., location) (Bridges, 2018; Bridges & Schendan, 2019b). These findings could be perceived as evidence on two fundamental features of SPS i.e., the deeper cognitive processing and the "pause to check" process.

Another fMRI study examined the increased responsiveness to social and emotional stimuli. In this research, Acevedo and colleagues (2014) investigated the neural responsivity to displays of people's emotions . The participants (N = 18) were scanned twice (almost one year apart) whilst looking at the happy, negative, or neutral facial expressions of a partner or a stranger. Prior to each facial display, participants were triggered with a corresponding sentence describing the image such as, "Your partner is feeling very happy because something wonderful has happened to them" or "Your partner is sad and suffering because something terrible has happened to them". Results demonstrated a strong association between SPS scores (measured with the 11-item HSP scale) and brain activation across all conditions, whereas HSPs exhibited increased brain activation on the cingulate and premotor area (PMA) involved in attention and action planning. Furthermore, on conditions of happy and sad face images, SPS was related with brain activation of the insula and inferior frontal gyrus (IFG) involved in sensory integration, awareness, empathy, and preparation for action and cognitive self-control (Acevedo et al., 2014).

Regarding the functions of the specific brain regions , the cingulate cortex is engaged in coordinating attention and awareness of other individuals behaviors (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996), whilst the PMA is associated to action planning and unconscious behavioral control (Cross, Hamilton, & Grafton, 2006). The insula is involved with the perception and integration of internal sensory stimuli (e.g., emotions and feelings), whereas activation of the insula indicates an association with consciousness as well as increased awareness of sensory and environmental stimuli (Craig, 2009). The IFG is related to intuition of others' goals, while IFG activation is involved with empathic processing (Van Overwalle & Baetens, 2009).

Thus, data from fMRI studies are consistent with fundamental facets of SPS, including depth of processing, awareness of subtleties, integration of sensory information, empathy, as well as a greater impact of others' tempers, detected during activation in distinct brain regions involving the cingulate, insula, IFG, and PMA. Overall, individuals high in SPS were found to empathize and respond to others' positive emotional states more effortlessly (especially to positive emotions of a partner), emphasizing an advantage of highly sensitivity.

Another fMRI study exploring the neural responses to emotional stimuli, investigated plausible associations between SPS and its interaction with the quality of childhood parenting (SPS x QCP) (Acevedo, Jagiellowicz, Aron, Marhenke, & Aron, 2017). Participants (N = 14) completed the HSP scale, a neuroticism scale, and retrospective reports of QCP, prior to their scans, where positive, negative, and neutral images from the standard International Affective Picture System (IAPS) were displayed (Lang & Bradley, 2007). Findings demonstrated substantial correlations of SPS and childhood environment, with differential activation of brain regions including the temporal / parietal areas, entorhinal area, hippocampus, and hypothalamus, associated with reflective thinking, memory, hormonal balance, and emotion in children from supportive environments. A stronger reward response to positive stimuli in the ventral tegmental area and nucleus accumbens was observed in individuals high in SPS, while a notable increased response was particularly evident to individuals reporting higher quality childhoods (a graphical representation of these results is presented in **Figure 5**). With regards to negative images, the interaction of SPS and childhood demonstrated increased neural activity in the brain areas of amygdala and PFC, associated in emotion-processing and self-regulation, without decreased reward response. These findings imply that positive environments may provide long-term effects, emphasizing the significance of childhood environment (particularly among HSPs) for self-regulation in adulthood. Self-regulation constitutes a crucial mechanism in SPS, affected by childhood quality and sensitivity level, with strong implications for the individual's development and adulthood.

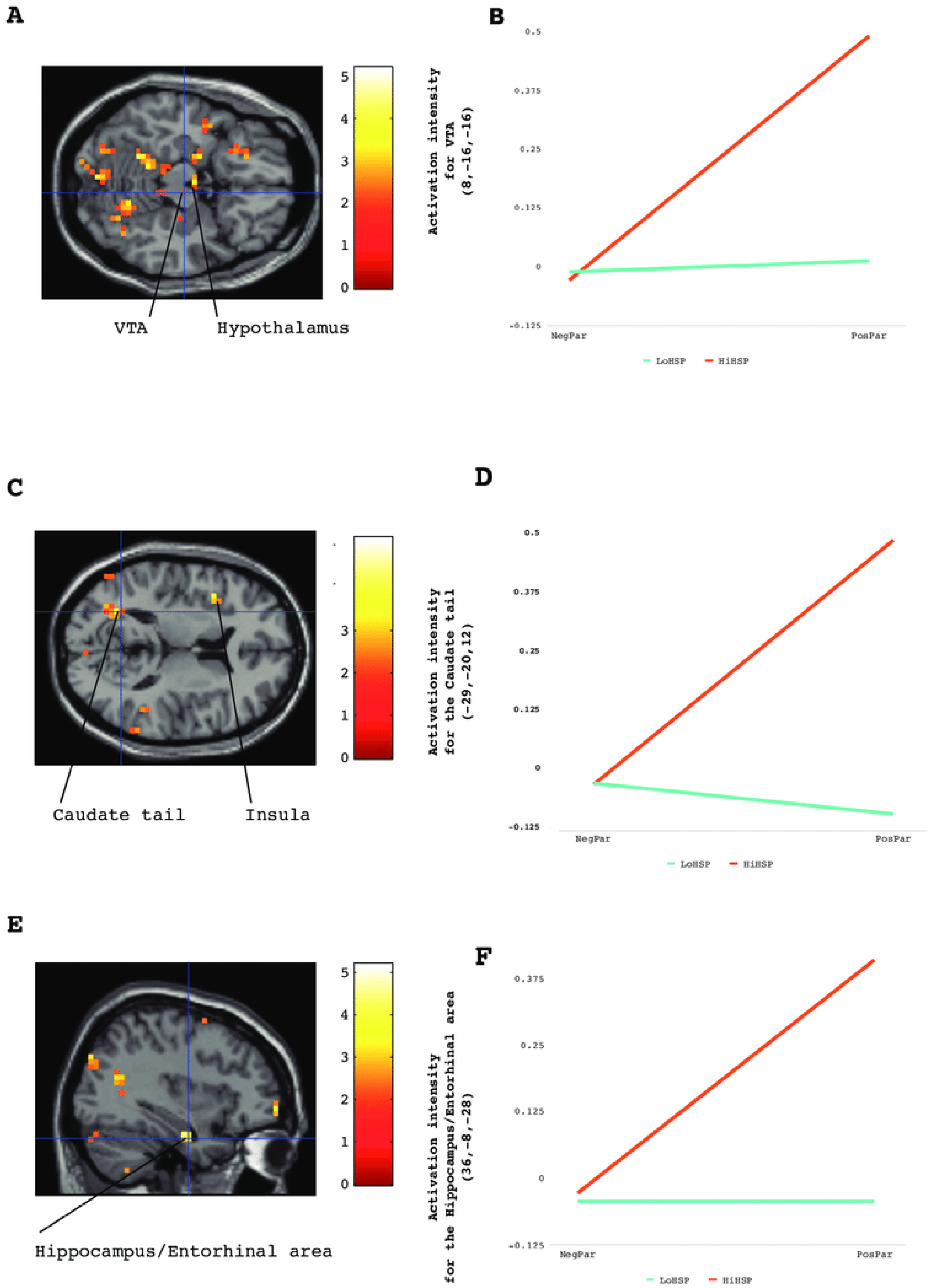


Figure 5: Brain areas affected by the interaction of Sensory processing sensitivity (SPS) and subjective quality of childhood parenting (QCP).

This graph illustrates brain's responsivity to positive images in the ventral tegmental area (VTA) / substantia nigra (SN) and hypothalamus (A), the caudate tail and insula (C), and the hippocampus / entorhinal area (E). Plots B, D, and F demonstrate the moderation of subjective positive childhood in relation to the response intensity in VTA / SN, the caudate tail, and the hippocampus / entorhinal area, respectively. Source: Acevedo et al. (2017).

Finally, there are two studies associated to SPS and resting-state brain activity, studying the effects of dopamine-related genes and the overall effects of the dopamine system to SPS, where 98 polymorphisms of dopamine-related genes were tested (Chen, Chen, Moyzis, Stern, He, Li, ... & Dong, 2011). Results indicated that the effects of dopamine-related genes on SPS were suppressed as a result of temporal consistency of local spontaneous activity in the precuneus - an area associated with episodic memory (Chen et al., 2011). Previous research has similarly implied the involvement of the precuneus with the integration of higher-order information, such as visuo-spatial imagery and emotional stimuli, particularly in instances of self-related mental representations and self-processing (Cavanna & Trimble, 2006). Thus, evidence implies that precuneus activity could function as a moderator in the association of SPS and dopamine genes.

The second, and most recent, study (N = 15) examined the association between resting-state functional connectivity and depth of processing as a function of SPS (Acevedo, Santander, Marhenke, Aron, & Aron, 2021). Participants completed the HSP scale and a social affective task prior to the fMRI scans, whilst SPS levels were additionally correlated to RS brain connectivity. Results revealed increased RS brain connectivity in regions associated to physiological homeostasis, attentional control, strengthening of memory, and premeditated cognition, indicating brain connectivity as a function of increased SPS. Additional analyses in other regions of interest demonstrated increased connectivity in wider areas of the hippocampus and the precuneus, whereas reduced connectivity was evident in areas of the amygdala and the periaqueductal gray (associated with anxiety), as well as the hippocampus and insula (involved in typical cognitive processing) (Acevedo et al., 2021). These findings are in line with the fundamental attribute of SPS regarding the “depth of processing”, whereas also reveal the underlying neural processes of the trait. **Figure 6** illustrates a comprehensive neural map of SPS based on all available findings, as presented by Greven and colleagues (2019).

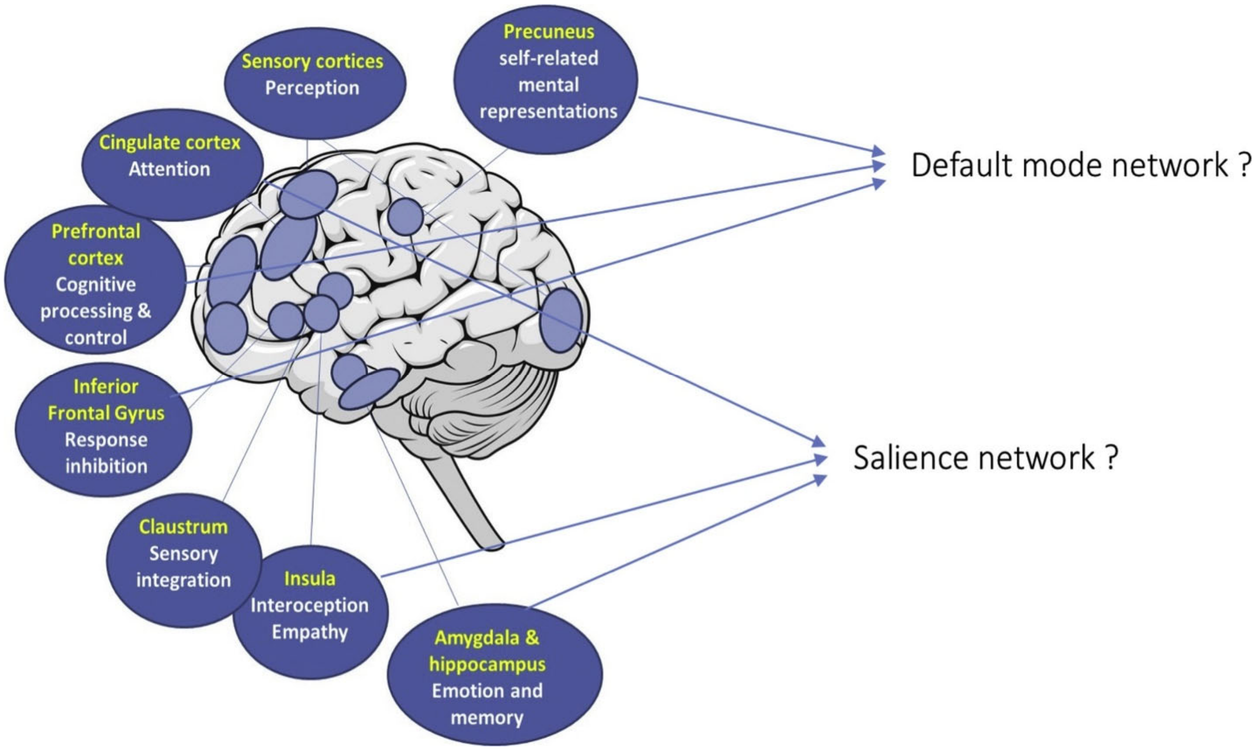


Figure 6: Neural map of SPS.
This graph demonstrates how numerous brain areas which specialize in increased depth of information processing (including the precuneus, prefrontal cortex, and inferior frontal gyrus) as well as heightened emotional reactivity (insula, claustrum, amygdala, and cingulate cortex) are highly activated in hypersensitive individuals, as measured by SPS. Incidentally, the same brain regions correspondingly comprise the default mode network and salience networks, which help orient our attention to salient and emotional stimuli. Source: Greven et al. (2019).

3.3 Neurocognitive Structures

Two behavioral studies have been conducted to explore neurocognitive mechanisms of SPS in high SPS groups of English undergraduate students regarding differences on controlled and automatic attention tasks (Bridges, 2018; Bridges & Schendan, 2019b). In the first study, individuals scoring high in either SPS or AES completed a change detection task and the Attention Network Task (ANT), where error rates were increased when HSPs were presented to targets with unrelated (vs. neutral) flankers. Findings are consistent with the SPS facets of greater attention to detail and deeper cognitive processing, possibly resulting in more errors (Bridges, 2018; Bridges & Schendan, 2019b). The second study investigated the automatic attention in relation to increased awareness of subtle stimuli, where results showed that HSPs exhibited greater interference with spatial compatibility on an orienting task involving automatic attention (Bridges 2018; Bridges & Schendan, 2019b). Hence, findings suggest that highly sensitive groups can show increased conscious awareness of subtle information when learning an implicit task, whilst variation in SPS indicate differences in controlled and automatic processes leading to either beneficial or detrimental implications for other aspects of cognition such as memory and creativity (Bridges & Schendan, 2019a; 2019b).

Chapter 4

SPS and Psychopathology

Although a theoretical overlap between the personality trait of SPS and clinical / developmental disorders has been observed, numerous studies investigating the relations between SPS and other (possibly comorbid) disorders demonstrate a clear distinction. This chapter will, therefore discuss possible interactions amongst SPS variations, childhood environments (optimal vs. less optimal), and the development of individuals (typical vs. atypical). Furthermore, the theoretical intersection between the personality trait of SPS and clinical / developmental disorders will be presented, whereas special emphasis will be given on the relation of SPS, Autistic Spectrum Disorders (ASD), and Autistic Traits (ATs).

4.1 Association of SPS Levels and (Mal)adaptive Individual's Development

A fundamental aspect of SPS is the reflection of sensitivity to both negative and positive environmental stimuli, resulting in atypical or typical (even flourishing) development, respectively. Although the exact nature of the association between high SPS and maladaptation has yet to be revealed, findings have suggested high susceptibility to negative outcomes in HSPs. Up to date research has largely focused on the clinical association with SPS, whereas only few studies have explored plausible interaction effects between HSPs and negative outcomes due to adverse environments. Studies on the relation between SPS and positive outcomes have recently prospered in regard to intervention therapy, though in depth research on typical and / or positive outcomes still fall behind.

4.1.1 SPS and Negative Outcomes

Thus far, findings posit SPS as a temperamental trait, differentiating it from clinical disorders. Healthy individuals scoring high in SPS though, are found to be more susceptible to adverse environments, increasing the risk for negative developmental outcomes and maladaptation (Ahadi & Basharpoor, 2010; Benham, 2006; Engel-Yeger & Dunn, 2011; Liss et al., 2005). Extensive behavioral research has associated high SPS to a variety of negative outcomes, including physical and mental symptoms. To further elaborate, series of studies have indicated positive correlations between high SPS and self-reports of increased pain sensitivity (Engel-Yeger & Dunn, 2011; Liss et al., 2005), tendencies of anxiety (Jonsson, Grim, & Kjellgren, 2014; Liss, Mailloux, & Erchull, 2008; Meredith, Bailey, Strong, & Rappel, 2016; Neal, Edelmann, & Glachan, 2002), alexithymia (Liss et al., 2008), depression (Bakker & Moulding, 2012; Liss et al., 2005; Liss et al. 2008; Yano & Oishi, 2018; 2021), panic disorder (Bakker & Moulding, 2012; Liss et al., 2005; Liss et al., 2008; Neal et al., 2002), and other internalizing difficulties (Boterberg & Warreyn, 2016).

SPS has also been associated with psychological difficulties affecting individual's emotional and physical well-being involving physical symptoms of morbidness (Benham, 2006), augmented work dissatisfaction and necessity for recuperation (Andresen, Goldmann, & Volodina, 2018; Evers, Rasche, & Schabracq, 2008), lower levels of subjective happiness (Sobocko & Zelenski, 2015), as well as overall reduced life satisfaction (Booth et al., 2015; Evans & Rothbart, 2008; Smolewska et al., 2006). Additionally, high sensitivity is implicated to difficulties in emotion regulation as well as weak stress management (Brindle, Moulding, Bakker, & Nedeljkovic, 2015) and elevated stress levels (Bakker & Moulding, 2012; Benham, 2006).

Moreover, exploratory studies have recently emerged to investigate plausible associations between SPS and parenting. Of interest, a study involving German parents (N = 614) has indicated a negative correlation between transition to parenthood and well-being in HSPs (Schmueckle, Lindert, & Schmolz, 2017). Consistent with these findings, a study involving a smaller sample of Chinese parents (N = 122) with children exhibiting ASD symptoms indicated negative effects on parental mental health in highly sensitive individuals (Su, Cai, & Uljarevic, 2018). In another research, the assessments of SPS, Parenting Difficulties, and Attunement to Child were utilized to investigate the relation of SPS and parenting (Aron,

Aron, Nardone, & Zhou, 2019). Mothers (N = 802) with high SPS demonstrated significantly increased scores on both parenting difficulties and attunement to child, whilst highly sensitive fathers (N = 65) showed similar high scores only regarding attunement (Aron et al., 2019). Similarly, a study on parenting practices of highly sensitive parents in parent-adolescent dyads (N = 121) used the HSP scale and Experiences in Close Relationships scale (ECRS) for the parents, and Weinberger Parenting Inventory (WPI) for the children (Goldberg & Scharf, 2020). Results demonstrated a particular challenging and more stressful parenting, possibly due to personal difficulties of their own emotion regulation decreasing their ability to parental care. This evidence indicates that individuals high on SPS are particularly susceptible to overstimulation of parenting, signifying the importance of finding tactics to cope with such difficulties ensuring their own and their children's well-being.

4.1.2 SPS and Positive Outcomes

Research on positive outcomes to HSPs has suggested various advantages of high sensitivity in cross-cultural, intervention, and electrophysiological studies. To further elaborate, SPS is found to relate with lessened culturally stimulated biases and increased perceptual processing of stimuli (Aron et al., 2010). High SPS has been also associated with reduced depression scores, bullying, and victimization as a result of intervention (Pluess & Boniwell, 2015), improved social skills in interaction with positive parental care (Slagt et al., 2017), heightened positive effects after positive mood induction tasks (Lionetti et al., 2018), and moderation of depressive predispositions as a result of physical exercise (Yano & Oishi, 2018). On a neural level, there are reports of increased activation in key reward regions of the brain (e.g., VTA, amygdala, hippocampus) responding to positive stimuli (e.g., positive emotional images) (Acevedo et al., 2014), as well as in brain regions associated with awareness, memory, processing of one's and other's self, and empathy (Acevedo et al., 2017; Jagiellowicz et al., 2011). Moreover, a positive relation between SPS and enhanced creativity moderated by neurobiological influences has been theorized, though additional research for its verification is demanded (Bridges & Schendan, 2019a; 2019b, Rizzo-Sierra, Leon-S, & Leon-Sarmiento, 2012).

Overall, high sensitivity has been initially proposed to be an evolutionary advantage, perceived as a negative-frequency-dependent trait. It is thus, of interest how a benefit, observed in roughly 30% of the general populace, could become a prevalent impairment. Although advantages of HSPs involve awareness of subtleties in the environment (including strong memory for obtaining resources and rewards as well as for perceiving threats and plausible risks) and proper response to distinct environmental conditions, psychological support could socially and emotionally prepare highly sensitive individuals about their attributes and strengthen them to reach their full potentials.

4.2 SPS in the Context of Clinical Symptoms and Disorders

It is established that SPS is associated with increased risk for atypical development and the manifestation of mental disorder symptoms. Up to date, most studies have been directed towards the association between SPS and indicators of anxiety and depression in non-clinical (usually non-representative e.g., student) samples. More recently, a novel theory, deriving from psychological structures of depression, has been developed to explore the plausible relation between SPS and psychological distress (comprising of symptoms of depression, anxiety as well as psychosomatic symptoms) (Wyller, Wyller, Crane, & Gjelsvik, 2017). According to the cognitive reactivity theory, psychological distress is perceived as a subordinate phenomenon of cognitive reactivity (such destructive thoughts) to sensory stimuli and negative affectivity. It is, thus these subordinate cognitive reactions of individuals to stimuli and emotions, rather than sensory stimuli or associated emotions per se, which are hypothesized to result in psychological distress. The model of cognitive reactivity has been therefore, proposed in the distinction between clinical and non-clinical highly sensitive individuals (Wyller et al., 2017). Moreover, it constitutes the first trans-diagnostic (or cross-disorder) model as it can alone explain psychological distress associated with the trait of SPS. Supportive evidence of this theory is exhibited in research of Brindle and colleagues (2015), where difficulties in emotion regulation are observed to partially mediate the relation between SPS and depression. An earlier study of Meyer and colleagues (2005) has suggested a more negative cognitive and affective reactivity to nebulous social situations in HSPs, whereas most recent research of Lau and Waters (2017) further indicated high SPS as a risk factor for anxiety and depression.

Higher levels in SPS are also found to relate to clinical and developmental disorders including schizophrenia (SZ), autism spectrum disorder (ASD), attention-deficit hyperactivity disorder (ADHD), and post-traumatic stress disorder (PTSD) (Acevedo et al., 2018, Ghanizadeh, 2011). Still, the exact associations are still under investigation and need to be yet elucidated. Different plausible links and theories concerning high SPS and psychiatric disorders have emerged over the last years, involving the plausibility of SPS functioning as a risk or protective factor, a modifying factor affecting the symptom manifestation and therapy, an endophenotype for clinical disorders, or lastly, a transdiagnostic trait (Greven et al., 2019). A review study of Acevedo and colleagues (2018) exploring the role of various brain regions in the similarities and differences between SPS and clinical disorders suggested that SPS is distinct from SZ, PTSD, and ASD. Findings paint the picture of the neural signature of SPS, with increased neural activity in regions implicated in awareness, reward processing, self and other processing, empathy, and physiological homeostasis (Acevedo et al., 2018). Yet, up to this date, there is no research investigating structural and functional differences between the brains of HSPs and individuals with similar environmental sensitivities disorders. Such research remains crucial, not only for the verification of these primary evidence, but also for a more accurate distinction between them, resulting in more precise diagnoses of clinical disorders.

4.3 Autism Spectrum Disorder, Autistic Traits, and Sensory Processing Sensitivity

According to the Center for Disease Control and Prevention (CDC), autism spectrum disorder constitutes a complex, neurodevelopmental condition defined by difficulties in social communication and interaction, along with restricted and repetitive interests and behaviors (American Psychiatric Association, 2013). It is a condition affecting nearly 1% of the world's population. Clinical symptoms of ASD in the Diagnostic and Statistical Manual of Mental Disorders 5th edition (DSM-5, American Psychiatric Association, 2013) have additionally included sensory processing difficulties associated with hyper-responsiveness to olfactory, auditory and tactile stimuli as well as to hypo-responsiveness (Marco, Hinkley, Hill, & Nagarajan, 2011). Nonetheless, it remains unknown whether individuals with ASD exhibit sensory sensitivities or rather differences in the responsiveness to the stimuli. At present, there are no available studies investigating the degree of overlapping structures between ASD and high SPS. Neurological research though has indicated that sensory symptoms in individuals with ASD and HSPs originate from distinct brain regions, which might imply distinct qualities in ASD and SPS (Robertson & Baron-Cohen, 2017; Acevedo et al., 2018).

Although ASDs are typically defined with regards to social interactions and communication complications, atypical responsiveness to sensory stimuli is also evident in individuals diagnosed in the spectrum (Ben-Sasson, Hen, Fluss, Cermak, Engel-Yeger, & Gal, 2009). Individuals with ASD are inclined to exhibit superior local processing in certain sensory stimuli (especially visual and auditory) and inferior to other. Such sensory instabilities are described in terms of hyper- and hypo-sensitivities (also referred to as hyper- and hypo-responsiveness) and are reflected in approximately 69-95% of the diagnosed populace (Hazen, Stornelli, O'Rourke, Koesterer, & McDougle, 2014; Posar & Visconti, 2018). More precisely, hyper-sensitivity refers to an "aversive response" of typically tolerated sensory stimuli (e.g., indistinct loud noises, insufferable bright lights), leading to physical pain in individuals with ASD. On the contrary, hypo-sensitivity refers to an "ostensive indifference" or a shutdown to stimuli that typically induce reaction (e.g., loud repetitive banging noises) (American Psychiatric Association, 2013; Robertson, Baron-Cohen, 2017).

Up to date, the aetiology as well as the neurobiological mechanisms in ASD remain unknown. Extensive research perceives ASD as the edge of a continuum of ATs approaching a normal distribution within the general populace (Colvert Tick, McEwen, Stewart, Curran, Woodhouse, ... & Bolton, 2015). Hence, research focused on the association between sensory processing alterations and quantitative ATs in the general population could be more enlightening than a strictly categorical clinical analysis of people with and without ASD (Neufeld, Hederos Eriksson, Hammarsten, Lundin Remnélius, Tillmann, Isaksson, & Bölte, 2021). Research on ATs and (self- or parent-reported) sensory processing alterations in typically developed (TD) adults (Horder, Wilson, Mendez, & Murphy, 2014; Robertson & Simmons, 2013; Tavassoli, Miller, Schoen, Nielsen, & Baron-Cohen, 2014) and children (Hilton, Graver, & LaVesser, 2007) as well as adults with ASD, has indicated a positive correlation, supporting the hypothesis of a potential linear association.

The earliest sensory processing alterations have been documented in infants of 6 months of age, who were later additionally diagnosed in the spectrum of autism (Estes, Zwaigenbaum, Gu, St John, Paterson, Elison, ... & Piven, 2015). Sensory symptoms could thus operate as early predictors of both social-communication deficits and repetitive behaviors in the early years of the life of a child; they could act as an additional diagnostic parameter as well (Turner-Brown, Baranek, Reznick, Watson, & Crais, 2013). More recently, genetic research on families with individuals with ASD studied the wide autism phenotype in relation to sensory atypicalities (Donaldson, Stauder, & Donkers, 2017; Glod, Riby, Honey, & Rodgers, 2017). Findings indicated a genetic facet to such sensory processing symptoms, as parents and siblings of diagnosed individuals demonstrated higher scores of self-reported sensory attributes compared to the general populace (Donaldson et al., 2017; Glod et al., 2017). More interestingly, families with higher genetic liability for autism showed greater sensory processing atypicalities than families with a single individual with ASD (Donaldson et al., 2017), indicating that sensory attributes could represent early markers of autism.

Unlike ASD, SPS has not been hypothesized or even, thus far, studied in relation to hypo-sensitivity. Research of Jerome and Liss (2005) (N = 133) investigated the subject of sensory processing in terms of sensitivity, seeking, avoidance, and low registration. Results revealed that highly sensitive individuals experienced low registration, positing that this could be an indicator of a compensatory mechanism emerging in over-arousing situations, where an individual actively shuts down (Jerome & Liss, 2005). The same mechanism is also hypothesized to arise in individuals diagnosed with ASD (Gillingham, 2000). Though an association between ASD diagnosis and atypical sensory sensitivities is fairly established, the exact nature of these atypicalities as well their basis remains a significant dispute amongst academics.

A study on the relationship between sensory sensitivity and ATs in the general population (N = 212) explored whether sensory difficulties experienced by individuals diagnosed with ASD could be similarly evident in individuals with high levels of ATs in the general populace (Robertson & Simmons, 2013). To assess the levels of sensory processing and the autistic traits of the sample, Robertson and Simmons (2013) used the Glasgow Sensory Questionnaire (developed by the researchers) and the AQ test (developed by Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). Atypical sensory responsiveness (including both hyper- and hypo-sensitivity) was found to be more frequent in individuals with higher levels of ATs, signifying a positive correlation between quantity of ATs and frequency of uncharacteristic reactions to sensory stimuli, proposing that sensory differences in individuals with ASD could also expand into the general population and thus, be considered an indicative of a sensory phenotype (Robertson & Simmons, 2013).

More recently, Neufield and colleagues (2021), attempted to explore the link between ASD / ATs diagnosis and sensory processing alterations in twins (N = 269). In their study, the adult / adolescent sensory profile was utilized to differentiate four sub-domains involving low registration, sensation seeking, sensory sensitivity, and sensation avoiding. Findings showed correlations between ATs and low registration and sensation avoiding between monozygotic twins, whereas sensory sensitivity was only associated with ATs in dizygotic twins. Additional analyses with various neurodevelopmental / psychiatric diagnoses as predictor variables, proposed ASD and ADHD as the main predictors for two adult / adolescent sensory profile sub-domains each (Neufeld et al., 2021).

These findings signify that the relation of ATs and sensory sensitivity is affected by genetics, whilst non-shared environmental influences affect the associations between ATs and low registration / sensation avoiding. Furthermore, rather than altered sensory processing being an indicator of ASD, research suggested ASD to be a robust predictor of certain sensory processing alterations, even in cases of diagnosing comorbid neurodevelopmental / psychiatric conditions (Neufeld et al., 2021), contradicting previous findings (Donaldson et al., 2017).

All data and findings on SPS are of crucial importance, not only for our understanding on the subject of sensitivity but also for future research. Nonetheless, it is apparent that the hypothesized relations, as well as obtained evidence, need further empirical authentication. Literature thus far, can only suggest associations between high SPS and clinical disorders / symptoms, without being able to explain such relations or the underlying mechanisms.

Chapter 5

Methodology

This chapter constitutes the empirical / research component of the present dissertation. First, the aim for the present research is declared, whereas goals are formulated. Next, the research methods and apparatus utilized to accomplish them are defined. Lastly, the results are presented.

5.1 Motivation for the Experimental Design

The experimental part of the dissertation is derived based on knowledge presented in the theoretical part and the absence of data regarding SPS and ATs in the general population. Preliminary findings have suggested a positive correlation between sensory processing atypicalities and autistic traits (Donaldson et al., 2017; Panagiotidi et al., 2020), though a twin-study recently indicated that rather than altered sensory processing, ASD is a predictor of sensory processing alterations (Neufeld et al., 2021). Therefore, more research to understand whether and how high SPS relates to sensory processing and ATs across the continuum is required, whilst the investigation between ATs in the general population and SPS remains crucial. This is the first study, to our knowledge, investigating plausible associations between sensory processing sensitivity and autistic traits in the general population. Our study utilizes two well-established (in terms of both validity and reliability) self-reported scales i.e., the HSP scale and the AQ test to assess these associations, if any.

5.2 Participants

The sample of the study consisted of 132 healthy adults (109 females [F], 18 males [M], 4 non-binary [NB], and 1 participant who did not state gender) with ages ranging from 18 to

66 years (M = 22.5, SD = 7.86). Participants included a random sample of both undergraduate psychology students (N = 98) and non-students (N = 34), who engaged through online recruitment ads. The recruitment method involved pool sampling from social media, whilst the students were recruited from an undergraduate psychology course. There was no reward for participation for non-students, whereas students were entitled to course credit. The majority of the participants was right-handed (N = 119), a minority was left-handed (N = 12), whilst one (1) participant was ambidextrous. Since the present study investigates levels of sensitivity and ATs in the general population, diagnosis of severe physical disabilities and / or mental disorders was used as an exclusion criterion.

5.3 Research Questions and Hypotheses

The experiment is designed in the way to describe and fit our research questions and hypotheses. We would like to investigate the plausible association between AT and SPS. Based on the literature review our main hypothesis was formed:

- Regarding the association between AT and SPS, we expect a significant positive correlation between the two variables. Given that no previous study has been conducted on this association, we do not have a specific prediction on the effect size, we can only predict the direction of the correlation.

Therefore, we operate on the following statistical hypotheses:
H0: SPS scores are independent from AT scores
H1: SPS scores are significantly positively correlated to AT scores

Apart from our main hypotheses we have several side hypotheses, which are best represented in the order of how successful we expect them to be:
H2: Gender is correlated to ATs with males scoring significantly higher in AQ test in comparison to females
H3: Gender and SPS are associated to AQ scores

We assume a positive correlation between the two scores based on the premise that sensory processing atypicalities found in individuals diagnosed with ASD will be also evident in HSPs. Even though we cannot discover the exact nature of the association between high SPS and ATs in the general population, establishing such an association is an important first step. Moreover, we assume higher scores of male participants in AQ test as logical assumption based on evidence of similar gender differences in ASD. Lastly, we assume that gender and SPS could predict AQ scores. There have not been stated null hypotheses to H2 and H3, as the main focus in on H1 and thus, the other hypotheses are only supplementary.

5.4 Research Design and Tools / Scales

The present study was designed in google forms and involved an online survey comprising of first, a section on demographic characteristics such as age, gender, and hand dominance, and second, the two self-reported questionnaires comprising of the HSP scale (Aron & Aron, 1997) and AQ test (Baron-Cohen, 2001). Data were analyzed using the software Jamovi version 2.2 and included demographic statistics, t-tests, as well as simple and multiple linear regression analysis .

5.4.1 The Highly Sensitive Person Scale

The HSP scale constitutes a self-reported Questionnaire consisting of 27 statements. Participants answered, in a scale of 1-7 (*not at all – extremely*), how strongly they agree or disagree with each statement. Statements were comprised of the components of EOE, including 12 items related to becoming mentally overwhelmed by both external (e.g., "Do you become unpleasantly aroused when a lot is going on around you?", "Do changes in your life shake you up?") and internal stimuli, ("Does being very hungry create a strong reaction in you, disrupting your concentration or mood?"), AES, consisted of 7 items related to aesthetic awareness ("Are you deeply moved by the arts or music?", "Do you seem to be aware of subtleties in your environment?", "Do you notice and enjoy delicate or fine scents, tastes, sounds, works of art?"), and LST involving 6 items related to unpleasant sensory arousal to external stimuli ("Are you made uncomfortable by loud noises?", "Do you make a point to avoid violent movies and TV shows?", "Are you bothered by intense stimuli, like loud noises or chaotic scenes?"). All the items are scored in the same direction thus, a higher score results in a higher sensitivity level.

5.4.2 The Autism-Spectrum Quotient Test

The AQ test is a self-reported diagnostic questionnaire designed to measure the expression of autism-spectrum traits in adults (age 16+) of average or higher intelligence. It is comprised of 50 statements, where participants answered, in a scale of 1-4 (*definitely disagree – definitely agree*), how strongly they agree or disagree with each statement. Items of AQ questionnaire included statements as "I prefer to do things the same way over and over again", "I often notice small sounds when others do not" as well as "I enjoy meeting new people". It makes no difference to the score whether the participant chooses slightly or definitely, as the statements are treated as a binary choice of "agree" and "disagree". Statements are divided into two groups for scoring in regard to the content of each statement. "Definitely agree" or "slightly agree" responses to questions 2, 4, 5, 6, 7, 9, 12, 13, 16, 18, 19, 20, 21, 22, 23, 26, 33, 35, 39, 41, 42, 43, 45, 46 score 1 point. "Definitely disagree" or "slightly disagree" responses to questions 1, 3, 8, 10, 11, 14, 15, 17, 24, 25, 27, 28, 29, 30, 31, 32, 34, 36, 37, 38, 40, 44, 47, 48, 49, 50 score 1 point. The score is thus, calculated with the addition of the points ranging between 50 and 200. The computation of results slightly differs from the proposed of Baron-Cohen (2001), as it has been modified for research purposes rather than diagnostic. Hence, continuous measurement fits better for the present study as it will result in more accurate correlation between the two self-reported assessments.

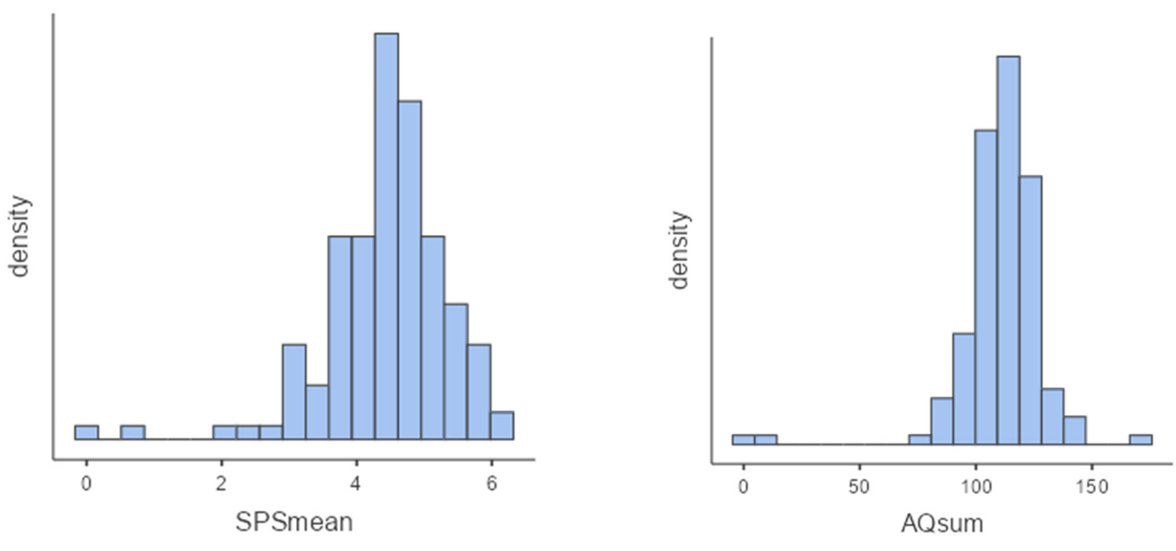
5.5 Procedure

Participants visited the link in google form from their own PC. The study was comprised of 7 sections. After the completion of each section, the next button was pressed to continue. There was no time constrain, though the whole procedure lasted approximately 15 minutes. First, appeared the title of the study, whereas thereafter the informed consent defined the purpose of the study, the procedure (including the estimated time of participation), the consent and acknowledged the confidentiality for the data. In case the participants agreed in taking part on the study, they would be transferred to the next section of demographic information, whereas in case of non-agreement to the study, they would be transferred to the end-section of the study, thanking them for their time. The demographic section included participants' information of age, gender, and hand dominance, whilst an additional question regarding physical disability (-ies) and / or clinical disorder (s) functioned as the excluding criterion. The next section included the Highly Sensitive Person (HSP)-scale Questionnaire, and after its completion, participants continued with the AQ test. At the next section, participants, who were students wishing for the granted credits, were asked for their academic e-mail address. The final section of the study thanked the participants for their time and participation. All sections of the study were completed in the same (aforementioned) order.

5.6 Results

Analyses were performed in 132 survey responses, though gender differences were examined between two levels of gender, female and male participants, due the negligible number of participants who defined themselves in a non-binary way (N = 127, F = 109, M = 18). SPS scores ranged from 1.89 to 6.15 (M = 4.48, SD = 0.77). AQ scores were calculated between 74 and 171 (M = 113, SD = 13.3). A schematic overview of the scores is presented in **Graph 1** (different forms including boxplot [**Graph 2**] and Q-Q plot [**Graph 3**] can be found in Appendix D.1).

a. b.



Graph 1: Histogram of SPS degrees of sensitivity (a) and sum of AQ scores (b).

The first hypothesis was evaluated by means of a regression analysis (Pearson correlation), where results show a significant weak association between overall HSP scale and AQ scores. The results of this analysis (see **Table 1**) showed a positive correlation between

SPS and AQ traits r(130) = .18, p < .03, confirming H1.

Correlation Matrix

		SPSmean	AQsum
SPSmean	Pearson's r	—	
	p-value	—	
	N	—	
AQsum	Pearson's r	**0.184** *	—
	p-value	**0.035**	—
	N	132	—

Note. * p < .05, ** p < .01, *** p < .001

Table 1: Correlation matrix demonstrating the association of the scores between Sensory Processing Sensitivity and AQ.

An independent sample t-test was used to investigate the hypothesis that gender would predict the scores of the AQ test. Gender was found to be positively correlated to AQ sum scores, demonstrating a substantial difference with a considerable effect size, with males (M =119.06, SD = 12.2) scoring 8 points higher than females (M =111.06, SD = 13.3), t(24.2) = 2.47 (p = .02, d = 0.61), supporting H2. The same test was similarly utilized to assess possible correlations between gender and SPS scores. SPS scores were positive correlated to gender with females (M = 4.54, SD = 0.79) scoring 0.36 higher, on average, than their male counterparts (M = 4.18 , SD = 0.50), t(32.8) = -2.55 (p = .01). An overview of the results is presented in **Table 2**.

Independent Samples T-Test

		Statistic	df	p	Mean difference	SE difference		Effect Size
SPSmean	Welch's t	**-2.55**	**32.8**	0.016	-0.360	0.141	Cohen's d	**-0.541**
AQsum	Welch's t	**2.47**	**24.2**	0.021	7.762	3.138	Cohen's d	**0.610**

Table 2: Gender differences between SPS and AQ scores.

Furthermore, multiple linear regression was employed to test whether AQ scores can be predicted based on different models comprising of gender, SPS, and the interaction of gender and SPS (gender x SPS) (see **Table 5** in Appendix D.2). A model with both the predictors of gender and SPS was found to account for roughly 6% of the instances, R2 = .05, F(1,124) = 6.27, p < .01 (**Table 3**), generating it as a significantly better fit. In this model, both gender and SPS scores could considerably contribute to the prediction (**Table 4**).

Model Comparisons

Comparison							
Model		**Model**	**ΔR^2**	**F**	**df1**	**df2**	**p**
1	-	2	**0.05641**	**7.701**	1	124	**0.006**
2	-	3	0.00609	0.830	1	123	0.364

Table 3: Gender and SPS predictions regarding AQ scores (model 1 denotes gender, whilst model 2 SPS).

Model Coefficients – AQsum

Predictor	Estimate	SE	t	p
Intercept [a]	93.36	6.96	13.42	< .001
SPSmean	3.95	1.51	2.62	0.010
Gender:				
Male – Female	9.18	3.31	2.78	0.006

[a] Represents reference level

Table 4: Gender and SPS predictions regarding AQ scores.

Chapter 6

Discussion

In the present chapter, both the literature review and the results of the research are discussed, limitations are declared, and future directions both in the subject of SPS and its relation to autistic traits are proposed. Lastly, implications on the importance of SPS are stated.

6.1 Findings Discussion

Although there is still a lot of disputes amongst academics concerning SPS, its attributes, the exact nature of the association to individual's experiences across their development, as well as genetic and environmental aetiologies, the findings of this dissertation contribute significantly to the subject of SPS. Based on the literature review, a possible association between high SPS and increased ATs in the general population could be fairly implied, though such relation has not yet been investigated. Thus far, research is limited not only due to the novelty of the subject, but also the state-of-the-art approaches and tools in the investigation of complicated phenotypic traits and their relation to clinical disorders and symptoms. Hence, the aim of the present dissertation was first, a holistic review of the SPS trait based on the available literature and empirical evidence and second, an innovative small-scale empirical research exploring the plausible association between autistic traits and high SPS for the first time, hypothesizing a positive correlation between SPS and AQ scores in the general populace.

SPS theory (also apparent in BSC and DS structures) assumes that only a minority possesses the trait of highly sensitivity, comprising an evolutionary advantage of social animals (Aron & Aron, 1997). Nonetheless, research has offered diverse results regarding a universal cut-off score of HSPs, whereas it is predominantly accepted that high sensitivity is evident in 10-35% of the population (Aron & Aron, 1997; Lionetti et al., 2018; Pluess et al., 2018). Similar inconclusive results refer to the classification of SPS as a continuous or a categorical trait. Whilst a continuous trait would suggest a difference in the significance (i.e., the extent) of the associations, a categorical view would rather suggest a different nature among the distinct groups indicating different results of the associations. Since SPS is established as a personality trait though, it appears more reasonable to consider SPS in a continuum, parsed in three primary levels of low, moderate, and high sensitivity, where both low and high SPS is found in a minority, whilst moderate SPS is found in the majority of the populace. In our empirical research, SPS is measured continuously in regard to the study's purposes. This is more effective and avoids the artificial / subjective nature of categorization, whilst the same consideration applies to the assessment of autistic traits, especially reflecting recent evidence in psychiatry suggesting a psychiatric diagnostic continuum rather than classification based on the comorbidity of disorders (Allsopp et al., 2019). Although the present study investigated the association between SPS and ATs in the general population, rather than in clinical, we managed the data in a similar way for the study's objectives. Results confirmed our hypothesis as data showed a positive correlation between AQ and SPS scores, suggesting a linear association independent of a categorization of the data in distinct levels. Such findings are consistent with the aforementioned literature verifying the classification of SPS in a continuum.

SPS was initially perceived as a behavioral indicator of sensitivity assessed with self-reported scales. The underlying neurobiological mechanisms of SPS including genetic factors, and physiological differences (e.g., cortisol levels, immune reactivity) in responsiveness to stressors have only recently begun to unravel (Belsky & Pluess, 2009; Boyce & Ellis, 2005). Neurobiological research has emerged to explore the fundamental neural processes of SPS expression and strengthen our understanding of the trait. Moreover, the exact association between SPS and developmental / clinical disorders such as attention-deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), and schizophrenia (SZ) remains nebulous. Neuroscientific research though, proposes a unique neural map of SPS, differentiating it from disorders with similar attributes (Acevedo et al., 2018). As hypothesized, analyses performed in this study revealed the first evidence of a positive correlation between high SPS and increased AQ scores, suggesting a deeper association between the two. Even if the low predictability of our model can be accountable for a minor degree to which correct predictions on autistic traits can be made based on SPS scores and gender, this model could considerably contribute to the prediction of AQ scores differentiating it from the personality trait. These results, thus signify the distinction between SPS and ATs, whilst indicating their correlation in terms of hyper-responsiveness (Aron et al., 2012; Hazen et al., 2014; Posar & Visconti, 2018).

Although most research has emphasized in negative aspects of SPS, it necessitates to keep in mind that high sensitivity constitutes an evolutionary advantage. Research has thus far, indicated that HSPs process stimuli at greater depth, independent of social and cultural norms demonstrating reduced influence of culturally induced biases, whereas beneficial implications for other aspects of cognition such as memory and creativity are also evident (Aron et al., 2010; Aron et al., 2012; Bridges & Schendan, 2019a; 2019b; Gerstenberg, 2012; Jagiellowicz et al., 2011). Hence, supportive environments, appropriate guidance, and psychological intervention (when required) can significantly benefit HSPs and consequently, society.

Furthermore, the experimental part of the present dissertation employed a small-scale empirical research to study the correlation between SPS and AQ scores and their significance to the subject of SPS. The chosen recruitment method involved pool sampling through advertisement in social media, though time constraints resulted in the inclusion of undergraduate psychology students as well, recruited in exchange of course credits. Research design employed demographic statistics and two self-reported measurements (i.e., HSP scale, AQ test) in an online survey created in google forms. Participants followed the link of the study using their own apparatus and completed the survey in approximately 15 minutes.

The main hypothesis of this study was a positive correlation between SPS and AQ scores. As a specific prediction on the effect size could not be made because of the innovative nature of the study, we rather predicted the direction of the correlation. Additional hypotheses stated a positive correlation between male participants and AQ scores as well as an association of gender and SPS variations to AQ scores. Obtained data were analyzed through Jamovi 2.2 software utilizing primary analysis, independent t-tests, simple and multiple linear regression. Gender differences in scores were examined between two levels, female and male participants (a negligible number of participants defined themselves in a non-binary way).

Although the results are preliminary, our hypotheses were confirmed. Data demonstrated a positive correlation between overall HSP scale scores and AQ test scores ($r = .18$, $p < .03$), confirming the main hypothesis of the research. These findings are consistent with previous research indicating a linear association between SPS scores and sensory processing alterations (Horder et al., 2014; Robertson & Simmons, 2013; Tavassoli et al., 2014), including the notion of high SPS as plausible indicator of a compensatory mechanism (i.e., shutting down) emerging in over-arousing situations (Jerome & Liss, 2005). In spite of the small effect sample of the correlation of SPS to autistic traits, these findings are important. The novelty of the trait and the significance that might provide in future research of SPS as well as in clinical practice if we consider SPS as a transdiagnostic trait, justifies the value of these results.

In line with previous findings of Donaldson and colleagues (2017) suggesting sensory attributes as possible early markers of autism, data obtained from linear regression analysis in the present study implied the model of SPS and gender as a significant predictor with low predictability (6%) to ATs. Such low predictability can only explain a minor degree to which correct predictions on autistic traits can be made based on SPS scores and gender, suggesting additional factors accountable for increased ATs. Such results contradict findings of Neufeld and colleagues (2021), suggesting rather ASD to be a robust predictor of certain sensory processing alterations. Nonetheless, according to our findings, the model of SPS and gender could considerably contribute to the prediction of AQ scores.

Lastly, independent t-tests further demonstrated a considerable difference with a significant effect size in AQ scores between males and females, with males scoring 8 points higher in comparison to the females, confirming our second hypothesis. These findings should be treated with caution as the majority of research and diagnostic assessments on both ASD and ATs is based on male symptomatology, therefore the scores of females may not reflect the accurate effect size. An additional finding of our study involves a positive correlation between gender and SPS, with females demonstrating increased mean scores, in comparison to males. Overall, these results, although significant, are only preliminary and cannot be easily generalized.

6.2 Limitations

We declare several possible limits of the dissertation. First, due to the innovation of the study, we focused on primary results of the association between SPS and ATs. Second, time constrains became a crucial barrier for both the dissertation and the study design. Regarding the participants, we would like to have a bigger sample with a more balanced representation, though lack of funding limited the participants with an overrepresentation of females and students. We, thus resigned on a heterogenous sample, in favor of a larger sample and more reliable results. Ideally, we would start with a larger sample to confirm and validate our data and would proceed to additional analyses. In this part, we would also like to declare no conflicts of interest.

6.3 Future directions

Additional research on the broad subject of SPS as well as on the association of SPS and ATs is essential. Although most recently, numerous studies have investigated the phenotypic trait of SPS, additional validation across continents and the lifespan is required. Similarly, genetic studies have shed important light in the subject of candidate gene (s) in SPS, though their results have been criticized due to their a priori assumptions. The utilization of GWAS method could significantly ameliorate our understanding on the genetic mechanisms of SPS, though it requires an enormous amount of participants making it expensive in cost and time. Associations between SPS and clinical disorders and / or externalization of mental symptoms need to be further studied, whereas longitudinal studies in relation to clinical samples could additionally unravel cognitive, genetic, and neurobiological underlying relations. Subsequently, an important and interesting direction would be to consider SPS as a transdiagnostic trait, also resulting in more accurate diagnoses and more appropriate treatments.

The association between SPS and ATs constitutes another unresolved issue. High SPS and high scores in AQ are both characterized by sensory sensitivities, which need to be further studied. Future research should also include large non-homogeneous samples of the general population to verify our primary results, and further investigate this correlation.

As ASD and SPS are found to associate only regarding hyper-sensitivities of stimuli and not hypo-sensitivities, the investigation of both hyper-and hypo-sensitivities among participants is equally required before any conclusions can be drawn regarding the association of SPS and ATs.

6.4 Implications

The present dissertation has reviewed the trait of sensory processing sensitivity, assessing it through different perspectives (e.g., genetic, neuronal, cognitive, psychological). True to the form of an exploratory study, the practical part utilized a small sample to particularly focus on the nature of the association between SPS and ATs. The significance of both the theoretical and practical parts persist not only in the subject's importance, but also the study's innovation and its prospects. More precise, the acknowledgment of SPS to the general populace can ameliorate the integration of highly sensitive individuals into society as well as benefit from their unique qualities. The assessment of SPS is accessible from a very young age across the lifespan and could provide crucial information to caregivers and educators for designing supportive environments. Promotion of initiatives such as psychological support focused on stress management and self-care (important due to increased empathy and overstimulation) throughout the development of people with high levels of SPS could further result in the development of the HSPs' potential and decrease of rates of maladaptive behaviors and externalization of clinical symptoms. Finally, SPS variance could (and should) be taken into account in medical practice, for a better patient-centered service. Information such as certain attributes of SPS (e.g., increased pain sensation) could be of value for clinicians. Such data could also help with clinical diagnoses, especially differential diagnoses of SPS and other disorders including ASD and ADHD.

Chapter 7
Conclusion

The sensory processing sensitivity theory suggests a novel underlying phenotypic (temperament) trait involving deeper cognitive processing of internal and external stimuli ensuing increased emotional reactivity and responsivity, greater awareness of environmental subtleties, and ease of overstimulation. Due to many challenges we had to conquer, this dissertation constitutes an innovative hybrid form of research, combining a bibliographic review of SPS trait with a small but significant experimental part of original research, investigating the association between SPS and AQ traits. First, the literature review provided a holistic evaluation of the framework of SPS and the distinct paradigms of sensitivity. Data from observational, genetic, and electrophysiological studies were presented and evaluated, separating the personality trait of SPS from other clinical disorders including ADHD, PTSD, ASD, and SZ. Nevertheless, individuals diagnosed with ASD are considered to be inclined to sensory hyper-sensitivities instabilities, apparent also in individuals with high SPS. Thus, the experimental part of the dissertation explored the association between SPS and autistic traits in the general population for the first time. Results demonstrated a positive association of SPS with AQ traits ($r = .18$, $p < .03$), confirming the hypothesis of the research. Differences in scores were examined between two levels of gender, female and male participants, due the negligible number of non-binary participants. Although the small sample of the present study and the results of linear regression of gender and SPS demonstrate low predictability (6%) to ATs, these findings are important considering the novelty of the trait and the significance it might provide in future research of SPS as a transdiagnostic trait. As this is the first study, to our knowledge, investigating such associations, our results are considered primary, but of vital importance not only for future research but also for a better understanding of SPS.

Appendix A
Consent Form

TITLE OF STUDY

Individual Differences in Sensory Processing Sensitivity

You are being asked to take part in a research study conducted by Athina Pylarinou as part of her master's degree in "Cognitive Systems" at the Open University of Cyprus. The study has been reviewed and approved by her mentor, Dr. Konstantinos Tsagkaridis. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. Please read the following information carefully. If you have any questions, or would like a copy of this consent letter, please contact the researcher (principal investigator) Athina Pylarinou via e-mail at pylarinouathi@gmail.com or via telephone at +436763804723.

PURPOSE OF STUDY

The researcher requests your consent for participation in a study about preferences, individual differences and sensory processing sensitivity. We ask you about preferences and individual differences such as attention to detail, multitasking, imagination, cooperation, social interactions and other things. Sensory processing sensitivity reveals individual differences in perceiving and processing environmental stimuli, such as art, smells, textures, and loud noises. The purpose of this study is to identify different levels of sensitivity and explore the individual differences in each level. This consent form asks you to allow the researcher to record and view the data to enhance understanding of the topic.

STUDY PROCEDURES

The study will be conducted in three parts, which refer to a section on demographic characteristics such as age, gender, hand dominance, etc., and two questionnaires. The participants will complete the Highly Sensitive Person (HSP)-Scale Questionnaire as well as a Questionnaire measuring preferences and individual differences in everyday tasks. The HSP-Scale Questionnaire consists of 27 statements, where participants will answer, in a scale of 1-7 (Not at all – Extremely), how strongly they agree or disagree with each statement. The additional Questionnaire on individual differences consists of 50 statements, where participants will answer, in a scale of 1-4 (Definitely Disagree – Definitely Agree), how strongly they agree or disagree with each statement.

Time duration: approximately 15 minutes.

CONSENT & CONFIDENTIALITY

Providing your consent allows the researcher to record and view the data to enhance understanding of the topic. Be aware that all scientific analyses will provide general conclusions on the main topics of interest in this study, after aggregating individual responses. Your answers will not provide individual results.

Your responses to this research will be anonymous. If you are a university student who is entitled to receive course credits by Dr. Konstantinos Tsagkaridis for your participation, you will also be asked to submit your institutional e-mail address. This information will only be used to grant you course credit and will not be a part of the final dataset of all results, to prevent identification and ensure your anonymity.

Participation in this study is completely voluntary. If you decide not to participate there will not be any negative consequences. Please be aware that if you decide to participate, you may stop participating at any time and you may decide not to answer any specific question.

The researcher will maintain the confidentiality of the research records or data, and all data will be destroyed after five years.

RISKS

The present study does not contain any physiological or psychological risks for the participants.

By submitting this form, you are indicating that you have read the description of the study, are over the age of 18, and that you agree to the terms as described.

Appendix B
HSP Scale Questionnaire

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

1	2	3	4	5	6	7
Not at All			**Moderately**			**Extremely**

____ 1. Are you easily overwhelmed by strong sensory input?
____ 2. Do you seem to be aware of subtleties in your environment?
____ 3. Do other people's moods affect you?
____ 4. Do you tend to be more sensitive to pain?
____ 5. Do you find yourself needing to withdraw during busy days, into bed or into a darkened room or any place where you can have some privacy and relief from stimulation?
____ 6. Are you particularly sensitive to the effects of caffeine?
____ 7. Are you easily overwhelmed by things like bright lights, strong smells, coarse fabrics, or sirens close by?
____ 8. Do you have a rich, complex inner life?
____ 9. Are you made uncomfortable by loud noises?
___ 10. Are you deeply moved by the arts or music?
___ 11. Does your nervous system sometimes feel so frazzled that you just have to go off by yourself?
___ 12. Are you conscientious?
___ 13. Do you startle easily?
___ 14. Do you get rattled when you have a lot to do in a short amount of time?
___ 15. When people are uncomfortable in a physical environment do you tend to know what needs to be
done to make it more comfortable (like changing the lighting or the seating)?
___ 16. Are you annoyed when people try to get you to do too many things at once?
___ 17. Do you try hard to avoid making mistakes or forgetting things?
___ 18. Do you make a point to avoid violent movies and TV shows?
___ 19. Do you become unpleasantly aroused when a lot is going on around you?
___ 20. Does being very hungry create a strong reaction in you, disrupting your concentration or mood?
___ 21. Do changes in your life shake you up?
___ 22. Do you notice and enjoy delicate or fine scents, tastes, sounds, works of art?
___ 23. Do you find it unpleasant to have a lot going on at once?
___ 24. Do you make it a high priority to arrange your life to avoid upsetting or overwhelming situations?
___ 25. Are you bothered by intense stimuli, like loud noises or chaotic scenes?
___ 26. When you must compete or be observed while performing a task, do you become so nervous or shaky

that you do much worse than you would otherwise?
___ 27. When you were a child, did parents or teachers seem to see you as sensitive or shy?

Appendix C
AQ Questionnaire

Instructions: For each statement below, choose one response that best describes how strongly that statement applies to you:

Definitely Agree
Slightly Agree
Slightly Disagree
Definitely Disagree

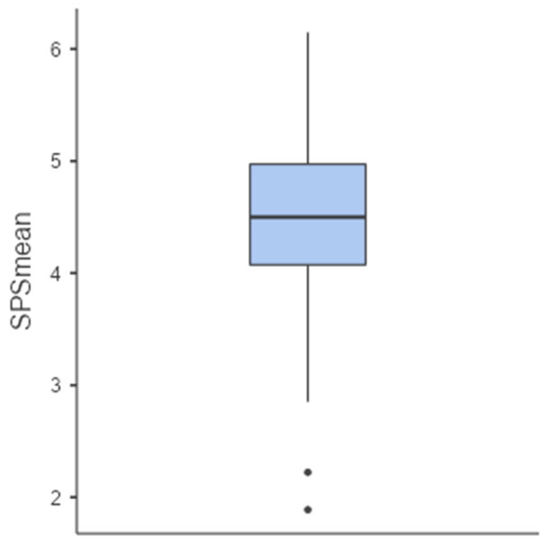
1. I prefer to do things with others rather than on my own.
2. I prefer to do things the same way over and over again.
3. If I try to imagine something, I find it very easy to create a picture in my mind.
4. I frequently get so strongly absorbed in one thing that I lose sight of other things.
5. I often notice small sounds when others do not.
6. I usually notice car number plates or similar strings of information.
7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.
8. When I'm reading a story, I can easily imagine what the characters might look like.
9. I am fascinated by dates.
10. In a social group, I can easily keep track of several different people's conversations.
11. I find social situations easy.
12. I tend to notice details that others do not.
13. I would rather go to a library than a party.
14. I find making up stories easy.
15. I find myself drawn more strongly to people than to things.
16. I tend to have very strong interests which I get upset about if I can't pursue.
17. I enjoy social chit-chat.
18. When I talk, it isn't always easy for others to get a word in edgeways.
19. I am fascinated by numbers.
20. When I'm reading a story, I find it difficult to work out the characters' intentions.
21. I don't particularly enjoy reading fiction.
22. I find it hard to make new friends.
23. I notice patterns in things all the time.
24. I would rather go to the theatre than a museum.
25. It does not upset me if my daily routine is disturbed.
26. I frequently find that I don't know how to keep a conversation going.
27. I find it easy to 'read between the lines' when someone is talking to me.
28. I usually concentrate more on the whole picture, rather than the small details.
29. I am not very good at remembering phone numbers.
30. I don't usually notice small changes in a situation, or a person's appearance.
31. I know how to tell if someone listening to me is getting bored.

32. I find it easy to do more than one thing at once.
33. When I talk on the phone, I'm not sure when it's my turn to speak.
34. I enjoy doing things spontaneously.
35. I am often the last to understand the point of a joke.
36. I find it easy to work out what someone is thinking or feeling just by looking at their face.
37. If there is an interruption, I can switch back to what I was doing very quickly.
38. I am good at social chit-chat.
39. People often tell me that I keep going on and on about the same thing.
40. When I was young, I used to enjoy playing games involving pretending with other children.
41. I like to collect information about categories of things.
42. I find it difficult to imagine what it would be like to be someone else.
43. I like to plan any activities I participate in carefully.
44. I enjoy social occasions.
45. I find it difficult to work out people's intentions.
46. New situations make me anxious.
47. I enjoy meeting new people.
48. I am a good diplomat.
49. I am not very good at remembering people's date of birth.
50. I find it very easy to play games with children that involve pretending.

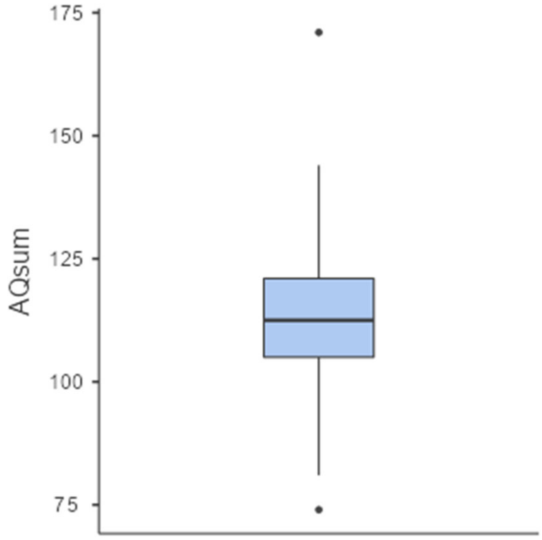
Appendix D
Supplementary tables

D.1 Additional Graphs

a.

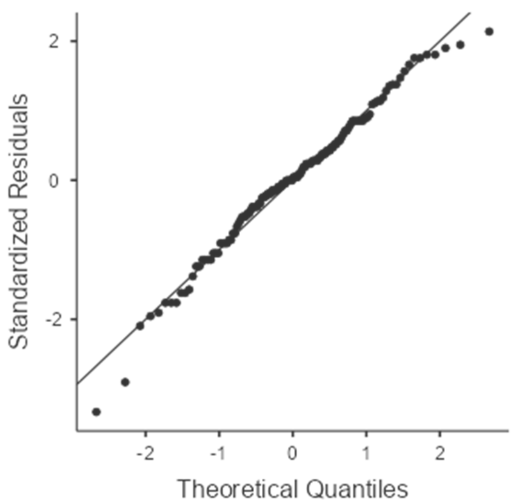


b.

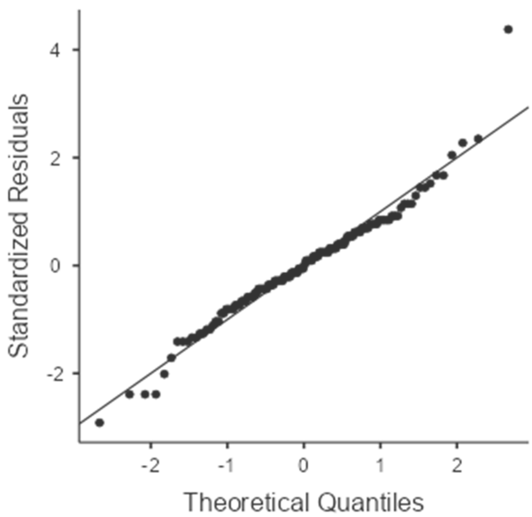


Graph 2: Boxplot of SPS mean (a) and AQ mean (b)

a.



b.



Graph 3: Q-Q Plot of SPS mean scores (a) and AQ mean scores (b).

D.2 Additional tables

Model Fit Measures

			Overall Model Test			
Model	**R**	**R^2**	**F**	**df1**	**df2**	**p**
1	0.188	0.0353	4.57	1	125	0.035
2	0.303	0.0917	6.26	2	124	0.003
3	0.313	0.0977	4.44	3	123	0.005

Table 5: Model fit among gender (1), gender and SPS (2), gender x SPS (3).

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