SAPIENZA
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'GROWING IN NATURE': EVALUATING THE IMPACT OF A NATURE-BASED INTERVENTION ON SENSORY, EMOTIONAL, SOCIAL, AND ADAPTIVE FUNCTIONING IN CHILDREN WITH AUTISM SPECTRUM DISORDER

Tutor
Prof. Francesco Pisani

Dottorando
Dott.ssa Federica Gigliotti

Supervisore
Dott.ssa Carla Sogos

Coordinatore
Prof.ssa Cristina Limatola

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ABSTRACT

Nature-based interventions are increasingly gaining attention as complementary approaches to support children with neurodevelopmental disorders, including Autism Spectrum Disorder (ASD). This pilot study aimed to evaluate the feasibility and preliminary effectiveness of a structured nature-based therapeutic program - "Growing in Nature" - designed to target core functional domains affected in school-aged children with ASD.

A single-group, pre–post quasi-experimental design was employed. Sixteen children aged 6–12 years participated in the intervention, which was implemented in outdoor natural settings and incorporated activities aimed at enhancing sensory processing, emotional regulation, social responsiveness, and adaptive functioning. Standardized and psychometrically validated instruments were administered before and after the intervention: the Sensory Processing Measure (SPM), the Child Behavior Checklist 6–18 (CBCL 6–18), the Social Responsiveness Scale–2 (SRS-2), and the Adaptive Behavior Assessment System–II (ABAS-II).

Preliminary analyses revealed statistically and clinically significant improvements across multiple domains, including sensory reactivity, emotional–behavioral functioning, social communication, and adaptive skills. Notably, significant associations emerged between changes in sensory processing and improvements in emotional, social, and adaptive functioning, suggesting potential cross-domain effects.

Despite methodological limitations—including the small sample size, the lack of a control group, and the short-term follow-up—this study represents one of the first Italian investigations to systematically evaluate the impact of a nature-based intervention in children with ASD using a multidimensional outcome assessment framework. The findings provide initial support for the feasibility, acceptability, and potential clinical utility of nature-based approaches as complementary interventions for ASD.

Keywords: Autism Spectrum Disorder, nature-based intervention, sensory processing, emotional regulation, adaptive functioning, social responsiveness, pilot study.

CHAPTER 1 – GENERAL INTRODUCTION

1.1 Neurodevelopmental Disorders in Early Childhood: A Dimensional Perspective

Neurodevelopmental disorders (NDDs) represent a broad group of early-onset conditions characterized by atypical development of cognitive, motor, communicative, emotional, and social functions. These conditions include autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), communication disorders, intellectual developmental disorders (ID), specific learning disorder, motor disorders and other unspecified or mixed presentations (American Psychiatric Association, 2022). Although historically conceptualized as distinct diagnostic categories, NDDs are now recognized to exhibit substantial overlap in terms of symptoms, underlying neurobiology, and developmental trajectories (Astle et al., 2022). Comorbidity is more often the rule than the exception (Bonti et al., 2024), with many children meeting criteria for multiple disorders simultaneously or transitioning from one diagnostic category to another as development unfolds (Gillberg, 2010; Thapar et al., 2017).

Such clinical complexity has increasingly challenged both the validity and utility of traditional categorical classification systems such as the Diagnostic and Statistical Manual of Mental Disorders (DSM) and the International Classification of Diseases (ICD). Although these systems provide operational criteria for diagnosis, they often fail to capture the full range of phenotypic variability nor the dimensional nature of developmental psychopathology (Kotov et al., 2017; Fusar-Poli et al., 2022). This has prompted a growing shift toward alternative, empirically grounded frameworks that conceptualize NDDs as continuous, overlapping dimensions of functioning and dysfunction.

Two prominent examples of this shift are the Hierarchical Taxonomy of Psychopathology (HiTOP) and the Research Domain Criteria (RDoC). The HiTOP model proposes a dimensional organization of psychopathology based on large-scale empirical data, emphasizing symptom clusters and transdiagnostic traits such as internalizing, externalizing, and cognitive dysfunctions (Kotov et al., 2017; Kotov et al., 2021). In contrast, the RDoC framework, developed by the National Institute of Mental Health (NIMH), adopts a neuroscience-informed, dimensional approach that organizes mental disorders according to core functional domains (e.g., negative valence systems, cognitive systems, social processes) and maps them onto behavioral, neurobiological, and genetic levels of analysis (Insel et al., 2010; Cuthbert, 2022). Both models converge in recognizing that key vulnerabilities - such as emotional dysregulation or sensory hyperreactivity - transcend traditional diagnostic categories.

These frameworks are particularly relevant during the preschool period (ages 2-6), which is marked by rapid neurodevelopment and heightened plasticity. Early signs of atypical development often emerge in broad functional domains such as communication, affective regulation, motor coordination, and sensory responsiveness - domains that are not diagnosis-specific but represent early expressions of neurodevelopmental divergence (Gotham et al., 2012; Zwaigenbaum et al., 2015; Astle et al., 2022). Developmental diagnostic fluidity is common: children may initially be diagnosed with LD, only to later meet criteria for ASD or ADHD, or may present with subthreshold symptoms that do not map onto any single category but still require clinical attention (Gillberg, 2010; Bonti et al., 2024).

In this context, dimensional and person-centered approaches - such as Latent Profile Analysis (LPA) and Latent Class Analysis (LCA) - are gaining traction. These data-driven statistical methods identify empirically derived subgroups (or profiles) based on shared characteristics, allowing researchers and clinicians to capture patterns of functioning that do not align with conventional diagnoses (Spurk et al., 2020). Such profiles can be constructed using continuous variables (e.g., sensory reactivity, cognitive level, emotional symptoms) and may offer a more ecologically valid foundation for personalized interventions. Notably, several recent studies have applied LPA to preschool samples with NDDs to delineate subtypes based on sensory processing, emotional regulation, or social functioning (Brandes-Aitken et al., 2024; Gigliotti et al., under review).

This dimensional view of neurodevelopment invites a reconceptualization of intervention strategies. Rather than targeting "diagnoses," clinicians are increasingly called to support specific functional domains - such as emotional self-regulation, sensory integration, or adaptive communication - based on a child's unique neurodevelopmental profile. This approach aligns with emerging calls for precision developmental psychiatry, emphasizing the need to tailor assessment and intervention to each child's neurodevelopmental profile rather than categorical diagnoses (Fusar-Poli et al., 2022; Gillberg, 2021). It also promotes the design of interventions that are both individualized and transdiagnostically informed, consistent with neurodiversity-affirming principles (Pellicano & den Houting, 2022).

1.2 Autism Spectrum Disorder: Core Features and Early Phenotypes

ASD is a heterogeneous and complex neurodevelopmental condition defined by persistent deficits in social communication and interaction, alongside restricted, repetitive patterns of behavior, interests, or activities. These core features are frequently accompanied by associated difficulties, including sensory processing abnormalities, emotional dysregulation, intellectual variability, and language impairments (American Psychiatric Association, 2022; Lord et al., 2018). ASD is typically diagnosed between 2 and 4 years of age, although early signs can often be retrospectively identified during infancy (Zwaigenbaum et al., 2015). In preschool-aged children, ASD presents with marked heterogeneity in both symptom severity and developmental profile, making early detection and diagnosis a persistent clinical challenge. Common early indicators include delayed or atypical language development, limited eye contact, lack of joint attention, restricted play, and hypo- or hyper-reactivity to sensory input. However, these features are not exclusive to ASD and may also appear in children with intellectual developmental disorders, communication disorders, or ADHD (Thapar et al., 2017; Hudry et al., 2014). This symptomatic overlap complicates the diagnostic process, particularly in children with co-occurring conditions or in those presenting with subtle, variable, or fluctuating presentations.

Recent research has highlighted the importance of going beyond binary diagnostic categories and instead focusing on neurodevelopmental dimensions - such as social motivation, executive functioning, or sensory processing - which are often distributed continuously in both clinical and non-clinical populations (Georgiades et al., 2022). From this perspective, ASD is increasingly conceptualized not as a unitary disorder, but as a dynamic convergence of multiple interacting vulnerabilities - genetic, neurobiological, cognitive, and environmental - that collectively shape the child's behavioral phenotype over time (Constantino & Charman, 2016). Some children present with average or above-average nonverbal intelligence and well-developed expressive language, while others are minimally verbal and have co-occurring intellectual disability. Emotional and behavioral functioning also varies widely: some children are emotionally withdrawn, while others exhibit elevated levels of irritability, anxiety, or impulsivity (Mazefsky et al., 2013; Stringer et al., 2020). This heterogeneity underpins the conceptualization of ASD as a spectrum encompassing not only symptom expression, but also broader dimensions of neurodevelopmental functioning and self-regulatory capacity.

Among the most consistent early predictors of poorer outcomes in ASD are difficulties in emotional regulation (Mazefsky et al., 2013) - defined as the ability to modulate affective responses in accordance with situational demands. Preschoolers with ASD often exhibit intense negative affect, low frustration tolerance, and delayed recovery following emotional arousal (Weiss, 2014). These difficulties are not only disruptive in their own right, but may also hinder social engagement, interfere with learning, and exacerbate other ASD symptoms. Importantly, emotional dysregulation has been closely associated with sensory processing alterations, particularly sensory over-responsivity, suggesting that sensory-affective coupling may constitute a key developmental mechanism in ASD (Carpenter et al., 2019; Green et al., 2015). Children who are hypersensitive to auditory, tactile, or visual stimuli may experience constant emotional overload, contributing to chronic stress and maladaptive coping strategies.

Another core domain in early ASD is sensory processing, now included in DSM-5-TR criteria (American Psychiatric Association, 2022). Sensory anomalies can involve hyperreactivity (e.g., aversive responses to sounds or textures), hyporeactivity (e.g., lack of response to pain), or sensory seeking (e.g., fascination with lights or movement). These behaviors are not merely peripheral symptoms but are thought to reflect altered neural processing in multisensory integration areas such as the insula, cerebellum, and somatosensory cortex (Marco et al., 2011; Cardon, 2018). Sensory processing differences are not only a diagnostic indicators but also a clinically meaningful dimension that correlates with anxiety, aggression, social avoidance, and parent stress (Cardon & Bradley, 2023; van den Boogert et al., 2021; Carpenter et al., 2019; Gourley et al., 2013).

Furthermore, many children with ASD exhibit co-occurring developmental disorders, particularly LD and ADHD. This further blurs the diagnostic boundaries, reinforcing the need for profiling based on functional domains rather than strict diagnostic silos. For instance, two children diagnosed with ASD may differ profoundly in terms of sensory sensitivity, verbal skills, and emotional control, calling for distinct therapeutic approaches.

In this light, emerging models advocate for the identification of phenotypic subtypes within ASD - such as sensory-emotional, language-impaired, or cognitively high-functioning profiles - each of which may respond differently to specific interventions (Brandes-Aitken et al., 2024; Gigliotti et al., under review).

1.3 Sensory Processing and Emotional Regulation in Neurodevelopmental Disorders

Sensory processing refers to the complex neurophysiological ability of the nervous system to detect, organize, and respond adaptively to sensory input from the environment and the body. It involves multiple levels of processing - from peripheral receptors to central integration - and plays a critical role in shaping perception, behavior, and emotional responses (Miller et al., 2007). Although sensory processing is a foundational component of early development in all children, it has gained increasing attention in the field of neurodevelopmental disorders (NDDs), where it is frequently atypical and associated with broad functional impairments (Ben-Sasson et al., 2009; Scheerer et al., 2024).

Children with NDDs - including ASD, ADHD, and language or intellectual disabilities - often present with altered patterns of sensory responsivity. These patterns may include hyperresponsivity (exaggerated reactions to sensory stimuli), hyporesponsivity (diminished or delayed reactions), and sensory seeking (craving or repetitive exploration of sensory input). Such patterns frequently co-occur and vary across modalities (e.g., auditory, tactile, visual, vestibular), forming complex sensory profiles that do not necessarily conform to diagnostic boundaries (Little et al., 2017; Scheerer et al., 2024).

In ASD, atypical sensory processing is now a formal diagnostic criterion (American Psychiatric Association, 2022), with up to 90% of individuals exhibiting clinically significant sensory features (Robertson & Baron-Cohen, 2017). However, these features are also prevalent in other NDDs. For example, children with ADHD may show high rates of sensory seeking and poor sensory modulation (Cheung & Siu, 2009; Ghanizadeh, 2011), while those with developmental coordination disorder (DCD) frequently display sensory processing difficulties - especially in proprioceptive and tactile domains, and in some cases auditory processing - which interfere with motor planning and daily functioning (Tran et al., 2022). This transdiagnostic distribution of sensory symptoms supports the view that sensory processing represents a shared neurobiological dimension across NDDs, rather than a disorder-specific symptom cluster.

From a neurophysiological standpoint, sensory processing relies on the functional integrity of cortical and subcortical structures involved in attention, salience detection, affect regulation, and motor coordination - including the thalamus (sensory gating), insula and anterior cingulate (salience network), and cerebellum (sensorimotor–affective integration) (Marco et al., 2011; Cakar et al., 2024). Disruptions in these systems may result in abnormal sensory gating, heightened arousal responses, and difficulty filtering irrelevant stimuli, which in turn impact the individual's capacity for emotional and behavioral regulation in daily contexts.

The relationship between sensory processing and emotional regulation is increasingly understood as bidirectional and developmentally intertwined. Emotional regulation refers to the ability to manage and modulate emotional experiences and expressions in accordance with situational demands and social norms. It involves a dynamic interplay between neurobiological reactivity and regulatory strategies - both of which may be influenced by the quality and intensity of sensory input (Beauchaine & Cicchetti, 2019). For instance, a child who is hypersensitive to auditory input may experience emotional dysregulation in noisy environments due to chronic overactivation of stress circuits, such as the amygdala-hypothalamus axis (Green et al., 2015; Than et al., 2024).

Conversely, a child with hyposensitivity may fail to register internal cues of distress or fatigue, leading to disorganized or delayed affective responses. Sensory seeking behaviors, often interpreted as behavioral disturbances, may instead reflect attempts to regulate internal arousal or emotional state through repetitive or intense sensory stimulation (Schaaf et al., 2011; Brandes-Aitken et al., 2024). These behaviors can thus be reinterpreted within a sensory-emotional regulation framework, rather than as isolated symptoms of a particular diagnosis.

Several studies have documented strong associations between atypical sensory responsivity and internalizing or externalizing symptoms in children with NDDs. Sensory over-responsivity has been linked to anxiety, irritability, sleep disturbances, and social withdrawal (Carpenter et al., 2019; Lane et al., 2012), while under-responsivity and poor sensory discrimination have been associated with inattentiveness, impulsivity, and difficulty with frustration tolerance, particularly in children with ADHD (Cheung & Siu, 2009; Keating et al. 2022). Importantly, these associations often remain significant even after controlling for diagnostic status, highlighting the transdiagnostic relevance of sensory-emotional coupling.

The importance of early identification of sensory-emotional profiles is further underscored by longitudinal studies. For example, children with early sensory hypersensitivity are at increased risk for later anxiety disorders (Carpenter et al., 2019; Green & Ben-Sasson, 2010), while those with poor sensory modulation may show difficulties in social adjustment, executive functioning, and academic readiness (Brown et al., 2021; Dellapiazza et al., 2018). These findings suggest that sensory profiles are not merely epiphenomena but may function as developmental pathways or mediators linking early neurobiological vulnerability to later adaptive outcomes.

Recent research has employed person-centered approaches such as Latent Profile Analysis (LPA) to uncover meaningful subtypes based on sensory and emotional functioning in early childhood, by identifying latent heterogeneity not captured by categorical diagnoses. For example, Brandes-Aitken et al. (2024) identified sensory-based phenotypes that differed not only in sensory reactivity but also in emotional regulation, cognitive performance, and functional outcomes. Such findings are supported by similar results in European clinical samples, including the empirical study presented in this thesis (Gigliotti et al., under review), where distinct profiles emerged that cut across ASD, LD, and other developmental conditions, revealing clusters of children with multisystemic sensory dysfunction, mixed subclinical sensitivity, or typical processing patterns.

These subtypes carry significant implications for clinical care. Children with multisystemic sensory and emotional dysregulation may benefit from low-arousal environments, sensory integration strategies, and co-regulation supports, while those with more isolated or mild sensory differences may respond better to targeted behavioral or cognitive interventions. Thus, profiling sensory-emotional dimensions may serve as a bridge between assessment and intervention, guiding personalized therapeutic planning.

From a theoretical perspective, this emerging literature calls for a redefinition of how clinicians and educators conceptualize developmental psychopathology. Rather than relying solely on static diagnostic labels, an ecological and dimensional view encourages attention to the interaction between the child and their sensory-affective environment. Such a framework is particularly valuable in preschool contexts, where traditional diagnoses are often unstable, and intervention outcomes hinge on accurate early characterization of the child's neurodevelopmental profile.

1.4 From Sensory Profiles to Personalized Interventions

The growing recognition of sensory processing differences as a core feature of neurodevelopmental disorders (NDDs) has significant implications for both assessment and intervention planning. While traditional therapeutic models often align treatment strategies with categorical diagnoses, such approaches may obscure meaningful individual variability within diagnostic groups - particularly in sensory and affective functioning (Astle et al., 2019; Gotham et al., 2015). This has prompted a growing body of research to advocate for a shift toward profile-based or trait-informed intervention frameworks, which prioritize the child's unique sensory and emotional profile over their diagnostic label (Astle & Fletcher-Watson, 2020). *Personalized approaches of this kind may enhance therapeutic engagement, reduce maladaptive behaviors*, and support more effective outcomes across neurodevelopmental conditions.

Profiling approaches, particularly those based on cluster analysis, Latent Class or Latent Profile Analysis (LCA/LPA), allow for the identification of subgroups of individuals who share similar constellations of traits - such as high sensory hyperreactivity, poor emotional regulation, or low cognitive flexibility - regardless of diagnostic assignment (Spurk et al., 2020). By moving beyond one-size-fits-all models, these approaches enable a more nuanced understanding of developmental risk and resilience, and they provide a framework for precision intervention design (Insel, 2014; Cuthbert & Kozak, 2013).

Building on this framework, several studies have successfully applied person-centered analyses to uncover distinct sensory–emotional profiles across diverse neurodevelopmental populations. One of the earliest and most comprehensive examples is the work by Ausderau et al. (2014), who conducted a Latent Profile Transition Analysis in a large national sample of children with ASD (aged 2-12 years). Their analysis revealed four stable sensory subtypes, ranging from mild to extreme impairment, which remained consistent over time and were differentially associated with behavioral outcomes. In a community-based cohort including children both with and without neurodevelopmental conditions (3-14 years), Little et al. (2017) identified five distinct sensory profiles through LPA, supporting the idea that sensory features reflect a dimensional continuum rather than being exclusive to clinical populations. Extending these findings to older age groups, Tillmann et al. (2020) applied factor mixture modeling to a heterogeneous sample of individuals with ASD aged 6 to 30 years, identifying three subgroups that differed in sensory severity and associated levels of anxiety, adaptive functioning, and attentional problems. More recently, Brandes-Aitken et al. (2024) used LPA to examine sensory and self-regulation patterns in a mixed clinical group of school-aged children (8-12 years). Their analysis yielded distinct phenotypes - characterized by over-responsivity, under-responsivity, and sensory seeking - each with specific emotional-behavioral correlates, particularly in anxiety levels and dysregulation, highlighting their clinical relevance.

Together, these studies demonstrate that data-driven profiling approaches can reveal clinically meaningful heterogeneity not captured by categorical diagnoses. They also suggest that sensory-emotional subtypes may serve as useful phenotypic markers to inform prognosis and personalize interventions across a broad range of neurodevelopmental conditions and age groups.

Similar findings have emerged from a recent research by the author and collaborators. This study applied person-centered profiling methods to a clinical sample of preschool children with ASD, LD, and other NDDs, revealing distinct sensory-emotional subtypes with differential clinical presentations. These findings offer preliminary support for the clinical utility of sensory-emotional profiling in informing personalized intervention planning (Gigliotti et al., under review). A more detailed description of this study and its empirical results is provided in Chapter 3.

This profile-based logic aligns closely with the principles of occupational therapy and developmentally-informed mental health care, which emphasize individualized, context-sensitive approaches. For instance, the Sensory Integration and Praxis Test (SIPT), and more recently the Sensory Processing Measure (SPM/SPM-P), help clinicians map a child's sensory strengths and vulnerabilities and design personalized sensory diets and structured activities (Schaaf et al., 2014). These practices are further strengthened when integrated with assessments of emotional and behavioral regulation, as sensory dysfunction and emotional dysregulation often co-occur as a syndromic phenotype in early childhood (Green et al., 2012; Carpenter et al., 2019). Recent reviews. - such as Dell'Osso et al. (2023) - highlight the neurodevelopmental interconnectedness of these processes and support a transdiagnostic perspective on early emotional regulation impairments.

Beyond clinical utility, profiling offers a conceptual advantage in understanding the developmental mechanisms that link sensory experience, emotional regulation, and adaptive behavior. Developmental neuroscience suggests that sensory input plays a key role in scaffolding emotion regulation, executive functioning, and even social cognition, through its impact on neural circuits involving the thalamus, insula, amygdala, and prefrontal cortex (Marco et al., 2011; Cakar et al., 2024). Dysregulated sensory input can lead to chronic overactivation of stress-response systems, limit opportunities for social engagement, and disrupt the development of self-regulatory strategies. Thus, interventions that modulate the sensory environment may indirectly support emotional growth, even in the absence of direct emotion-focused techniques.

This principle underlies several therapeutic models that prioritize structured and predictable environments to support regulation and engagement - most notably the TEACCH framework for ASD and the DIR/Floortime model, both of which emphasize individualized, relational, and developmentally appropriate interventions. Building on these foundations, more recent approaches have extended the therapeutic setting beyond the clinic or classroom to incorporate naturalistic, multisensory environments, such as therapeutic gardens, forest schools, or animal-assisted programs. Often described under the umbrella term *green care*, these interventions draw on insights from environmental psychology, ecotherapy, and sensory integration to propose that nature offers a uniquely supportive context for children with sensory and emotional vulnerabilities (Bratman et al., 2019; Chawla, 2015).

Natural environments provide rich but low-threat sensory input, promote movement and embodied interaction, and reduce the sensory overload often encountered in urban or institutional settings. By offering opportunities for self-directed exploration, rhythmic motor activity, and affective co-regulation, these settings may enhance emotional resilience and stress recovery, particularly for children who struggle with traditional therapy formats. Moreover, the flexibility and responsivity of natural spaces align well with a profile-informed logic, in which the environment is actively shaped to match the child's sensory thresholds, affective needs, and engagement patterns.

In this regard, the transition from sensory profiling to ecological intervention becomes not only conceptually sound but also clinically strategic. If sensory-emotional profiles are robust markers of regulatory capacity in early childhood, then interventions should be designed to match not only the child's cognitive or behavioral level, but also their sensory-affective needs and capacities. A child with tactile defensiveness and emotional lability, for example, may benefit more from outdoor sensory exploration in natural environments than from classroom-based activities that rely on fine motor precision or verbal interaction.

Moreover, the ecological match between child's sensory-emotional profile and therapeutic context may critically moderate treatment outcomes. As argued by Schaaf and colleagues (2014b), effectiveness in sensory processing interventions depends not only on specific techniques, but also of environmental attunement - whether the setting supports or frustrates the child's ability to engage, regulate, and learn. This perspective has been echoed in studies on sensory-friendly classrooms, animal-assisted interventions, and sensory-integrated outdoor learning, all of which highlight how context-sensitive modifications can enhance engagement and reduce distress (Clément et al., 2022; Dettweiler et al., 2017).

Taken together, these findings and theoretical models support a developmentally sensitive, profile-informed, and ecologically grounded approach to intervention in NDDs. Rather than assigning children to standardized treatments based solely on diagnostic criteria, clinicians and educators are encouraged to consider how individual sensory-emotional traits interact with environmental affordances to shape behavior, learning, and well-being. This shift from diagnosis to profile, and from intervention to environment, opens the door for innovative therapeutic pathways that are both personalized and sustainable. Among these, nature-based interventions represent a promising and timely frontier, which will be explored in depth in the next sections.

1.5 Nature-Based Therapies: A Theoretical Overview

Over recent decades, a growing body of research has highlighted the therapeutic benefits of nature exposure for psychological well-being, stress reduction, and cognitive functioning across both clinical and non-clinical populations. This emerging movement - commonly referred to as green care, ecotherapy, or nature-based therapy - encompasses a diverse range of interventions that utilize nature as a medium for therapeutic change, including horticultural therapy, forest bathing, animal-assisted interventions, and outdoor education programs (Mittly et al., 2023; Lu et al., 2023; Chawla, 2015). Although traditionally explored within the contexts of adult mental health and public health promotion, these interventions are now gaining increasing attention in child and adolescent developmental psychiatry (Mygind et al., 2019; Fyfe-Johnson et al., 2021). Particular interest has emerged regarding their application for neurodevelopmental disorders, including ASD, with recent evidence suggesting their potential as effective complementary interventions in this population (Fan et al., 2023).

Nature-based therapies are grounded in the premise that human beings are biologically predisposed to benefit from interactions with natural environments - a concept known as biophilia (Wilson, 1984). Two key theoretical frameworks underpin this body of work: Attention Restoration Theory (ART) and Stress Recovery Theory (SRT). According to ART, proposed by Kaplan and Kaplan (1989), natural settings engage involuntary attention in a soft and non-taxing manner (referred to as "soft fascination"), allowing the recovery of directed (voluntary) attention depleted by cognitive overload. Conversely, SRT, developed by Ulrich (1983), posits that nature facilitates physiological and psychological recovery from stress through its calming and predictable sensory features - such as natural light, vegetation, and the sounds of water or birds - thereby reducing sympathetic arousal and promoting parasympathetic activation.

These theoretical models are supported by a robust empirical literature demonstrating the positive effects of nature exposure on emotional regulation, attentional control, and physiological arousal. Meta-analyses indicate that even brief interactions with nature - such as a walk in the park or viewing greenery through a window - can lower cortisol levels, reduce rumination, enhance working memory, and boost positive affect (Ríos-Rodríguez et al., 2024; Bratman et al., 2019; Twohig-Bennett & Jones, 2018). In children, nature contact has been associated with better self-regulation, increased prosocial behavior, and improved mood and concentration, particularly in urban or high-stress environments (Ernst & Stelley, 2024; Zare Sakhvidi et al, 2022; Wells & Evans, 2003).

Crucially, nature-based interventions differ from conventional therapeutic modalities in their emphasis on sensory immersion, multisensory integration, and embodied experience. Whereas traditional therapies often rely on verbal or cognitive techniques, nature-based approaches engage the whole body and multiple sensory systems simultaneously. For example, walking barefoot on grass, smelling herbs in a garden, or climbing a tree involve proprioceptive, tactile, vestibular, olfactory, and visual input - all of which contribute to the regulation of arousal and affective state. These multisensory affordances are particularly relevant for children with sensory processing differences, who may find traditional indoor settings overstimulating, unpredictable, or aversive (Fan et al., 2023; Mårtensson et al., 2009; Dettweiler et al., 2017).

Beyond sensory regulation, nature provides a predictable yet dynamic structure for exploration and learning. Unlike built environments, natural settings typically foster curiosity and flexible engagement without imposing rigid demands, supporting a balance between autonomy and safety. According to affordance theory (Gibson, 1979), environments offer opportunities for action based on individual capabilities. Nature may thus represent a particularly rich landscape of affordances for children with neurodevelopmental differences. For instance, a fallen log may afford climbing for one child, balancing for another, and simple observation for a third - all equally valid and self-directed modes of engagement.

From a developmental perspective, these characteristics support autonomy, mastery, and intrinsic motivation - key ingredients in healthy psychological growth. Moreover, nature-based activities are often socially low-demand and scaffolded by shared attention on objects or tasks (e.g., collecting leaves, feeding animals), which may reduce performance anxiety and facilitate parallel or cooperative play. These features may be especially beneficial for children with ASD or social anxiety, who may struggle with unstructured social interactions in conventional settings (Friedman et al., 2024).

Nature-based therapies have also been linked to enhanced executive functioning, including inhibition, working memory, and cognitive flexibility - domains often compromised in children with NDDs (Amicone et al., 2018; van den Berg & van den Berg, 2011). The restorative and arousal-regulating properties of natural environments may indirectly support these executive processes by lowering cognitive load and reducing sensory overstimulation. Several experimental studies have shown that children with ADHD, for example, display improved attentional performance after time spent in natural versus built environments (Kuo et al., 2018; Kuo & Taylor, 2004; Taylor & Kuo, 2009).

In parallel, animal-assisted interventions (AAIs) have shown promising effects on emotional regulation, anxiety reduction, and social engagement in children with ASD and other developmental conditions. Interacting with animals—particularly dogs, horses, or small mammals—can elicit oxytocin release, lower cortisol, and provide consistent nonverbal feedback, fostering affective attunement and relational safety (Galvany-López et al., 2024; Gabriels et al., 2015; O'Haire, 2013; Beetz et al., 2012). When delivered in natural settings, AAIs may further enhance the sensory and emotional benefits of nature exposure, creating synergistic opportunities for co-regulation, play, and therapeutic alliance.

Despite growing interest, research on nature-based interventions for children with NDDs remains methodologically diverse and relatively limited. Many studies are qualitative or quasi-experimental, often lacking control groups or standardized outcome measures. Nevertheless, preliminary evidence suggests that green therapies can improve mood, reduce aggressive behaviors, enhance emotional regulation, and promote engagement in therapeutic activities among children with ASD and related conditions (Li et al., 2019).

Importantly, these effects may not be uniform across children but rather moderated by individual differences in sensory-emotional profiles. For instance, children with high sensory sensitivity may benefit from the low-arousal, predictable input of natural environments, while children with under-responsivity may respond more to intense, movement-based exploration (e.g., climbing, swinging, digging). This suggests that nature-based interventions are most effective when tailored to the child's sensory and regulatory needs - a hypothesis that remains underexplored in empirical research.

Moreover, the environmental accessibility and sustainability of nature-based approaches make them attractive options for community-based and preventive models of care.

Gardens, parks, schoolyards, and animal sanctuaries are increasingly being recognized as valuable therapeutic spaces, particularly in low-resource settings or for children who are difficult to engage in conventional therapy formats. Integrating green care into existing educational and clinical infrastructures could offer a cost-effective, low-risk complement to traditional interventions, especially in early childhood populations.

In summary, nature-based interventions are rooted in well-established psychological and neurobiological theories and show promise as sensory-regulatory, emotionally supportive, and developmentally enriching therapeutic approaches. Their emphasis on multisensory engagement, embodied regulation, and contextual adaptability makes them particularly well-suited to the needs of children with NDDs. However, more research is needed to understand for whom, how, and under what conditions these interventions are most effective. The next section will examine how these principles intersect with the sensory and emotional profiles commonly observed in ASD, laying the groundwork for tailored, ecologically grounded therapeutic models.

1.6 Nature and Autism Spectrum Disorder: A Sensory–Ecological Match

ASD is characterized by a constellation of behavioral, cognitive, and neurobiological features that interact in complex and dynamic ways across development. Among the most robust and clinically salient of these features are atypical sensory responses, now formally included within the diagnostic criteria for ASD (American Psychiatric Association, 2022). These sensory patterns - encompassing hyperreactivity, hyporeactivity, and sensory seeking - are observed in over 90% of autistic individuals (Robertson & Baron-Cohen, 2017) and are strongly associated with emotional dysregulation, anxiety, aggression, and social withdrawal (Green & Ben-Sasson, 2010; Carpenter et al., 2019; MacLennan et al., 2020). Given the central role of sensory processing in shaping both the lived experience and behavioral expression of ASD, it is imperative that therapeutic environments accommodate and address sensory needs in developmentally informed and individualized ways.

This section examines how natural environments may offer an optimal sensory ecology for autistic children, potentially enhancing engagement, self-regulation, and therapeutic responsiveness. Given the multifaceted nature of this topic, the section is organized into thematic subsections addressing sensory regulation, social engagement, cognitive alignment, clinical applications, and research implications. The overarching concept of a "sensory-ecological match" posits that certain environments are inherently more suitable than others for supporting the regulatory and perceptual needs of neurodivergent individuals. Unlike many built or clinical settings - often characterized by excessive stimulation, unpredictability, and high social demands - natural environments provide structured complexity, sensory modulation, and flexible affordances that may align more closely with the sensory-emotional profiles frequently observed in ASD (Chawla, 2015; Dettweiler et al., 2017; Fan et al., 2023).

1.6.1 Sensory Regulation in Natural Environments

Natural settings offer rich multisensory input that is typically non-invasive, rhythmic, and self-paced. Elements such as wind, rustling leaves, water sounds, birdsong, and filtered light constitute forms of “soft” stimulation, which can help modulate autonomic arousal without overwhelming the sensory system (Kaplan & Kaplan, 1989; Ulrich, 1991). This stands in stark contrast to typical indoor environments, where artificial lighting, reverberating acoustics, unpredictable noise, and tactile clutter often contribute to sensory dysregulation, particularly in children with sensory hypersensitivity (Ashburner et al., 2008).

From a neurophysiological perspective, exposure to natural environments has been shown to reduce sympathetic nervous system activation and promote parasympathetic regulation, as evidenced by reductions in cortisol levels and increases in heart rate variability among both children and adults (Varadarajan et al., 2025; Zare Sakhvidi et al., 2022; Bratman et al., 2019). These physiological changes are consistent with enhanced emotion regulation capacity, a domain frequently compromised in autistic individuals exhibiting sensory hyperreactivity (Mazefsky et al., 2013).

Furthermore, many autistic children experience a chronic mismatch between their internal regulatory capacities and the demands of their environment. Educational and clinical settings often require sustained attention, behavioral inhibition, and verbal processing - skills that may be underdeveloped in children with ASD. By contrast, natural environments afford movement-based self-regulation, self-directed exploration, and repetitive engagement with sensory stimuli (e.g., watching flowing water, touching leaves, listening to birdsong), all of which may serve adaptive sensory-seeking and self-soothing functions (Koenig & Rudney, 2010; Schaaf et al., 2012). Such affordances are especially relevant for children with sensory modulation difficulties, as they provide opportunities for self-regulatory sensory behaviors that help maintain or restore optimal levels of arousal.

1.6.2 Social Demands and Emotional Safety

Beyond sensory benefits, natural environments offer social contexts characterized by lower structural rigidity, reduced performance expectations, and greater permissiveness. For children with ASD - who often experience difficulties with social reciprocity, interpreting social cues, and initiating interactions - structured indoor settings may evoke heightened social anxiety and behavioral dysregulation. Nature-based contexts frequently facilitate parallel play, shared attention on external stimuli, and nonverbal forms of communication, thereby reducing social demands and enhancing emotional safety (Mygind et al., 2019; Chawla, 2015). These settings allow children to engage socially on their own terms, at their own pace, and with reduced risk of social failure or overstimulation (Vanaken & Danckaerts, 2018).

Moreover, when nature-based activities involve co-regulation with an adult (e.g., exploring a stream, feeding animals, building structures), they can foster relational attunement without necessitating continuous verbal exchange. This mode of interaction may support affective engagement and attachment, particularly in children with co-occurring language delays or sensory defensiveness. In this respect, nature may serve as a third element within the therapeutic dyad, facilitating connection through shared sensory and affective experiences.

1.6.3 Cognitive and Motivational Alignment

Natural environments also provide developmentally appropriate challenges and open-ended problem-solving opportunities that align with the intrinsic interests and cognitive styles frequently observed in autistic individuals. Children with heightened attention to detail or a proclivity for pattern recognition may be naturally drawn to activities such as collecting leaves, observing insects, or arranging natural materials, thereby fostering cognitive engagement and intrinsic motivation. Predictable routines within a natural rhythm - such as feeding animals or watering plants - can further provide temporal scaffolding for children with ASD, who often benefit from consistent sequencing of events (Lord et al., 2020).

Additionally, nature-based activities integrate executive function demands—such as planning, inhibition, and cognitive flexibility - into embodied, goal-directed tasks that are often more motivating and less abstract than traditional cognitive exercises. For example, building a shelter or navigating a nature trail inherently involves sensory-motor coordination, sequencing, and social negotiation, yet these demands are embedded within real-world activities, making them more accessible and less anxiety-provoking for children with executive functioning difficulties (Diamond & Lee, 2011; Becker et al., 2017; Ernst et al., 2022).

1.6.4 Clinical Applications and Emerging Evidence

Although the evidence base for nature-based interventions in ASD remains emergent, preliminary studies and pilot programs have reported promising outcomes. Interventions such as outdoor play therapy, horticultural therapy, and animal-assisted outdoor programs have been associated with improvements in mood, social initiation, sensory regulation, and emotional expressiveness in children with ASD (Gabriels et al., 2015; Fan et al., 2023). Caregiver reports also frequently highlight increased engagement, reduced oppositional behavior, and enhanced therapeutic receptivity in natural settings compared to indoor clinical environments (Sempik et al., 2005; Fan et al., 2023).

However, the existing literature is characterized by notable methodological limitations, including small sample sizes, lack of standardized outcome measures, and limited control for potential confounding variables such as therapist-child rapport or novelty effects (Mygind et al., 2019). There is therefore a pressing need for rigorously designed randomized controlled trials to evaluate the differential effectiveness of green therapies across varying sensory-emotional profiles, cognitive levels, and developmental stages.

One particularly promising research direction involves profiling children with ASD based on sensory and affective characteristics—such as sensory over-responsivity, irritability, or cognitive flexibility—and systematically matching them to intervention formats (e.g., indoor versus outdoor, structured versus open-ended) that optimize their regulation and engagement. This precision ecological approach, although still nascent, aligns with the broader transdiagnostic and developmental paradigms increasingly adopted in contemporary psychiatry (Fan et al., 2023; Vanaken & Danckaerts, 2018).

1.6.5 Summary and Research Implications

In summary, a growing body of theoretical and empirical literature supports the notion that natural environments may offer distinctive therapeutic affordances for autistic children, particularly those with co-occurring sensory and emotional regulation challenges. Nature provides predictable yet rich multisensory input, fosters nonverbal social engagement, supports embodied cognition, and mitigates both environmental and interpersonal stressors. These features closely align with the core needs of many children on the autism spectrum and may enhance both the accessibility and effectiveness of therapeutic interventions.

CHAPTER 2 – LITERATURE REVIEW

2.1 Green Therapy in Autism Spectrum Disorder: Current Evidence

Building on the sensory and ecological considerations outlined in the previous chapter, the past two decades have witnessed growing research attention toward the therapeutic potential of nature-based interventions - often referred to as green therapy - for children with ASD. These interventions are grounded in diverse theoretical frameworks, including ecological psychology, biophilia theory, stress recovery theory, and embodied developmental models. Collectively, these perspectives suggest that structured interaction with natural environments may enhance self-regulation, social engagement, and overall well-being in neurodiverse populations (Bratman et al., 2019; Chawla, 2015; Kaplan & Kaplan, 1989). This section critically reviews the emerging empirical literature on green therapy in ASD, focusing on intervention formats, targeted outcomes (e.g., emotional regulation, sensory modulation, social functioning), and key methodological limitations that characterize the current evidence base.

2.1.1 Modalities of Nature-Based Interventions

Green therapy is an umbrella term that encompasses a broad range of practices. Among the most commonly applied to children with ASD are:

- **Horticultural Therapy** (**HT**), which uses gardening and plant-based activities to support fine and gross motor development, attention, and emotion regulation (Sempik et al., 2005; Flick, 2012; Nevil & Beela, 2023; Karthikeyan, 2023);
- **Forest School Programs**, which offer exploratory, child-led learning within wooded settings, aiming to promote autonomy, curiosity, and social participation (Knight, 2013; Friedman et al., 2022);
- **Nature-Based Occupational Therapy**, integrating sensory-motor activities with nature-focused tasks (e.g., digging, balancing on logs, collecting leaves) to enhance emotional regulation and executive functioning (Burke et al., 2024);
- **Animal-Assisted Interventions** (**AAI**) conducted in natural contexts, which improve socio-emotional functioning via interaction with animals such as horses, dogs, or goats (Nieforth et al., 2023; Gabriels et al., 2015; O'Haire, 2013);
- **Urban Green Space Play**, structured or unstructured play in parks and green schoolyards, aimed at enhancing socialization and behavioral outcomes (Aghabozorgi et al., 2023; Wu et al, 2022).

Altough these interventions differ in their structure, intensity, and theoretical background, they share a common emphasis on multisensory integration, autonomy-supportive scaffolding, and contextual flexibility - elements that are highly relevant to the neurodevelopmental profiles and regulatory needs frequently observed in ASD.

2.1.2 Sensory and Emotional Outcomes

A key rationale for nature-based approaches lies in their capacity to modulate sensory input in ways that are rhythmic, predictable, and self-paced, offering a clear alternative to the overstimulating and unpredictable sensory landscapes typical of many built environments. This modulation appears particularly beneficial for autistic children with sensory over-responsivity, a trait closely linked to emotional dysregulation and internalizing symptoms (Ben-Sasson et al., 2009).

A recent systematic review by Odame-Asante et al. (2025) synthesized the available evidence on nature-based learning and its effects on emotional and behavioral outcomes in children with ASD. Across the included studies, participation in outdoor and nature-based programs was consistently associated with reductions in anxiety, emotional reactivity, and behavioral dysregulation, as well as improvements in mood, self-regulation, and emotional well-being. Gabriels et al. (2015) similarly found that equine-assisted therapy conducted in outdoor contexts reduced irritability and hyperactivity, particularly in children with pronounced sensory sensitivity.

Supporting these findings, Griffioen et al. (2023) examined the effects of dog-assisted therapy on physiological stress markers in children with ASD and Down syndrome, observing significant reductions in salivary cortisol levels within each session, indicative of decreased physiological stress.

Although not conducted exclusively with children with ASD, Lee et al. (2018) reported that horticulture-related activities, such as flower arrangement and planting, significantly reduced salivary cortisol concentrations in elementary school children with behavioral adjustment difficulties, suggesting that nature-based interventions may broadly support stress regulation in neurodiverse populations.

Consistent with these physiological and behavioral findings, Mårtensson et al. (2009) observed improved frustration tolerance and persistence among preschoolers engaged in outdoor therapy, further supporting the role of nature in facilitating embodied self-regulation.

Qualitative findings by Friedman et al. (2022) further support this view: in a forest school setting, autistic children showed increased emotional well-being, self-confidence, and autonomy over time. These improvements in emotional well-being and self-regulation were especially pronounced among children with lower verbal skills or comorbid anxiety, suggesting that nature-based interventions may offer a particularly supportive context for emotionally vulnerable subgroups within the autism spectrum.

2.1.3 Social Interaction and Communicative Engagement

Beyond sensory and emotional regulation, nature-based interventions also appear to facilitate more accessible and spontaneous forms of social interaction for children with ASD. Animal-assisted interventions conducted in outdoor settings have been associated with increased emotional expression and social responsiveness in autistic children, as shown in a systematic review by O'Haire (2013).

The natural context may reduce the cognitive and communicative demands typically associated with conventional social exchanges, allowing children to engage through shared attention to external stimuli such as planting, feeding animals, or exploring natural elements. Such object- and activity-mediated forms of interaction align with the communicative preferences of many autistic children, especially those with limited verbal skills or heightened social anxiety.

Qualitative findings by Ang and MacDougall (2023), based on therapist and parent perspectives, further support this view: their study on animal-assisted therapy for children with ASD highlighted perceived improvements in social engagement, affective responsiveness, and behavioral participation, particularly in low-pressure, nature-integrated contexts. More broadly, Becker et al. (2017), in a systematic review on outdoor education programs, reported positive effects on peer engagement and social skills development in children with special educational needs. Although not ASD-specific, these findings further support the idea that nature-based settings may offer a socially accommodating environment that fosters spontaneous and low-demand social interactions. Collectively, these findings suggest that natural contexts may lower social barriers and provide emotionally safe settings where autistic children can engage in meaningful, self-paced social interactions.

2.1.4 Attention, Executive Functioning, and Adaptive Skills

Nature may also act as a cognitive scaffold, enhancing attentional control, behavioral flexibility, and adaptive functioning in children, including those with NDDs. Early experimental studies demonstrated that exposure to green spaces can improve attention in children. For example, Kuo and Taylor (2004) reported that children showed improved attentional capacity following a walk in a green environment, compared to urban or indoor walks. Taylor and Kuo (2009) later confirmed these effects in a larger sample.

More recently, Fan et al. (2023) conducted a systematic review and meta-analysis focused specifically on nature-based interventions for autistic children. The analysis revealed significant short-term improvements in attention, hyperactivity, and irritability, with additional benefits for sensory processing domains often linked to executive control (e.g., sensory seeking and sensitivity).

Beyond attention, there is growing evidence that natural settings can support broader executive functions. Ernst et al. (2022), in a narrative review focused on early childhood education contexts, highlighted that embodied, goal-directed outdoor tasks - such as navigating uneven terrain or engaging in group problem-solving - can improve core executive skills like inhibitory control, cognitive flexibility, and working memory. These domains are frequently impaired in children with ASD (Demetriou et al., 2018).

Complementing these findings, Johnstone et al. (2022), in a mixed-methods systematic review, emphasized that nature-based early education programs contribute to improved social-emotional skills and adaptive behavior in young children, while Van den Berg et al. (2016) found that green schoolyard play was associated with enhanced selective attention and emotional regulation.

Taken together, these studies suggest that natural environments facilitate executive control and adaptive functioning through bottom-up sensory and motor engagement, offering ecologically valid, real-world problem-solving experiences that do not rely solely on abstract verbal instruction - an important consideration for children with ASD who often experience challenges in this area. This, in turn, may support more effective adaptive generalization.

2.1.5 Methodological Challenges and Gap

Despite promising outcomes, the current evidence base is characterized by significant limitations. Many studies rely on small samples, lack control conditions, and use non-standardized outcome measures. For example, the qualitative richness of Friedman et al. (2022) and Sempik et al. (2005) provides valuable insight into children’s lived experiences, but their findings are not readily generalizable. Similarly, Fan et al. (2023), in their systematic review, identified moderate effects of nature-based interventions on emotional well-being and stress reduction but also highlighted substantial heterogeneity in intervention protocols, target outcomes, and measurement tools.

A critical gap is the lack of stratification by sensory, emotional, or behavioral profiles. Very few studies consider whether intervention effects differ based on individual characteristics such as sensory sensitivity, internalizing symptoms, or executive dysfunction. Ernst et al. (2022) similarly noted that most nature-based research in early childhood fails to incorporate systematic phenotyping, limiting the ability to tailor interventions to individual needs. As a result, clinicians and educators are left without clear guidelines on which children are most likely to benefit from green therapy and under what specific conditions.

Moreover, longitudinal follow-up studies are rare, and few investigations explore the sustainability of observed gains or their generalization to other settings (e.g., school, home). Johnstone et al. (2022) underscored the scarcity of long-term evaluations in nature-based early education programs, limiting understanding of whether initial benefits persist over time. Finally, contextual variables such as climate, socio-economic status, and access to green spaces are often underreported, limiting the scalability and real-world applicability of current findings.

These methodological gaps underscore the need for rigorously designed, stratified, and longitudinal studies.

2.1.6 Summary and Clinical Implications

Overall, the current literature provides compelling preliminary evidence that nature-based interventions can offer meaningful benefits for autistic children across several domains – particularly in sensory regulation, emotional modulation, social engagement, and adaptive functioning. These effects appear most robust in younger children, and in those with co-occurring sensory and emotional vulnerabilities.

However, the methodological limitations outlined in the previous section underscore the need for more rigorous, phenotype-sensitive research designs. Future studies should incorporate standardized profiling tools to identify individual predictors of treatment response and enhance intervention personalization.

2.2 Nature and Sensory Regulation

Children with neurodevelopmental disorders, particularly those with ASD, often exhibit atypical sensory processing patterns, which can significantly impact their emotional regulation, attention maintenance, and adaptive engagement with their environment (Ben-Sasson et al., 2009; Green et al., 2012). Sensory reactivity - manifesting as hyperresponsivity, hyporesponsivity, or sensory seeking - is increasingly recognized as a core feature of ASD, often emerging early in development and predicting both internalizing and externalizing difficulties (Carpenter et al., 2019; Lane et al., 2012).

Natural environments may serve as therapeutic contexts that support sensory regulation in children with ASD. For instance, Mårtensson et al. (2009) found that preschool children who engaged in play within large, integrated outdoor areas rich in natural elements such as trees and varied terrain exhibited fewer inattentive behaviors compared to those in less natural settings. This suggests that green outdoor environments can have restorative effects on attention in young children.

Additionally, Dettweiler et al. (2017) reported that outdoor learning experiences are associated with reduced cortisol levels in children, indicating lower physiological stress. Such findings imply that nature-based activities can positively influence stress regulation, which is often intertwined with sensory processing challenges in ASD.

These studies collectively suggest that natural settings, through their multisensory and less structured nature, may provide beneficial contexts for sensory regulation in children with ASD. However, further research is needed to delineate the specific mechanisms and to identify which subgroups of children may benefit the most from such interventions.

2.2.1 Theoretical Foundations of Sensory Modulation

Sensory modulation refers to the neurological and behavioral processes by which individuals regulate, organize, and respond to incoming sensory information in a graded and adaptive manner (Miller et al., 2007). This capacity allows individuals to maintain an optimal level of arousal and engagement in different environmental contexts. Difficulties in sensory modulation are characterized by an inability to appropriately filter, prioritize, or habituate to sensory stimuli, resulting in either hyper-responsivity (exaggerated responses to sensory input), hypo-responsivity (reduced or delayed responses), or sensory seeking behaviors (Dunn, 1997).

According to Dunn's (1997) model of sensory processing, these patterns reflect individual differences in neurological thresholds and behavioral self-regulation strategies. Children with low sensory thresholds may exhibit heightened reactivity and emotional dysregulation in response to ordinary environmental stimuli such as noise, lights, or tactile contact. Conversely, children with high thresholds may require more intense sensory input to achieve an alert state, often engaging in repetitive or high-intensity sensory-seeking behaviors. Both profiles can contribute to difficulties in emotional regulation, attention, and social participation.

At the neurobiological level, atypical sensory modulation in ASD has been linked to altered connectivity across key cortico-subcortical circuits involved in sensory processing and emotional regulation. Structural and functional imaging studies have identified differences in the thalamus, insula, amygdala, and primary somatosensory cortex among individuals with ASD, suggesting disrupted sensory gating and affective salience processing (Green et al., 2015; Marco et al., 2011). Furthermore, children with ASD often show reduced habituation to repeated sensory stimuli, indicating impaired neural mechanisms for filtering redundant information (Green et al., 2015).

These neurophysiological abnormalities may undermine the ability of children with ASD to predict, integrate, and regulate incoming sensory information, contributing to the development of internalizing symptoms, behavioral dysregulation, and social withdrawal (Carpenter et al., 2019; Neil et al., 2016). Understanding these mechanisms is critical for designing interventions - such as nature-based approaches - that leverage environmental affordances to support sensory regulation and emotional well-being.

2.2.2 The Sensory Ecology of Nature

Natural environments offer a unique sensory ecology that contrasts sharply with the complexity and intensity often found in urban or indoor contexts. The sensory stimuli encountered in nature - rustling leaves, birdsong, variations in light, air temperature, and textures - tend to be rhythmic, graded, and multimodal, fostering bottom-up regulation through self-directed exploration (Pretty et al., 2005; Bratman et al., 2019). From an ecological psychology perspective, such settings provide a range of sensory affordances - action possibilities that emerge from the interaction between the individual and the environment (Heft, 1988). These affordances encourage spontaneous motor activity, multisensory engagement, and adaptive interaction with the surroundings.

From a sensory integration standpoint, these environmental characteristics may facilitate more effective arousal modulation, especially for children with sensory over-responsivity or high sensory seeking tendencies. Unlike artificial environments, which often bombard the nervous system with unpredictable or socially demanding stimuli, natural settings provide rich sensory input with low social demand, allowing children to regulate sensory intake at their own pace (Chawla, 2015).

Neurophysiological studies support these assumptions. Exposure to natural environments has been associated with enhanced parasympathetic activity, reduced cortisol levels, and accelerated neurophysiological recovery following stress (Ulrich et al., 1991; Li et al., 2007). Functional neuroimaging studies have also shown that time spent in nature modulates activation in the default mode network and insula - brain regions implicated in interoception, self-referential processing, and emotional regulation (Aspinall et al., 2015; Bratman et al., 2019).

These findings align with the hypothesis that nature may act as a low-demand sensory context, supporting self-regulation through modulation of autonomic and cortical activity.

Empirical studies in pediatric populations provide further evidence of these regulatory effects. Mårtensson et al. (2009) observed that preschool children engaged in nature-rich play environments displayed better attentional control and frustration tolerance compared to peers in urban play settings. Dettweiler et al. (2017) reported reduced cortisol levels among children participating in outdoor educational programs, suggesting lower physiological stress. Specifically for children with ASD, Friedman et al. (2022) found that participation in a forest school program was associated with caregiver-reported improvements in self-regulation and sensory engagement over time. These effects appeared especially pronounced among children with heightened sensory sensitivity or comorbid anxiety.

Taken together, these findings suggest that the sensory ecology of natural environments—characterized by multimodal, predictable, and self-paced sensory inputs—may support sensory modulation and emotional regulation in children with ASD. By offering real-world, low-demand sensory experiences, nature-based contexts may act as therapeutic environments that align with the unique sensory profiles of these children, facilitating adaptive engagement and stress reduction.

2.2.3 Sensorial Fit and Self-Regulation

The concept of "sensory fit" refers to the degree of compatibility between a child's sensory processing profile and the demands or affordances of the surrounding environment (Schaaf & Davies, 2010). According to sensory integration theory, a poor match between environmental stimuli and an individual's sensory thresholds can exacerbate dysregulation, emotional reactivity, and behavioral challenges (Miller et al., 2007). Conversely, environments that are attuned to a child's sensory needs can scaffold more adaptive regulation, engagement, and learning opportunities.

Natural settings, by virtue of their spatial openness, multisensory richness, and relative predictability, may provide an optimal context for adaptive sensory–motor engagement, especially for children with ASD who present with sensory processing challenges. For example:

- Children with proprioceptive and vestibular seeking tendencies may benefit from activities such as climbing, digging, and running on uneven surfaces, which provide deep pressure and movement input that supports arousal regulation.
- Children with tactile sensitivity may experience graded and non-threatening exposure to varied textures (e.g., grass, bark, water), facilitating desensitization and improved sensory tolerance.

- Children with auditory filtering difficulties may find natural settings less overwhelming due to the lower intensity, predictability, and harmonious quality of environmental sounds.

These affordances not only support physiological arousal modulation but also promote emotional soothing, attention restoration, and opportunities for reciprocal social engagement - domains frequently compromised in children with ASD (Kaplan, 1995; Chawla, 2015; Friedman et al., 2022).

By aligning environmental sensory properties with individual sensory profiles, nature-based settings may act as ecological scaffolds for self-regulation, providing a strong theoretical foundation for their use in therapeutic interventions targeting sensory and emotional regulation.

2.2.4 Clinical Implications

Building on the theoretical and empirical foundations outlined above, interventions conducted in natural settings can be strategically leveraged to modulate sensory input, reduce environmental stressors, and foster embodied self-regulation in children with ASD. Nature-based contexts inherently provide opportunities for multisensory engagement, allowing children to explore, process, and integrate sensory stimuli in a graded and self-directed manner (Fan et al., 2023; Burke et al., 2024).

Occupational therapy practices, such as sensory diets - typically designed to provide targeted sensory input throughout the day - may gain enhanced effectiveness when implemented within green environments. In such settings, movement-based tasks, tactile exploration, and visual attention can occur simultaneously and with greater ecological validity, promoting spontaneous and intrinsically motivated engagement (Burke et al., 2024).

Matching a child's sensory-emotional profile to specific features of nature-based interventions may enhance therapeutic impact. For instance, children with high tactile sensitivity may benefit from slow, repeated, and non-threatening exposure to natural textures such as water, soil, or leaves, thereby facilitating desensitization through graded sensory experiences. Conversely, children with low proprioceptive awareness or high sensory-seeking behaviors may respond better to gross motor challenges involving climbing, digging, or carrying natural materials- activities commonly embedded within forest school programs or horticultural therapy (Friedman et al., 2022).

Beyond sensory modulation, these individualized approaches may also enhance emotional regulation, attention restoration, and social engagement - domains frequently compromised in children with ASD (Chawla, 2015; Kaplan, 1995).

These considerations underscore the importance of individualized, profile-informed intervention design when planning nature-based therapies. Rather than adopting a one-size-fits-all model, clinicians and educators are encouraged to integrate sensory assessment tools with contextual analysis of environmental affordances to optimize therapeutic outcomes (Schaaf & Davies, 2010; Miller et al., 2007).

2.3 Eco-Psychology and Developmental Neuroscience

The intersection between ecological psychology and developmental neuroscience has generated growing interest in how environmental experiences shape early brain development and emotional regulation. Eco-psychology emphasizes the reciprocal relationship between humans and the natural world, viewing nature not simply as a passive backdrop but as an active co-regulator of psychological states and developmental trajectories (Roszak, 1992; Buzzell & Chalquist, 2009). In recent years, this perspective has converged with empirical findings in affective neuroscience, offering a biologically grounded framework for understanding how nature-based interventions may benefit children with neurodevelopmental disorders (NDDs), including ASD.

This integrative perspective aligns with emerging models of environmental neuroscience, emphasizing the role of nature exposure in modulating neural circuits involved in stress, emotion, and self-regulation.

2.3.1 Developmental Embodiment and Environmental Affordances

Contemporary developmental science increasingly acknowledges the embodied and situated nature of early development (Thelen & Smith, 1994; Adolph & Hoch, 2019). Sensorimotor experiences are not isolated inputs but form the foundation for cognitive, emotional, and social functions through perception-action loops that are constantly modulated by context.

Natural environments provide rich affordances for exploratory action, offering opportunities for multisensory integration, dynamic motor adaptation, and relational attunement. For example, traversing uneven ground, balancing on rocks, or navigating spaces with varying light and sound conditions requires complex postural control, visuomotor coordination, and flexible problem-solving—capacities often delayed or impaired in children with ASD (Bhat et al., 2011).

In this sense, green spaces may serve as developmental scaffolds: environments where core processes such as self-regulation, joint attention, and emotion processing can emerge more naturally through embodied, context-sensitive interactions.

2.3.2 Stress Regulation, Brain Plasticity, and Nature Exposure

Environmental experiences during early childhood play a critical role in shaping the development of brain systems involved in stress regulation, emotional control, and executive functioning (Lupien et al., 2009; Tottenham & Galván, 2016). Prolonged exposure to adverse sensory, social, or emotional environments can dysregulate the hypothalamic-pituitary-adrenal (HPA) axis and alter the maturation of brain regions such as the amygdala, hippocampus, and prefrontal cortex - areas critical for affect regulation and cognitive control (McEwen & Gianaros, 2011). These effects are particularly salient for children with ASD, who frequently exhibit heightened physiological reactivity, impaired cortisol regulation, and reduced stress-buffering capacity (Corbett et al., 2006).

Natural environments appear to counteract these developmental risks by promoting parasympathetic activation, lowering cortisol levels, and modulating neural activity in brain regions responsible for interoception and affective regulation, including the insula and anterior cingulate cortex (Ulrich et al., 1991; Li et al., 2007; Bratman et al., 2019).

From a neurofunctional perspective, emerging evidence highlights the role of nature exposure in modulating brain networks involved in emotion regulation and interoception. Functional magnetic resonance imaging (fMRI) studies have shown that walking in natural environments reduces activation in the amygdala - a key structure in the neural circuitry of fear and stress - and increases functional connectivity within prefrontal regions associated with cognitive control and affect regulation (Sudimac et al., 2022). Additionally, exposure to green spaces has been linked to enhanced activity in the insula and anterior cingulate cortex, regions involved in interoceptive awareness and emotional salience processing (Dimitrov-Discher et al., 2022).

Beyond acute stress modulation, there is growing interest in the long-term neuroplastic effects of repeated exposure to natural settings. Davidson and McEwen (2012) emphasize that experiences that consistently modulate stress systems can foster durable changes in brain circuits related to emotional resilience. Similarly, animal studies on environmental enrichment suggest that exposure to complex, multisensory environments can stimulate neurogenesis, synaptic plasticity, and improved cognitive-emotional functioning (Nithianantharajah & Hannan, 2006).

Taken together, these findings suggest that nature exposure may serve as both an immediate buffer against physiological stress and a long-term facilitator of neurodevelopmental plasticity - mechanisms that are especially relevant for children with ASD and related neurodevelopmental disorders.

2.3.3 Eco-psychological Perspectives on Belonging and Connection

Eco-psychology offers a complementary lens to neuroscientific frameworks by conceptualizing human–nature interactions as relational processes that foster connection, psychological safety, and emotional regulation. Rather than viewing nature solely as a stress-reducing backdrop, eco-psychological theories emphasize the active role of the natural world in co-regulating emotional states and enhancing a sense of belonging and agency (Jordan & Hinds, 2016).

This perspective is particularly relevant for autistic individuals, who often report feeling more at ease, less judged, and freer to express themselves in natural settings compared to conventional social environments (Galbraith & Lancaster, 2020; Bystrom et al., 2019). Such experiences align with the eco-psychological concept of a therapeutic alliance between organism and habitat, in which the sensory, spatial, and affective qualities of the environment promote self-regulation, engagement, and emotional well-being.

For children with ASD who experience social anxiety, sensory defensiveness, or difficulties with peer interaction, nonverbal forms of co-regulation with the natural world—such as observing animals, listening to rainfall, or engaging in plant care—may offer alternative pathways to emotional soothing and attentional engagement that bypass conventional social demands (Bystrom et al., 2019; Scartazza et al., 2020).

Moreover, structured nature-based programs like healing gardens and outdoor adventure activities have been shown to foster joint attention, social participation, and affective responsiveness in children with ASD (Scartazza et al., 2020; Galbraith & Lancaster, 2020). These findings suggest that nature is not merely a calming setting but represents a relational partner capable of fostering inter-species and inter-environmental attunement—mechanisms that may be especially valuable for neurodivergent children who perceive the human social world as overwhelming or unpredictable.

2.3.4 Toward an Integrated Developmental Framework

By integrating insights from ecological psychology, affective neuroscience, and developmental psychopathology, it becomes possible to conceptualize nature not merely as a passive context for intervention but as an active developmental agent capable of shaping regulatory capacities and emotional well-being in children with neurodevelopmental disorders (NDDs), including ASD. This reframing encourages a departure from traditional intervention models that focus exclusively on symptom reduction, toward approaches that emphasize environmental fit, contextual responsiveness, and the cultivation of agency and engagement.

For children with ASD and other NDDs, this integrated perspective suggests that nature-based interventions may yield the greatest benefits when they are:

- Tailored to individual sensory and emotional phenotypes, recognizing the heterogeneity within ASD and the need for personalized environmental scaffolding;
- Embedded within relational and play-based formats, leveraging the motivational and regulatory power of naturalistic, child-led interactions;
- Conceptualized as dynamic co-regulatory processes, wherein the child, caregiver, and environment interact reciprocally to support emotional, attentional, and behavioral adaptation.

Such a framework aligns closely with person-centered and developmental models of care, emphasizing the interaction between biological predispositions and environmental affordances. It also resonates with broader ecological-developmental theories that view children's functioning as the product of continuous, bidirectional exchanges between the individual and their surroundings (Bronfenbrenner & Morris, 2006).

Taken together, these theoretical considerations lay the foundation for the empirical study presented in the following chapter, which aims to investigate whether and how nature-based therapeutic contexts can be optimized to support self-regulation and adaptive functioning in children with ASD, based on their unique sensory-emotional profiles.

CHAPTER 3 – EVIDENCE BASE AND RATIONALE FOR THE EMPIRICAL STUDY

3.1 Sensory and Emotional Regulation in Childhood ASD

As detailed in Chapter 1, children with ASD commonly experience persistent difficulties in sensory processing and emotional regulation, which significantly impact their daily functioning and quality of life. Sensory processing differences - including hyperresponsivity, hyporesponsivity, and sensory-seeking behaviors - are now recognized as core features of ASD, affecting over 90% of individuals diagnosed with the condition (Robertson & Baron-Cohen, 2017). These sensory challenges often co-occur with emotional dysregulation, manifesting as heightened anxiety, irritability, mood lability, and internalizing symptoms such as withdrawal and sadness (Green & Ben-Sasson, 2010; Carpenter et al., 2019; MacLennan et al., 2020). The interplay between sensory and emotional difficulties can compromise children's ability to engage in social interactions, participate in educational settings, and perform adaptive daily living tasks. Notably, these challenges may become more pronounced during middle childhood and the school-age years, a developmental period marked by increasing social and environmental demands (Mastorci et al., 2024). As a result, there is a growing clinical interest in interventions that can simultaneously address both sensory and emotional domains in children with ASD.

3.2 Sensory–Emotional Phenotypes: A Theoretical Framework

Building on the conceptual foundation introduced in Chapter 1, recent autism research underscore the importance of considering sensory processing and emotional regulation difficulties as interrelated dimensions rather than isolated domains that together shape distinct phenotypic profiles in children with ASD. These sensory-emotional phenotypes reflect heterogeneous patterns of sensory responsivity (e.g., hyperreactivity, hyporeactivity, sensory seeking) coupled with varied emotional and behavioral regulation capacities (Marco et al., 2011; Chen et al., 2024).

Theoretical models suggest that atypical sensory processing may directly influence emotional responses by modulating arousal levels, stress reactivity, and coping strategies (Dunn, 2007; Ben-Sasson et al., 2009). For example, heightened sensory sensitivity may increase vulnerability to anxiety and irritability, whereas sensory hyporesponsivity might contribute to social withdrawal and reduced emotional engagement. Moreover, these sensory-emotional patterns are dynamic, fluctuating across contexts and developmental stages, and can fluctuate across contexts and developmental stages, thereby supporting the need for a dimensional and person-centered approach (Robertson & Simmons, 2013).

Understanding sensory–emotional phenotypes is critical for personalized intervention planning. Tailoring therapeutic strategies to specific profiles may enhance engagement and efficacy by addressing both the sensory triggers and emotional consequences of dysregulation (Green & Ben-Sasson, 2010; Schauder & Bennetto, 2016). This theoretical framework provides a foundation for empirical efforts to classify phenotypic subgroups and informs the development of integrated treatment models.

3.3 Profiling Sensory-Emotional Phenotypes: Context and Emerging Evidence

As discussed in Chapters 1 and 2, the heterogeneity of sensory and emotional regulation difficulties in ASD has prompted increasing use of data-driven methods such as LPA to identify meaningful subgroups based on patterns of sensory responsivity and emotional functioning (Ausderau et al., 2014; Little et al., 2017; Tillmann et al., 2020; Brandes-Aitken et al., 2024). These approaches have deepened understandingof NDDs, including ASD, beyond categorical diagnosis, uncovering transdiagnostic phenotypic profiles associated with differential clinical outcomes.

Although the present study does not employ LPA as part of its analytic framework, it is informed by this growing body of literature. Notably, an article currently under review by the author applies LPA to a clinical sample of preschool children with NDDs, identifying distinct sensory-emotional profiles that underscore the clinical relevance of phenotypic stratification for personalized intervention planning (Gigliotti et al., under review).

The current empirical study adopts a pre-post intervention design to evaluate the effectiveness of a structured nature-based therapy on sensory processing, emotional regulation, social responsiveness, and adaptive functioning in children with ASD aged 6 to 12 years. While not incorporating latent profile methods, the study recognizes the underlying heterogeneity of sensory-emotional challenges and uses this perspective to justify the exploration of tailored, ecologically grounded interventions.

3.4 Evidence from Latent Profile Analysis: Sensory–Emotional Phenotypes in Neurodevelopmental Disorders

Expanding on the theoretical framework, a recent study conducted by the author and collaborators (Gigliotti et al., under review) applied LPA to parent-report data collected from a clinical sample of 263 preschool children aged 21 to 71 months, diagnosed with ASD, LD, or other

NDDs. The assessment battery included standardized measures of sensory processing (Sensory Processing Measure-Preschool, SPM-P) and emotional-behavioral functioning (Child Behavior Checklist for ages 1½-5 years, CBCL 1½-5).

The LPA identified three distinct sensory-emotional phenotypes:

- **Multisystemic Sensory Dysfunction Profile (20.1%)**: characterized by pervasive sensory difficulties across multiple domains, coupled with significant emotional challenges. This profile showed the highest representation among children with ASD.
- **Typical Sensory Processing Profile (44.9%)**: children in this profile exhibited largely normative sensory processing patterns and relatively preserved emotional functioning. This profile was predominantly composed of children diagnosed with LD.
- **Mixed Subclinical Profile (35%)**: this group displayed mild and selective sensory processing impairments alongside moderate emotional dysregulation, often subthreshold for clinical diagnosis but potentially impacting adaptive functioning. Children from all diagnostic groups were represented.

Importantly, these phenotypes did not align strictly with diagnostic categories, as children with ASD, LD, and other NDDs were distributed across all profiles. This finding highlights the dimensional and transdiagnostic nature of sensory-emotional heterogeneity in early neurodevelopment.

From a clinical perspective, the profiles differed in key domains:

- Children in the **multisystemic profile** exhibited the highest levels of emotional and behavioral dysregulation, including elevated internalizing and externalizing symptoms, suggesting a need for comprehensive, multimodal interventions targeting both sensory modulation and emotional regulation.
- Children in the **typical profile** may benefit from less intensive, targeted support.
- The **mixed subclinical group** may require monitoring and preventive strategies to support adaptive functioning and emotional well-being

These results underscore the value of sensory-emotional profiling for individualized treatment planning, supporting a shift away from categorical diagnoses toward personalized, profile-informed care. Although the current nature-based intervention study does not incorporate LPA directly, these findings provide a conceptual and empirical foundation for understanding heterogeneity in treatment response and for designing ecologically sensitive interventions.

Furthermore, the phenotypic distinctions emphasize the importance of selecting intervention contexts that align with individual sensory-emotional needs. For example, children characterized by multisystemic sensory and emotional challenges may particularly benefit from therapeutic settings that provide low-arousal, sensory-rich, and predictable environmental inputs - features inherently present in nature-based interventions.

Limitations of the study include the relatively small sample size and reliance on parent-report measures, which may be subject to reporting bias. Future research will benefit from longitudinal designs, larger cohorts, and integration of biological markers to further elucidate the developmental trajectories and neurobiological underpinnings of these phenotypes.

3.5 Evidence Supporting Nature-Based Interventions for Sensory and Emotional Regulation

Building on the theoretical background and empirical overview presented in Chapter 2, nature-based interventions have garnered increasing attention for their potential to support sensory modulation and emotional regulation in children with neurodevelopmental disorders, particularly ASD (Fan et al., 2023; Odame-Asante et al., 2025). Natural environments provide multisensory input that is tipically rhythmic, predictable, and non-threatening - qualities that contrast with the often overwhelming sensory experiences encountered in indoor or urban settings (Kaplan & Kaplan, 1989; Ulrich, 1991). These sensory affordances may facilitate autonomic regulation and reduce behavioral dysregulation.

Empirical studies have reported improvements in anxiety, irritability, attention, and social engagement following participation in green therapies (Mårtensson et al., 2009; Gabriels et al., 2015; Friedman et al., 2022). However, despite promising results, existing studies often suffer from methodological heterogeneity, small samples, and a lack of standardized outcome measures, limiting firm conclusions about efficacy and individual moderators of response (Ernst et al., 2022; Johnstone et al., 2022; Fan et al., 2023). Moreover, the interaction between individual sensory-emotional profiles and intervention efficacy remains underexplored, representing a critical gap in the literature.

3.6 Rationale and Aims of the Present Study

In light of the above, the present study aims to evaluate the impact of a structured nature-based therapeutic intervention on sensory processing, emotional regulation, social responsiveness, and adaptive functioning in children with ASD aged 6 to 12 years.

Specifically, the objectives are:

- To assess changes in sensory processing, emotional functioning, social abilities, and adaptive skills pre- and post-intervention using standardized parent-report measures, including the Sensory Processing Measure (SPM), Child Behavior Checklist (CBCL 6-18), Social Responsiveness Scale-2 (SRS-2), and Adaptive Behavior Assessment System-II (ABAS-II).

- To explore variability in treatment response, considering baseline heterogeneity in sensory-emotional characteristics.
- To provide preliminary evidence on the feasibility and clinical relevance of nature-based therapies for children with ASD, laying groundwork for future, more personalized intervention studies.

Although the present study does not incorporate latent profile analyses within its design, it acknowledges the importance of sensory-emotional profiling as an underpinning conceptual framework. The ongoing research conducted by the author and collaborators (Gigliotti et al., under review) illustrates how profiling can reveal meaningful subgroups and inform targeted intervention strategies.

By integrating sensory-emotional dimensions within an ecological and developmental framework, this work aims to contribute to precision developmental psychiatry, supporting individualized, context-sensitive treatment approaches that respect the complexity and heterogeneity of ASD.

This chapter has outlined the theoretical and empirical foundations supporting the present study, highlighting the relevance of sensory-emotional dimensions and nature-based interventions in ASD. The following chapter presents the methodological approach, including participant characteristics, intervention protocol, and outcome measures, followed by a detailed analysis of the study results evaluating the efficacy of the nature-based therapy.

CHAPTER 4 - METHOD

4.1 Study Design

Building upon the theoretical framework and aims outlined in the previous chapter, the present study adopted a single-group, quasi-experimental pre-post design to evaluate the effects of a structured nature-based therapeutic intervention on core functional domains in children with ASD. This design was chosen to align with the exploratory and feasibility-oriented nature of the research, aiming to generate preliminary evidence regarding the clinical relevance and acceptability of nature-based interventions in this population.

Given the exploratory and pilot nature of the project, no control group was included. The primary objective was to assess within-subject changes across four key outcome areas: sensory processing, emotional-behavioral functioning, social responsiveness, and adaptive skills.

Participants underwent two assessment points:

- A pre-intervention assessment (T1) conducted within two weeks prior to the start of the intervention, and
- A post-intervention assessment (T2) conducted within two weeks following the conclusion of the program.

For a subset of participants, longitudinal data were also collected at a third time point (T3), corresponding to the conclusion of a second participation in the intervention during a subsequent annual cycle. While the primary analyses focused on first-time participation to ensure data independence, this additional data allowed for an exploratory analysis of potential cumulative effects of repeated exposure to the nature-based program.

The intervention cycles were conducted between January 2022 and June 2025, as part of the clinical and therapeutic activities offered by the Child and Adolescent Neuropsychiatry Unit of the Policlinico Umberto I. The outdoor sessions of the intervention were implemented at the Società Agricola Fiore del Deserto, a peri-urban agricultural site, characterized by a combination of horticultural areas, natural green spaces, and structured sensory pathways.

This methodological approach allowed for the evaluation of pre-post changes associated with participation in the nature-based therapy, while also providing initial insights into the feasibility and potential benefits of structured exposure to natural environments for children with ASD.

Given the absence of a control group, findings should be considered preliminary and hypothesis-generating, rather than conclusive in terms of causal inference. Nonetheless, this pilot study represents an important step toward understanding the potential benefits of ecologically grounded therapeutic approaches for children with ASD.

4.2 Participants

The final study sample consisted of 16 children with a clinical diagnosis of ASD, aged between 72 and 129 months (equivalent to 6 years to 10 years and 9 months), including 5 females and 11 males. All participants were recruited between January 2022 and June 2025 through the Day Hospital Service for Neurodevelopmental Disorders at the Child and Adolescent Neuropsychiatry Unit of the Policlinico Umberto I, as part of routine diagnostic and therapeutic care pathways. The final intervention cycle concluded in June 2025. Participation in the study was voluntary, and written informed consent was obtained from all caregivers prior to enrollment.

4.2.1 Recruitment Procedures

Eligible families were informed about the project during clinical follow-up visits or at the conclusion of their diagnostic assessment. Detailed information about the study aims, procedures, and intervention activities was provided by the clinical team.

A total of 18 families initially expressed interest and were screened for eligibility. Two participants subsequently withdrew after attending some intervention sessions (due to scheduling conflicts), resulting in a final analyzed sample of 16 children who completed both the pre- and post-intervention assessments.

4.2.2 Diagnostic Procedures

All participants received an ASD diagnosis according to DSM-5 criteria, established by an experienced multidisciplinary team. The diagnostic process included:

- Developmental history assessment using the Autism Diagnostic Interview-Revised (ADI-R);
- Direct behavioral observation with the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2);
- Comprehensive clinical evaluation, including cognitive testing and adaptive functioning measures.

Cognitive functioning was assessed using standardized psychometric instruments appropriate for the child's developmental level (e.g., Wechsler scales, Leiter-3, or other age-appropriate cognitive tests). Participants demonstrated intellectual functioning ranged from borderline to average levels, with no child scoring below 50 in non-verbal IQ, in accordance with the exclusion criteria.

4.2.3 Inclusion and Exclusion Criteria

Inclusion Criteria

- Clinical diagnosis of ASD (DSM-5), confirmed via ADOS-2 and ADI-R;
- Age between 6 and 12 years (72-144 months) at pre-intervention assessment;
- Sufficient cognitive and behavioral capacities to participate actively in group-based, outdoor intervention sessions.

Exclusion Criteria

- Severe intellectual disability (non-verbal IQ < 50);
- Major neurological disorders (e.g., uncontrolled epilepsy, cerebral palsy);
- Severe sensory or motor impairments limiting participation in physical outdoor activities;
- Unstable medical conditions potentially interfering with intervention participation;
- Severe psychiatric comorbidities requiring intensive or inpatient psychiatric treatment (e.g., psychosis, severe mood disorder).

Mild psychiatric comorbidities, such as anxiety or ADHD, were not considered exclusion criteria, reflecting the typical clinical heterogeneity of children with ASD.

4.2.4 Management of Repeated Participations

Among the 16 participants, 4 children completed the intervention twice, taking part in two separate annual cycles. To ensure data independence in the primary analyses, only data from each child's first participation were included. However, an exploratory longitudinal analysis was conducted on this subgroup to examine potential cumulative effects of repeated exposure to the nature-based intervention.

4.3 Intervention

The nature-based therapeutic program implemented in this study was titled "Growing in Nature". The intervention was designed to promote sensory integration, emotional regulation, social engagement, and adaptive functioning in children with autism spectrum disorder (ASD) through structured, ecologically grounded activities.

4.3.1 Structure and Duration

The program spanned a total of six months, combining both hospital-based and outdoor nature-based sessions. Specifically:

- For the first five months, children attended weekly sessions (one per week) held at the Child and Adolescent Neuropsychiatry Unit of the Policlinico Umberto I.
- In addition, during this five-month phase, one outdoor session per month was conducted at the Società Agricola Fiore del Deserto.
- In the final month, the frequency of outdoor sessions increased to twice weekly, with all sessions taking place exclusively at the agricultural site.

Each session lasted approximately two hours.

4.3.2 Intervention Setting

The outdoor sessions were conducted at the Società Agricola Fiore del Deserto, characterized by horticultural areas, animal enclosures, open green spaces, and structured sensory pathways. This setting was selected for its capacity to provide multi-sensory, low-demand, and ecologically rich environments conducive to therapeutic engagement for children with ASD.

Although the program followed a semi-structured format, session content and task demands were flexibly adjusted based on each child's sensory profile, emotional state, and behavioral regulation needs. This individualization was achieved through ongoing observation and regular team discussions, allowing facilitators to tailor environmental demands and social expectations to optimize each child's participation and engagement. Moreover, session content was modulated across the intervention timeline, with progressive increases in task complexity and social demands during the final phase.

4.3.3 Content and Activities

The intervention targeted multiple developmental domains through four main thematic areas, summarized in Table 4.1.

Table 4.1 Thematic Areas and Example Activities of the “Growing in Nature” Program

Thematic Area	Example Activities	Therapeutic Objectives
Horticultural Therapy	Planting vegetables and flowers; watering and harvesting crops	Sensory integration; responsibility; fine and gross motor coordination

Thematic Area	Example Activities	Therapeutic Objectives
Sensory-Based Activities	Tactile exploration (e.g., soil, leaves, water); olfactory games (e.g., identifying herbs); proprioceptive tasks (e.g., carrying watering cans)	Arousal modulation; sensory discrimination; body awareness
Cooperative Play and Group Tasks	Team-based games; turn-taking activities; collaborative problem-solving tasks (e.g., building small structures with natural materials)	Social engagement; communication; peer interaction; behavioral regulation
Animal Care	Feeding farm animals; grooming and cleaning animal enclosures	Empathy; routine following; emotional regulation; task responsibility

4.3.4 Facilitation and Professional Team

Sessions were conducted by an interdisciplinary team composed of:

- Primary school teachers with experience in inclusive education;
- Child and adolescent neuropsychiatrists;
- A clinical psychologist specialized in neurodevelopmental disorders.

All staff worked collaboratively to ensure continuity of care, individualized support, and therapeutic consistency across hospital and outdoor settings. The team met regularly for session planning and case discussions, and post-session debriefings, ensuring that each child's needs were addressed while maintaining group coherence.

4.3.5 Attendance and Adherence

Overall, the program showed high levels of participant adherence. On average, each child missed approximately two sessions over the entire six-month period, reflecting a good engagement rate across both hospital-based and outdoor phases of the intervention.

4.3.6 Therapeutic Rationale

The therapeutic rationale underlying the “Growing in Nature” program was grounded in contemporary models of sensory integration, stress regulation, and developmentally supportive environments for children with ASD. By leveraging the affordances of natural settings - characterized by predictability, multi-sensory input, and reduced social demand - the intervention aimed to facilitate self-regulation, emotional well-being, and social participation. The structured combination of sensory-motor, relational, and adaptive skill-building activities was designed to provide scaffolded opportunities for engagement and functional improvement across multiple developmental domains.

4.4 Measures

A multi-informant, multi-domain assessment approach was employed to evaluate pre-post changes in sensory processing, emotional and behavioral functioning, social responsiveness, and adaptive skills in participating children. All measures were administered at two time points: pre-intervention (T1) and post-intervention (T2). Assessments were completed by parents using standardized questionnaires with established psychometric properties and validated Italian versions where available.

4.4.1 Sensory Processing Measure (SPM)

Sensory processing abilities were assessed using the Sensory Processing Measure (SPM) (Parham et al., 2007), a standardized caregiver-report questionnaire designed to evaluate sensory processing difficulties, praxis, and social participation in children aged 5 to 12 years across home and school environments.

For this study, the Home Form was used, consisting of 75 items rated on a 4-point Likert scale (Never, Occasionally, Frequently, Always), reflecting the frequency of sensory-related behaviors observed in daily life. The SPM generates scores across seven sensory domains: Social Participation (SOC); Vision (VIS); Hearing (HEA); Touch (TOU); Body Awareness (BOD); Balance and Motion (BAL); Planning and Ideas (PLA). An overall Total Sensory Score can also be calculated. Higher scores indicate greater levels of sensory dysfunction. The SPM has demonstrated good internal consistency and test-retest reliability (Parham et al., 2007). For this study, the Italian adaptation by Del Signore et al. (2020) was used.

4.4.2 Child Behavior Checklist for Ages 6-18 (CBCL 6-18)

Emotional and behavioral functioning was evaluated using the Child Behavior Checklist for ages 6-18 (CBCL 6-18) (Achenbach & Rescorla, 2001), a widely used parent-report measure assessing a broad range of emotional and behavioral problems in children and adolescents.

The instrument includes 113 items, each rated on a 3-point Likert scale (0 = Not True, 1 = Somewhat or Sometimes True, 2 = Very True or Often True), covering the child's behavior over the past six months.

The CBCL 6-18 generates scores for:

- Eight Syndrome Scales (e.g., Anxious/Depressed, Withdrawn/Depressed, Attention Problems);
- Two Broadband Scales (Internalizing Problems, Externalizing Problems);
- Total Problems Score.

Scores are converted to T-scores based on normative data. T-scores ≥ 65 fall in the borderline-clinical range, while scores ≥ 70 indicate the clinical range. The CBCL 6-18 has demonstrated high internal consistency, test-retest reliability, and construct validity across multiple international and Italian samples. In this study, we adopted the Italian version of this parent-report questionnaire (Frigerio et al., 2001), focusing on the T-scores of the Syndrome scales and the broad-band scales.

4.4.3 Social Responsiveness Scale, Second Edition (SRS-2)

Social responsiveness and autism-related social impairments were measured using the Social Responsiveness Scale, Second Edition (SRS-2) (Constantino & Gruber, 2012), Italian adaptation by D'Ardia et al. (2021).

The SRS-2 is a 65-item parent-report**,** rated on a 4-point Likert scale (from "Not True" to "Almost Always True"), providing scores across five domains: Social Awareness; Social Cognition; Social Communication; Social Motivation; Restricted Interests and Repetitive Behavior. The Total Score offers an overall index of autism symptom severity. T-scores ≥ 60 indicate the presence of significant difficulties in social responsiveness, with higher scores reflecting greater symptom severity. The SRS-2 has demonstrated excellent internal consistency and good convergent validity with other autism diagnostic measures.

4.4.4 Adaptive Behavior Assessment System, Second Edition (ABAS-II)

Adaptive functioning was assessed using the Adaptive Behavior Assessment System, Second Edition (ABAS-II) (Harrison & Oakland, 2003), Italian version by Ferri et al. (2014). This standardized measure evaluates the practical, social, and conceptual skills required for daily living. The Parent Form for ages 5-21 years was used in this study. The ABAS-II evaluates adaptive behavior across three primary domains:

- Conceptual skills (communication, functional academics, self-direction)
- Social skills (leisure, social interaction)
- Practical skills (self-care, home living, community use, health and safety)

The ABAS-II yields a General Adaptive Composite (GAC) score, in addition to domain-specific standard scores (mean = 100, SD = 15). Higher scores reflect better adaptive functioning.

The ABAS-II has demonstrated strong internal consistency (Cronbach's alpha > .90), good test-retest reliability, and adequate validity in both American and Italian normative samples.

4.5 Procedure

4.5.1 Assessment Timeline

Data collection was conducted at two primary time points for all participants:

- Pre-intervention assessment (T1): Conducted within two weeks prior to the start of the intervention cycle.
- Post-intervention assessment (T2): Conducted within two weeks following the conclusion of the intervention.

For the subgroup of children who participated in two consecutive annual cycles, an additional time point was included:

- Follow-up assessment (T3): Conducted within two weeks after the conclusion of the second intervention cycle, enabling exploratory longitudinal analyses of potential cumulative effects.

All assessments were conducted between January 2022 and June 2025, in accordance with the program timeline.

4.5.2 Recruitment, Ethical Considerations, and Informed Consent

Families were informed about the project during clinical consultations within the Day Hospital Service for Neurodevelopmental Disorders at the Policlinico Umberto I. Clinicians introduced the study during diagnostic feedback sessions or routine follow-up appointments, outlining the study objectives, procedures, and potential benefits. Families were informed about:

- The voluntary nature of participation;
- The right to withdraw at any time without consequences for ongoing clinical care;
- The confidentiality and secure handling of all collected data.

Parents were given the opportunity to ask questions and were allowed a reflection period before providing consent. Written informed consent was obtained from all parents prior to enrollment.

The study was conducted in accordance with the principles outlined in the Declaration of Helsinki (World Medical Association, 2013) regarding ethical conduct in research involving human participants. Given the low-risk nature of the intervention and its integration within standard clinical care pathways, no adverse events or ethical concerns were reported during the study period.

4.5.3 Assessment Administration

At each assessment point (T1, T2, and where applicable, T3), parents were invited to complete the full battery of standardized questionnaires (SPM, CBCL 6-18, SRS-2, and ABAS-II).

Data collection was conducted in person at the hospital setting, in a dedicated, quiet room to minimize distractions. Trained clinical psychologists provided standardized instructions for each instrument, both orally and in written form.

Parents were encouraged to complete the questionnaires during the scheduled assessment session. In cases where this was not feasible (e.g., time constraints, family needs), a take-home version of the questionnaires was provided, with clear instructions and a scheduled follow-up for data return and verification.

To enhance data quality and completeness:

- Real-time checking for missing responses was conducted by the research team upon collection.
- When incomplete questionnaires were identified, parents were contacted by phone and invited to provide the missing information, either verbally or by returning the corrected forms.

No incentives were provided for participation, in line with ethical standards for non-interventional clinical research within the hospital setting.

4.5.4 Data Management and Confidentiality

Each participant was assigned a unique alphanumeric identification code to ensure anonymity. All paper-based materials were stored in locked cabinets within the clinical research facility.

Electronic data were entered into a password-protected database, accessible only to authorized research personnel. Double-entry procedures were implemented to minimize data entry errors, with regular cross-checking between two independent data operators.

Data were stored and analyzed in compliance with the European General Data Protection Regulation (GDPR 2016/679) and the internal data protection policies of the Sapienza University of Rome - Policlinico Umberto I Hospital.

4.6 Data analysis

4.6.1 Software and Data Preparation

All statistical analyses were conducted using jamovi software (version 2.6.44; The jamovi project, 2023). Prior to conducting inferential statistics, the dataset was carefully screened for:

- Missing data;
- Outliers;
- Normality of distribution,
- Homogeneity of variance (where applicable).

For each outcome variable, descriptive statistics (means, standard deviations, ranges) were calculated at both T1 and T2.

Missing data analysis was performed to evaluate the extent and pattern of missingness. No missing data were observed for the primary outcome measures at either assessment point. Therefore, all participants with complete pre- and post-intervention data were included in the analyses.

Each participant was assigned a unique alphanumeric identification code to ensure anonymity. All paper-based materials were stored in locked cabinets within the clinical research facility.

4.6.2 Primary Analyses: Pre-Post Comparisons

The primary objective of the data analysis was to examine within-subject changes from pre- to post-intervention across four key outcome domains:

- Sensory processing (SPM)
- Emotional and behavioral functioning (CBCL 6-18)
- Social responsiveness (SRS-2)
- Adaptive functioning (ABAS-II)

Given the small sample size and potential non-normal distribution of the data, the choice of statistical tests was guided by a thorough assessment of data distribution characteristics. Normality was evaluated using the Shapiro–Wilk test, visual inspection of histograms and Q-Q plots, and by examining skewness and kurtosis values.

For variables that met the assumption of normality, paired-samples t-tests were conducted to compare pre- and post-intervention scores (T1 vs. T2). For non-normally distributed variables, the Wilcoxon signed-rank test was applied as a non-parametric alternative.

For each analysis, effect sizes were calculated to provide an estimate of the magnitude of change:

- Cohen's d for parametric tests
- r for non-parametric tests

A two-tailed significance level of $p < .05$ was set for all analyses.

In addition to pre-post comparisons, exploratory Spearman's rank-order correlation analyses were conducted to examine associations between pre–post change scores (Δ) across the different outcome domains (sensory processing, emotional-behavioral functioning, social responsiveness, and adaptive functioning). Given the exploratory nature of these analyses, only statistically significant correlations ($p < .05$) were reported.

To complement the primary non-parametric analyses, supplementary paired-sample t-tests were conducted for each outcome measure to calculate standardized effect sizes (Cohen's d). This additional analysis was performed to provide standardized metrics commonly used in intervention research, allowing for clearer interpretation of the magnitude of observed changes. Given the small sample size and exploratory nature of the study, these parametric results were considered descriptive and were interpreted with caution.

4.6.3 Exploratory Analyses: Repeated Participation Subgroup

For the subgroup of four participants who completed the intervention twice, an exploratory longitudinal analysis was conducted across three time points (T1, T2, T3).

Given the very small sample size, these analyses were descriptive and exploratory in nature. Visual inspection of score trajectories was performed, and individual case profiles were examined to explore potential cumulative effects of repeated exposure to the nature-based intervention. No inferential statistics were performed on this subgroup due to insufficient statistical power.

4.6.4 Handling of Multiple Comparisons

Given the pilot and exploratory nature of the study and following established recommendations for preliminary intervention research (Bender & Lange, 2001; Leon et al., 2011; Whitehead et al., 2016), no formal correction for multiple comparisons was applied. This decision was made to avoid inflating the risk of Type II errors, which can occur when applying stringent corrections in studies with small sample sizes and exploratory aims. This is particularly relevant given the large number of outcome variables and the additional exploratory correlation and parametric analyses conducted. However, results were interpreted with caution, focusing on effect sizes and the clinical relevance of observed changes, rather than relying solely on statistical significance. Findings should therefore be considered hypothesis-generating, with the goal of informing future, larger-scale, controlled studies.

CHAPTER 5 – RESULTS

This chapter presents the results of the pre-post evaluation of the “Growing in Nature” intervention for children with ASD. Descriptive statistics, effect sizes, and results from paired sample analyses are reported for each outcome domain. The focus is on both statistical significance and clinical relevance, given the pilot and exploratory nature of the study.

5.1 Sample Inclusion and Retention

As detailed in Chapter 4, a total of 18 children with ASD were initially enrolled in the study, of whom 16 (88.9%) completed both the intervention and the pre- and post-intervention assessments and were included in the primary analyses. Two participants withdrew after baseline assessment and were excluded from outcome analyses.

As previously described (Section 4.2.4), four children participated in two separate intervention cycles. However, only data from their first participation were included in the primary analyses to preserve data independence. No adverse events or safety concerns were reported during the intervention period. A summary of enrollment and retention rates is provided in Table 5.1.

Table 5.1 Overview of Sample Inclusion and Retention

Parameter	**N (%)**
Total participants enrolled	18 (100%)
Completed intervention and both assessments	16 (88.9%)
Drop-outs (after baseline assessment)	2 (11.1%)
Participated in two intervention cycles	4 (22.2%)
Included in primary analyses (first participation only)	16 (88.9%)

5.2 Baseline characteristics

Baseline demographic and clinical characteristics are summarized in Table 5.2 The mean age of participants at the time of pre-intervention assessment was 89.8 months (SD = 16.8).

In terms of clinical profiles, the mean cognitive composite score was 87.8 (SD = 15.8), and the ADOS-2 Calibrated Severity Score (CSS) averaged 6.25 (SD = 2.14), reflecting a moderate level of autism symptom severity.

Regarding sensory processing, the SPM Total Sensory Score was 65.5 (SD = 10.4), indicative of borderline to clinically significant sensory processing difficulties.

Emotional and behavioral functioning, assessed by the CBCL 6-18, showed a mean Total Problems T-score of 64.7 (SD = 6.92), within the clinically significant range.

Social responsiveness was also impaired, with a mean SRS-2 Total T-score of 76.7 (SD = 12.1). Finally, adaptive functioning measured by the ABAS-II Global Adaptive Composite (GAC) yielded a mean score of 76.9 (SD = 12.6), reflecting below-average adaptive skills relative to age-based norms.

Table 5.2 Baseline characteristics of the sample

Variable	Mean (SD)	Range
Age (months)	89.8 (16.8)	72 – 129
Cognitive composite score	87.8 (15.8)	67 – 117
ADOS-2 CSS	6.25 (2.14)	1 – 9
SPM Total Sensory T-score	65.5 (10.4)	52 – 80
CBCL 6-18 Total Problems T-score	64.7 (6.92)	46 – 77
SRS-2 Total T-score	76.7 (12.1)	54 – 90
ABAS-II GAC score	76.9 (12.6)	54 – 95

SD = standard deviation; ADOS-2 = Autism Diagnostic Observation Schedule, 2nd Edition; CSS = Calibrated Severity Score; SPM = Sensory Processing Measure; CBCL 6-18 = Child Behavior Checklist for Ages 6-18; SRS-2 = Social Responsiveness Scale; ABAS-II = Adaptive Behavior Assessment System, 2nd Edition; GAC = Global Adaptive Composite.

5.3 Baseline Associations Between Sensory, Emotional, Social, and Adaptive Domains

To explore baseline interrelations between sensory processing, emotional and behavioral functioning, social responsiveness, and adaptive skills, Spearman's rank-order correlations were computed among all outcome measures assessed at pre-intervention (T1). This non-parametric approach was selected due to the small sample size and the non-normal distribution observed in several variables. Several statistically significant cross-domain associations ($p < .05$) emerged, highlighting the interconnected nature of sensory, emotional, social, and adaptive functioning in children with ASD.

Higher total sensory processing difficulties (SPM Total Score) were significantly associated with greater overall social impairment (SRS-2 Total Score). Difficulties in Social Participation (SPM-SOC) showed strong negative associations with multiple domains of adaptive functioning, including the ABAS-II Global Adaptive Composite (GAC) and its Conceptual, Social, and Practical domains. Additionally, SPM Social Participation was positively associated with SRS-2 Social Awareness, suggesting that children with more difficulties in social participation also exhibited more pronounced deficits in social awareness. Further, visual and auditory sensory processing difficulties were positively associated with internalizing and thought-related problems on the CBCL 6-18. Specifically, SPM Vision correlated with CBCL 6-18 Internalizing Problems and CBCL 6-18 Thought Problems, while SPM Hearing was significantly associated with CBCL 6-18 Thought Problems.

Regarding social and adaptive functioning, higher SRS-2 Total Scores were significantly associated with lower ABAS GAC scores. Finally, CBCL 6-18 Total Problems were negatively correlated with SRS-2 Social Awareness.

In summary, significant cross-domain associations were observed between sensory processing difficulties (particularly in social participation, vision, and hearing domains), emotional-behavioral symptoms, social responsiveness, and adaptive functioning. A full list of all significant cross-domain correlations ($p < .05$) is provided in Appendix Table A1.

5.4 Changes in Sensory Processing

Significant improvements emerged for the SPM Total Sensory Score ($p = 0.037$; r = 0.692), indicating a moderate-to-large effect.

At the subscale level, statistically significant changes were found in Social Participation ($p = 0.004$; r = 0.901), Vision ($p = 0.010$; r = 0.846), Hearing ($p = 0.019$; r = 0.889), Touch ($p = 0.013$; r = 0.848), Body Awareness ($p = 0.044$; r = 0.756), and Balance and Motion ($p = 0.027$; r = 0.731). Effect sizes ranged from moderate to large across most domains, with the largest effects observed in Social Participation, Vision, Hearing, and Touch.

A marginally non-significant trend was observed for Taste and Smell ($p = 0.079$; r = 0.606), whereas no significant change emerged for Planning and Ideas ($p = 0.235$; r = 0.436). Full statistical details are reported in Table 5.3.

Table 5.3 Pre-Post Changes in SPM Total and Subscale Scores

SPM Domain	Pre Mean (SD)	Post Mean (SD)	Mean Difference	SE Difference	95% CI (Lower-Upper)	*p*-value	Effect Size (r)
SOC T-score	70.2 (6.75)	66.4 (9.42)	4.00	1.305	2.00 – 5.50	.004*	0.901
VIS T-score	66.4 (9.93)	63.2 (10.1)	4.50	0.867	3.00 – 6.50	.010*	0.846
HEA T-score	66.6 (10.4)	63.7 (10.4)	6.00	0.961	1.50 – 8.00	.019*	0.889
TOU T-score	63.3 (13.5)	61.4 (13.7)	3.00	0.634	0.50 – 4.50	.013*	0.848
TAS raw score	7.81 (3.95)	6.75 (3.17)	1.50	0.551	0.00 – 3.00	.079	0.606
BOD T-score	58.4 (8.94)	57.1 (9)	3.00	0.595	0.00 – 4.50	.044*	0.756
BAL T-score	60.6 (9.96)	58.1 (9.96)	3.03	1.037	0.50 – 5.50	.027*	0.731
PLA T-score	68.8 (7.86)	67.3 (7.61)	4.00	1.061	-0.50 – 6.50	.235	0.436

TOT T-score	65.5 (10.4)	64.4 (12)	2.50	1.258	1.00 – 4.00	.037*	0.692

SPM = Sensory Processing Measure-Preschool; SD = standard deviation; SE = standard error; CI = confidence interval; SOC = social participation; VIS = vision; HEA = hearing; TOU = touch; TAS = taste and smell; BOD = body awareness; BAL = balance and motion; PLA = planning and ideas; TOT = total sensory score. Effect sizes are reported as rank-biserial correlations. * $p < .05$. *Lower bounds of confidence intervals that were very close to zero (positive or negative) were rounded to 0.00 for clarity.*

5.5 Changes in Emotional and Behavioral Functioning

A significant reduction was observed in the CBCL 6-18 Total Problems T-score ($p = .005$; r = 0.794), indicating a large effect in reducing overall emotional and behavioral difficulties.

At the broadband scale level, significant improvements emerged in both Internalizing Problems ($p < 0.001$; r = 1.000) and Externalizing Problems ($p = .010$; r = 0.758).

Syndrome scales showed significant reductions in Anxious/Depressed ($p = .006$; r = 0.808), Withdrawn/Depressed ($p = .009$; r = 1.000), Somatic Complaints ($p = .012$; r = 0.771), Social Problems ($p = .008$; r = 0.783), Thought Problems ($p = .005$; r = 0.890), Attention Problems ($p = .002$; r = 1.000), Rule-Breaking Behavior ($p = .003$; r = 0.895), and Aggressive Behavior ($p = .006$; r = 0.897).

Effect sizes ranged from large to very large across all domains, with the most pronounced effects observed for Withdrawn/Depressed, Attention Problems, and Internalizing Problems. Full statistical details, including mean differences, confidence intervals, and effect sizes, are presented in Table 5.4.

Table 5.4 Pre-Post Changes in CBCL 6-18 Total, Broadband, and Syndrome Scale Scores

CBCL 6-18 Scale T-Scores	**Pre Mean (SD)**	**Post Mean (SD)**	**Mean Difference**	**SE Difference**	**95% CI (Lower-Upper)**	***p*-value**	**Effect Size (r)**
Anxious/Depressed	63.5 (10.4)	60.9 (9.07)	2.50	0.719	1.50 – 4.00	.006*	0.808
Withdrawn/Depressed	63.3 (8.20)	60.4 (8.91)	5.00	0.790	3.00 – 7.00	.009*	1.000
Somatic Complaints	64.8 (7.61)	60.9 (6.22)	4.00	1.293	2.50 – 8.50	.012*	0.771
Social Problems	67.6 (8.99)	64.9 (8.92)	3.00	0.711	1.00 – 4.50	.008*	0.783
Thought Problems	71.3 (7.57)	68.7 (8.55)	2.50	0.866	1.50 – 5.00	.005*	0.890
Attention Problems	69.6 (10.5)	65.6 (8.70)	4.00	1.131	3.00 – 8.50	.002*	1.000
Rule-Breaking Behavior	61.9 (6.84)	58.9 (7.86)	3.50	0.766	2.00 – 5.00	.003*	0.895
Aggressive Behavior	57 (7.55)	55.1 (6.10)	1.50	0.785	1.00 – 4.50	.006*	0.897
Internalizing Problems	66.3 (8.90)	61.4 (10.6)	4.50	0.776	3.00 – 6.50	<.001*	1.000
Externalizing Problems	59.8 (9.17)	55.4 (11.3)	4.50	1.458	1.50 – 7.50	.010*	0.758
Total Problems	64.7 (6.92)	60.9 (10.9)	3.00	1.376	1.50 – 6.00	.005*	0.794

CBCL 6-18 = Child Behavior Checklist for Ages 6-18; SD = standard deviation; SE = standard error; CI = confidence interval. Effect sizes are reported as rank-biserial correlations. * $p < .05$.

5.6 Changes in Social Responsiveness

Pre-post analyses showed significant improvements across all SRS-2 domains. In particular, a significant reduction in the Total T-score (p = .001; r = 1.000) indicated a very large effect on overall social responsiveness.

At the subscale level, statistically significant reductions were observed in Social Awareness (p = .002; r = 0.943), Social Cognition (p < .001; r = 1.000), Social Communication (p = .001; r = 0.971), Social Motivation (p = .002; r = 1.000), Restricted Interests and Repetitive Behavior (p = .001; r = 0.942), and in the Social Communication and Interaction domain (p = .002; r = 1.000).

Effect sizes ranged from large to very large across all domains, with the most pronounced effects observed in Social Cognition, Social Motivation, and the SCI composite. Full statistical details are reported in Table 5.5.

Table 5.5 Pre-Post Changes in SRS-2 Total and Subscale Scores

SRS-2 Scale T-scores	Pre Mean (SD)	Post Mean (SD)	Mean Difference	SE Difference	95% CI (Lower-Upper)	*p*-value	Effect Size (r)
Social Awareness	73.9 (11.7)	69.2 (13.5)	5.00	1.094	3.50 – 7.00	.002	0.943
Social Cognition	78 (11.7)	75.1 (11.7)	3.00	0.539	2.00 – 4.00	< .001	1.000
Social Communication	73.1 (13.2)	69.9 (14.2)	3.00	1.019	2.00 – 4.50	.001	0.971
Social Motivation	71.3 (13.8)	66.8 (14)	4.36	1.508	2.00 – 10.50	.002	1.000
Restricted Interests and Repetitive Behavior	73.8 (13.3)	70.5 (14.4)	3.14	0.705	2.00 – 4.50	.001	0.942
Social Communication and Interaction	76.5 (12.6)	72.9 (13.6)	4.00	1.004	2.50 – 5.00	.002	1.000
Total	76.7 (12.1)	72.8 (13.6)	4.00	0.983	3.00 – 5.00	.001	1.000

SRS-2 = Social Responsiveness Scale, 2nd Edition; SD = standard deviation; SE = standard error; CI = confidence interval. Effect sizes are reported as rank-biserial correlations. * p < .05.

5.7 Changes in Adaptive Functioning

Significant pre-post improvements were observed in adaptive functioning, as measured by the ABAS-II. A statistically significant increase was found in the Global Adaptive Composite (GAC) score (p = .004; r = –0.824), with large effects.

At the domain level, significant pre-post increases were observed in both the Conceptual (p = .010; r = –0.790) and Social (p = .002; r = –0.882) domains. No significant change was found in the Practical domain (p = .187; r = –0.410). Effect sizes ranged from moderate to large across the significant domains, with the strongest effect in the Social domain. Full statistical details, including mean differences, standard errors, confidence intervals, and effect sizes, are presented in Table 5.6.

Table 5.6 Pre-Post Changes in ABAS-II Total and Domain Scores

ABAS-II Scale Standard Scores	Pre Mean (SD)	Post Mean (SD)	Mean Difference	SE Difference	95% CI (Lower-Upper)	*p*-value	Effect Size (r)
Conceptual	80.5 (16.3)	85.8 (13.9)	-5.00	1.799	-10.00 – -1.50	.010	-0.790
Social	79.9 (10.8)	84.8 (9.39)	-5.00	1.076	-7.50 – -2.00	.002	-0.882
Practical	81.6 (18.2)	82 (12.6)	-2.50	2.927	-7.00 – 4.00	.187	-0.410
GAC	76.9 (12.6)	80.6 (12.1)	-3.00	1.059	-6.00 – -1.50	.004	-0.824

ABAS-II = Adaptive Behavior Assessment System, 2nd Edition; SD = standard deviation; SE = standard error; CI = confidence interval; GAC = Global Adaptive Composite. Effect sizes are reported as rank-biserial correlations. Negative mean differences and effect sizes reflect higher post-intervention scores (improvement). * $p < .05$.

5.8 Clinically Significant Change

To assess the clinical relevance of the observed changes, we examined the number and percentage of participants who showed a clinically significant improvement across sensory, emotional-behavioral, social, and adaptive functioning domains. Clinically significant change was defined as a shift from the clinical to the non-clinical range on standardized outcome measures, based on established cut-off scores from each instrument's manual.

For sensory processing, the most notable improvements were observed in SPM Body Awareness (50.0% of clinically affected participants improved), Social Participation (44.4%), and both Vision and Hearing (33.3% each).

In terms of behavioral and emotional functioning, substantial changes were observed for CBCL 6-18 Somatic Complaints, where all participants who were in the clinical range at baseline improved post-intervention (100.0%), and for Social Problems, Attention Problems, Rule-Breaking Behavior and Total Problems, with improvements in 33.3% of cases.

Regarding adaptive functioning (ABAS-II), the Social domain showed the highest rate of clinically significant improvement (100.0%) followed by the Practical (50.0%) and conceptual domains. A detailed summary of clinically significant changes across all outcome measures is presented in Table 5.7.

Table 5.7 Clinically Significant Change from Pre- to Post-Intervention Across Outcome Domains

Outcome Measure	N in Clinical Range at Pre-Intervention	N Improved Post-Intervention	% Improved
SPM SOC	9	4	44.4
SPM VIS	6	2	33.3
SPM HEA	6	2	33.3
SPM TOU	6	1	16.7
SPM BOD	2	1	50.0
SPM BAL	3	0	0.0
SPM PLA	6	1	16.7
SPM TOT	6	0	0.0

CBCL 6-18 - Anxious/Depressed	5	1	20.0
CBCL 6-18 - Withdrawn/Depressed	4	1	25.0
CBCL 6-18 - Somatic Complaints	4	4	100.0
CBCL 6-18 - Social Problems	6	2	33.3
CBCL 6-18 - Thought Problems	11	2	18.2
CBCL 6-18 - Attention Problems	9	3	33.3
CBCL 6-18 - Rule-Breaking Behavior	3	1	33.3
CBCL 6-18 - Aggressive Behavior	1	0	0.0
CBCL 6-18 - Internalizing Problems	10	2	20.0
CBCL 6-18 - Externalizing Problems	5	0	0.0
CBCL 6-18 - Total Problems	9	2	22.2
SRS-2 TOT	13	1	7.7
ABAS-II - Conceptual	6	2	33.3
ABAS-II - Social	3	3	100.0
ABAS-II - Practical	4	2	50.0
ABAS-II - GAC	5	1	20.0

SPM = Sensory Processing Measure; SOC = social participation; VIS = vision; HEA = hearing; TOU = touch; BOD = body awareness; BAL = balance and motion; PLA = planning and ideas; TOT = total sensory score; CBCL 6-18 = Child Behavior Checklist for Ages 6-18; SRS-2 = Social Responsiveness Scale, 2nd Edition; ABAS-II = Adaptive Behavior Assessment System, 2nd Edition; GAC = Global Adaptive Composite.

5.9 Supplementary Parametric Analyses and Standardized Effect Sizes

Given the small sample size and non-normal distribution observed for several variables, the primary analyses were conducted using non-parametric Wilcoxon signed-rank tests. However, to facilitate comparison with previous literature and to provide standardized effect size estimates, exploratory paired-sample t-tests were also performed for each outcome measure to calculate standardized effect sizes (Cohen's d).

Overall, the results of the paired t- largely mirrored those obtained from the Wilcoxon signed-rank test findings, confirming statistically significant pre-post changes across most outcome domains. Cohen's d effect sizes ranged from small to very large, with the strongest effects observed for internalizing symptoms, social responsiveness, and adaptive functioning domains.

These analyses are intended for descriptive and comparative purposes only and should be interpreted with caution, given the pilot nature of the study and the limited statistical power associated with the small sample size.

Full results of these supplementary parametric analyses, including t-values, degrees of freedom, *p*-values, mean differences, and Cohen's d values for each scale and subscale, are reported in Appendix Table A2.

5.10 Associations Between Pre–Post Changes in Outcome Measures

Spearman's rank-order correlations were conducted to explore associations between pre–post change scores across sensory processing, emotional-behavioral functioning, social responsiveness, and adaptive functioning domains. Table 5.8 presents all statistically significant correlations ($p < .05$).

Positive associations emerged between changes in sensory processing and improvements in social responsiveness, particularly in the domains of Social Communication and Interaction, Social Motivation, Social Awareness, and Restricted Interests and Repetitive Behaviors as measured by the SRS-2. Specifically, changes in auditory processing (Δ SPM HEA), visual processing (Δ SPM VIS), and social participation (Δ SPM SOC) were significantly correlated with multiple SRS-2 subscales.

Regarding emotional and behavioral functioning, changes in CBCL 6-18 Total Problems and specific CBCL 6-18 subscales (e.g., Aggressive Behavior, Rule-Breaking Behavior, Attention Problems) were significantly associated with changes in both sensory processing domains and social responsiveness dimensions. For example, changes in social participation and visual processing showed significant correlations with CBCL 6-18 Aggressive Behavior, while changes in tactile processing (Δ SPM TOU) were negatively associated with CBCL 6-18 Withdrawn/Depressed scores.

Furthermore, improvements in adaptive functioning as measured by the ABAS-II (particularly the Social, Conceptual, and GAC domains) were significantly associated with reductions in CBCL 6-18 Internalizing Problems and Somatic Complaints.

Given the exploratory nature of these analyses and the absence of correction for multiple comparisons, findings should be interpreted with caution and considered preliminary.

Table 5.8 Significant Associations Between Pre–Post Changes Across Outcome Measures

Variables	**Spearman ρ**	***p*-value**
Δ SPM SOC – Δ SRS-2 Social Communication	0.595	.015
Δ SPM SOC – Δ SRS-2 Social Motivation	0.548	.028
Δ SPM SOC – Δ SRS-2 Social Communication and Interaction	0.556	.025
Δ SPM VIS – Δ SRS-2 Social Awareness	0.571	.021
Δ SPM VIS – Δ SRS-2 Social Communication	0.520	.039
Δ SPM VIS –	0.507	.045

Δ SRS-2 Social Communication and Interaction		
Δ SPM HEA – Δ SRS-2 Social Communication	0.530	.035
Δ SPM HEA – Δ SRS-2 Social Motivation	0.587	.017
Δ SPM HEA – Δ SRS-2 Restricted Interests and Repetitive Behaviors	0.607	.013
Δ SPM HEA – Δ SRS-2 Social Communication and Interaction	0.576	.019
Δ SPM HEA – Δ SRS-2 Total	0.564	.023
Δ SPM SOC – Δ CBCL 6-18 Rule-Breaking Behavior	0.554	.026
Δ SPM SOC – Δ CBCL 6-18 Aggressive Behavior	0.589	.016
Δ SPM VIS – Δ CBCL 6-18 Aggressive Behavior	0.502	.048
Δ SPM HEA – Δ CBCL 6-18 Total	0.739	.001
Δ SPM TOU – Δ CBCL 6-18 Withdrawn/Depressed	-0.552	.027
Δ SPM BOD – Δ CBCL 6-18 Aggressive Behavior	0.695	.003
Δ SPM BAL – Δ CBCL 6-18 Externalizing Problems	0.547	.028
Δ CBCL 6-18 Thought Problems – Δ SRS-2 Social Awareness	0.498	.049
Δ CBCL 6-18 Attention – Δ SRS-2 Restricted Interests and Repetitive Behaviors	-0.628	.009
Δ CBCL 6-18 Rule-Breaking Behavior – Δ SRS-2 Social Communication	0.513	.042
Δ CBCL 6-18 Aggressive Behavior – Δ SRS-2 Social Communication	0.513	.042
Δ CBCL 6-18 Total – Δ SRS-2 Social Awareness	0.530	.035
Δ CBCL 6-18 Total – Δ SRS-2 Restricted Interests and Repetitive Behaviors	0.589	.016
Δ CBCL 6-18 Total – Δ SRS-2 Total	0.499	.049
Δ ABAS-II Conceptual – Δ CBCL 6-18 Somatic Complaints	0.530	.035
Δ ABAS-II Social – Δ CBCL 6-18 Attention Problems	0.527	.036
Δ ABAS-II Social – Δ CBCL 6-18 Internalizing Problems	0.775	<.001
Δ ABAS-II GAC – Δ CBCL 6-18 Internalizing Problems	0.640	.008

SPM = Sensory Processing Measure; SOC = social participation; VIS = vision; HEA = hearing; TOU = touch; BOD = body awareness; BAL = balance and motion; CBCL 6-18 = Child Behavior Checklist for Ages 6-18; SRS-2 = Social Responsiveness Scale, 2nd Edition; ABAS-II = Adaptive Behavior Assessment System, 2nd Edition; GAC = Global Adaptive Composite. Only statistically significant correlations ($p < .05$) are reported.

5.11 Exploratory Observations on Participants Completing Two Intervention Cycles

As previously noted, four children participated in two separate cycles of the "Growing in Nature" intervention. To preserve data independence, only data from their first participation were included in the primary analyses. However, for exploratory purposes, we examined changes in sensory processing, emotional-behavioral functioning, social responsiveness, and adaptive skills across both cycles for these participants.

During the first intervention cycle (T1 to T2), all four children showed at least some improvement in one or more outcome domains. Notable changes included reductions in CBCL 6-18 Total Problems for two participants and increases in ABAS-II GAC scores for three out of four children.

Following the second intervention cycle (T2 to T3), further improvements were observed in multiple domains. Specifically:

- Two children showed additional reductions in SPM Total Sensory Scores, suggesting decreased sensory processing difficulties.
- One participant exhibited further reductions in CBCL 6-18 Total Problems, and two children demonstrated small but notable gains in adaptive functioning (ABAS-II GAC).
- However, no consistent additional changes were observed in SRS-2 Total Scores across the four participants following the second cycle.

Overall, while these data should be interpreted with extreme caution due to the small sample size and absence of a control condition, the observed patterns suggest that some participants may derive incremental benefits from repeated exposure to the nature-based intervention, particularly in sensory and adaptive domains. Further controlled studies with larger samples are needed to systematically evaluate the potential cumulative effects of multiple intervention cycles.

CHAPTER 6 – DISCUSSION AND CONCLUSIONS

6.1 Summary of Key Findings

The present pilot study aimed to evaluate the short-term effects of the nature-based intervention “Growing in Nature” on multiple functional domains in children with ASD. Based on pre- and post-intervention assessments, statistically and clinically meaningful changes were observed across sensory processing, emotional-behavioral functioning, social responsiveness, and adaptive skills.

In the sensory domain, children exhibited reduced sensory difficulties, both at the total score level and across specific SPM subscales, with the most pronounced improvements observed in Social Participation, Vision, Hearing, and Touch.

Emotional and behavioral functioning, assessed by the CBCL 6-18, showed significant reductions in Total Problems, Internalizing, and Externalizing symptoms, with moderate-to-large effect sizes. Improvements were also evident across multiple syndrome scales, notably in Anxious/Depressed, Withdrawn/Depressed, Thought Problems, Rule-Breaking Behavior and Aggressive Behavior.

Social responsiveness, measured by the SRS-2, demonstrated significant enhancements across all domains, with large to very large effect sizes consistently observed. Adaptive functioning, as assessed with the ABAS-II, also improved significantly in the Global Adaptive Composite, as well as in the Conceptual and Social domains, with moderate-to-large effect sizes.

Beyond these domain-specific improvements, significant cross-domain associations emerged between sensory, behavioral, social, and adaptive changes. Notably, improvements in sensory processing were positively associated with reductions in emotional-behavioral problems and with enhancements in social responsiveness. In particular, changes in SPM Vision and Hearing, as well as in Social Participation, were significantly correlated with improvements in several SRS-2 subscales. Furthermore, reductions in behavioral problems, including aggressive behavior and attention difficulties, were significantly associated with gains in both adaptive functioning (ABAS-II) and social responsiveness (SRS-2).

Finally, clinically significant changes were documented for a proportion of participants across all outcome domains, with the most significant improvements observed in somatic complaints, social functioning, and specific dimensions of sensory processing.

6.2 Interpretation of Multidimensional Outcomes

The findings of this pilot study highlight multidimensional improvements across sensory processing, emotional-behavioral functioning, social responsiveness, and adaptive skills following participation in a structured nature-based intervention for children with ASD. This pattern of change aligns with emerging evidence on the therapeutic potential of nature-based interventions in pediatric populations with neurodevelopmental difficulties.

The observed improvements in sensory processing, particularly in the SPM domains of Social Participation, Vision, Hearing, and Touch, are consistent with previous research suggesting that natural environments may promote adaptive sensory modulation, offering rich, low-threat, and predictable multisensory stimuli (Dettweiler et al., 2017; Mårtensson et al., 2009; Mygind et al., 2019). The affordances theoretical framework (Gibson, 1979), widely applied in environmental and developmental psychology, provides a useful lens to interpret these findings. Natural settings provide a wide range of sensory opportunities that encourage active engagement and facilitate gradual exposure to diverse sensory input (Chawla, 2015; Mygind et al., 2019), a mechanism particularly relevant for children with ASD who often experience heightened sensory sensitivity (Robertson & Baron-Cohen, 2017). This exposure likely promoted habituation processes and improved children's ability to modulate sensory input more effectively.

These findings align with emerging intervention studies suggesting that nature-based interventions may improve sensory processing in children with ASD. For example, Ramshini et al. (2018) reported significant post-intervention improvements in sensory modulation following a family-centered nature-based therapy program for children with ASD. Similarly, a recent systematic review and meta-analysis by Fan et al. (2023) identified sensory processing as one of the key domains showing significant improvement after participation in nature-based interventions, along with gains in behavioral and social functioning.

The particularly significant improvements observed in social participation in the current study may reflect the unique combination of social and sensory affordances inherent in outdoor, group-based activities, where children engage in shared, goal-directed tasks within low-demand, flexible, and multisensory environments.

Finally, the present results further support existing literature on the close relationship between sensory processing and emotional-behavioral regulation in ASD, suggesting that improved sensory modulation may have contributed to broader functional gains observed across emotional, social, and adaptive domains (Green et al., 2015; Carpenter et al., 2019; Ben-Sasson et al., 2009).

Beyond sensory changes, significant reductions were observed in emotional and behavioral difficulties, as measured by the CBCL 6-18, including Total Problems, Internalizing Problems, and Externalizing Problems, as well as specific syndrome scales such as Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Rule-Breaking Behavior, and Aggressive Behavior, suggest a broad-based impact on emotional and behavioral regulation. These findings align with theoretical models such as the Stress Recovery Theory (Ulrich, 1991) and the Attention Restoration Theory (Kaplan & Kaplan, 1989), both of which posit that exposure to natural environments facilitates reductions in psychophysiological stress, improved mood, and greater attentional control. The low-demand, multisensory, and restorative characteristics of natural environments may have contributed to the reduction of emotional distress and behavioral dysregulation, mechanisms that are especially relevant for children with ASD, who are often vulnerable to heightened stress reactivity and difficulties in emotional self-regulation (Green & Ben-Sasson, 2010; Carpenter et al., 2019).

Empirical research supports these mechanisms. For example, studies on outdoor education and green schoolyards have reported reduced behavioral problems and improved psychological well-being among children exposed to nature-rich environments (Dettweiler et al., 2017; Mårtensson et al., 2009; Van den Berg et al., 2016). Furthermore, exposure to green spaces has been associated with lower rates of emotional and behavioral problems in childhood, as highlighted by evidence from experimental and epidemiological studies on the mental health benefits of nature exposure (Bratman et al., 2019).

Another possible explanatory pathway involves the observed improvements in sensory processing, documented in the current study. Given the well-established link between sensory overresponsivity and emotional dysregulation in ASD (Green & Ben-Sasson, 2010; Carpenter et al., 2019; Ben-Sasson et al., 2009), it is plausible that the modulation of sensory difficulties contributed to improved emotional regulation and reduction of behavioral symptoms.

Overall, these findings provide further preliminary support for the potential of nature-based interventions to reduce both internalizing and externalizing symptoms in children with ASD, through mechanisms likely involving stress reduction, sensory modulation, and improved attentional and emotional self-regulation.

The intervention also yielded substantial improvements in social responsiveness, as measured by the SRS-2, with large effect sizes across all domains. This finding is consistent with literature suggesting that natural settings may provide unique opportunities to encourage peer interaction, joint attention, and cooperative play (Chawla, 2015; Mygind et al., 2019; Dettweiler et al., 2017). Furthermore, for children with ASD, who often experience difficulties with social communication and motivation (Green & Ben-Sasson, 2010; Carpenter et al., 2019), the reduction in sensory overload and emotional distress observed in this study may have further facilitated social engagement, consistent with theoretical models linking sensory modulation and emotional regulation to social functioning (Ben-Sasson et al., 2009; MacLennan et al., 2020).

In terms of adaptive functioning, significant improvements were observed in the Global Adaptive Composite, as well as in the Conceptual and Social domains of the ABAS-II. This finding aligns with previous research suggesting that naturalistic settings can enhance children's real-world functional competencies, including communication and daily living skills (Mittly et al., 2023). Furthermore, consistent with previous research, engagement in outdoor, hands-on activities may improve executive functioning, behavioral flexibility, and goal-directed behavior (Taylor & Kuo, 2009; Mygind et al., 2019). Such mechanisms may help explain the observed improvements in the Conceptual and Social domains of adaptive functioning.

These findings are particularly encouraging, as adaptive skills represent generalizable and real-world skills that cut across sensory, emotional, and social domains. The observed adaptive gains may reflect the cumulative impact of improvements across multiple functional areas, suggesting a potential for broad developmental benefits following nature-based interventions.

Importantly, the significant cross-domain associations observed in this study reinforce the interconnected nature of sensory, emotional, social, and adaptive functioning in children with ASD. Consistent with dimensional and transdiagnostic models (Astle & Fletcher-Watson, 2020), improvements in one domain appeared to influence others, suggesting synergistic effects across functional areas.

Taken together, these multidimensional outcomes contribute to the growing evidence base supporting the feasibility and potential effectiveness of nature-based interventions in children with ASD across multiple outcome domains, including sensory processing, behavioral regulation, social functioning, and adaptive skills (Fan et al., 2023). They also underscore the relevance of incorporating naturalistic, ecologically grounded interventions into therapeutic planning for children with ASD.

6.3 Strengths and Limitations of the Study

This pilot study presents several methodological strengths that enhance the credibility and relevance of the findings, while also acknowledging important limitations that must be considered when interpreting the results.

6.3.1 Strengths

A key strength of the study lies in its multidimensional assessment approach, encompassing sensory processing, emotional-behavioral functioning, social responsiveness, and adaptive skills. This comprehensive battery allowed for an integrated evaluation of intervention effects across multiple functional domains central to ASD. Furthermore, the use of standardized and psychometrically validated instruments (e.g., SPM, CBCL 6-18, SRS-2, ABAS-II) strengthens the methodological quality of the study by providing reliable and valid assessments across multiple functional domains. This approach aligns with current recommendations for the evaluation of complex interventions in neurodevelopmental populations.

Another important strength is the ecological validity of the intervention setting. By delivering the program in natural outdoor environments, the study reflects real-world contexts that are relevant for future implementation in educational, therapeutic, and community-based settings.

Moreover, the inclusion of pre-post assessments, combined with both non-parametric and parametric analyses (including effect size estimation), provides a robust and transparent examination of intervention effects despite the small sample size. The supplementary calculation of Cohen's d allows for cross-study comparisons and situates the current findings within the broader field of intervention research.

Finally, the study adopted a multi-informant perspective, relying on caregiver-reported outcomes across all domains. This approach captures the child's functioning in naturalistic, everyday contexts, providing ecologically valid insights into the impact of the intervention.

6.3.2 Limitations

Despite these strengths, several limitations must be acknowledged. First and foremost, the small sample size (N = 16) limits the statistical power of the analyses and raises concerns about the generalizability of the findings. The lack of a control or comparison group further constrains causal interpretations, as observed improvements may reflect non-specific factors such as maturation, regression to the mean, or placebo effects.

Second, the short duration of the intervention and the absence of long-term follow-up preclude conclusions about the maintenance of observed gains over time. Future studies integrating longitudinal assessments would help clarify the durability of intervention effects.

Third, the reliance on parent-reported measures introduces the possibility of reporting bias, particularly given the non-blinded nature of the assessments. Although caregiver reports offer valuable insights into children's daily functioning, future research should integrate multi-method approaches, including direct behavioral observations or physiological measures, to strengthen data validity.

Another limitation concerns the heterogeneity of the sample in terms of age, cognitive functioning, and autism symptom severity. While reflecting clinical reality, this variability may have introduced uncontrolled confounding effects.

Finally, the use of multiple statistical tests without correction for multiple comparisons increases the risk of Type I error, especially in exploratory correlation analyses. Although such exploratory analyses provide valuable preliminary insights, the findings should be interpreted with due caution.

6.4 Innovative Contribution, Clinical and Theoretical Implications

The findings of this pilot study offer preliminary but meaningful insights with important clinical and theoretical implications for the management of children with ASD. To our knowledge, this is among the first Italian pilot studies to systematically examine the effects of a structured nature-based intervention on sensory processing, emotional-behavioral functioning, social responsiveness, and adaptive skills in school-aged children with ASD using a comprehensive set of standardized outcome measures.

From a clinical perspective, the observed multidimensional improvements suggest that nature-based interventions could represent a feasible and ecologically valid adjunct to conventional treatment approaches, such as behavioral therapy, occupational therapy, or social skills training. The ability of nature-based interventions to simultaneously address sensory modulation, emotional regulation, social responsiveness, and adaptive functioning aligns with the need for holistic and integrative intervention models in ASD care.

Furthermore, the outdoor, low-demand, and multisensory nature of the intervention setting may provide a more accessible and engaging therapeutic context for children who struggle in conventional clinical settings, particularly those with co-occurring sensory processing difficulties, who may perceive these settings as overstimulating or aversive (Robertson & Baron-Cohen, 2017; Mygind et al., 2019).

From a social developmental perspective, the study provides preliminary support for the use of outdoor group-based activities to promote social responsiveness in children with ASD. Given the intervention's ability to foster spontaneous peer interactions and collaborative problem-solving, such programs may be particularly valuable for children with ASD who exhibit limited social motivation or communication skills.

Theoretically, the findings contribute to emerging models emphasizing the interplay between sensory processing, emotional regulation, and social-adaptive functioning in ASD (Green & Ben-Sasson, 2010; MacLennan et al., 2020). The significant associations observed between sensory improvements and gains in social and adaptive domains suggest that sensory modulation may act as a key mediator of broader functional change.

Furthermore, the study highlights the relevance of ecological and embodied approaches to intervention. Unlike traditional clinic-based models, nature-based interventions intrinsically integrate sensory, motor, emotional, and social experiences, offering a unique platform for holistic developmental support (Bratman et al., 2019; Chawla, 2015).

These preliminary findings underscore the importance of considering naturalistic, context-sensitive interventions in clinical practice and point to the value of further developing evidence-based guidelines for the implementation of nature-based interventions in ASD treatment planning.

6.5 Directions for Future Research

Given the pilot nature of this study, several important directions for future research emerge to further clarify the effectiveness, mechanisms, and applicability of nature-based interventions for children with ASD.

First, there is a clear need for larger, adequately powered trials, ideally employing randomized controlled designs (RCTs), to confirm the preliminary findings and to establish causal relationships between intervention participation and observed outcomes. Including control groups (e.g., waitlist or active control) or comparing nature-based interventions to other established therapeutic modalities would enhance internal validity and allow for stronger effectiveness claims.

Second, future research should include longitudinal follow-up assessments to evaluate the sustainability of treatment effects over time. Understanding whether improvements in sensory processing, emotional regulation, social functioning, and adaptive behavior persist after the end of the intervention is essential to inform clinical practice.

Third, investigations into the mechanisms of change are warranted. Multimodal assessment strategies, including physiological indicators of stress (e.g., cortisol levels, heart rate variability), observational measures of behavior, and direct assessments of executive functioning, may help identify the underlying processes driving the observed improvements.

In addition, moderator analyses examining individual child characteristics - such as baseline sensory profiles, cognitive functioning, or autism severity - could help identify which children are most likely to benefit from nature-based interventions, consistent with current trends in individualized and targeted care for neurodevelopmental disorders.

Future studies should also explore the potential dose-response relationship, investigating whether longer or more intensive exposure to nature-based programs leads to greater or more sustained benefits. Furthermore, examining the impact of different types of nature-based activities (e.g., horticultural therapy, forest bathing, adventure-based learning) may help clarify which intervention modalities are most effective for specific ASD profiles.

Finally, given the importance of ecological validity, research should explore the feasibility and effectiveness of integrating nature-based interventions into school settings, community programs, and outpatient clinical services, thereby increasing their access and scalability. By addressing these methodological and conceptual gaps, future research may advance the field toward evidence-based guidelines for the implementation of nature-based interventions in the care of children with ASD.

6.6 Conclusions

This pilot study provides preliminary evidence supporting the feasibility and potential effectiveness of nature-based interventions in improving sensory processing, emotional-behavioral functioning, social responsiveness, and adaptive skills in children with ASD. Participation in the "Growing in Nature" program was associated with statistically significant and clinically meaningful changes across multiple domains, with moderate-to-large effect sizes observed for most outcomes.

Importantly, the findings highlight the interconnected nature of sensory, emotional, social, and adaptive functioning in ASD, suggesting that improvements in one domain may facilitate positive changes in others. The observed cross-domain associations emphasize the value of adopting holistic, multidimensional intervention models that address the complex and interrelated challenges faced by children with ASD.

Although these findings are promising, the methodological limitations of the study, including the small sample size, lack of a control group, and short-term follow-up, underscore the need for caution in interpreting the results. These limitations also highlight essential directions for future research, including the need for larger randomized controlled trials, longitudinal follow-up assessments, and investigations into mechanisms of change and moderators of treatment response.

Despite these constraints, the present study offers valuable preliminary support for the inclusion of nature-based interventions within comprehensive intervention frameworks for children with ASD. By harnessing the therapeutic potential of natural environments, such programs may provide an engaging, accessible, and developmentally supportive context to promote sensory modulation, emotional regulation, social engagement, and adaptive functioning in this population.

In conclusion, this study contributes to the growing body of evidence advocating for holistic, ecologically valid interventions in ASD care and lays the groundwork for more rigorous future research aimed at optimizing therapeutic outcomes for children with autism.

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APPENDIX – Supplementary Statistical Tables

Table A1 Significant Cross-Domain Spearman Correlations at Baseline ($p < .05$)

Variable 1	Variable 2	Spearman ρ	*p*-value
SPM SOC	ABAS-II GAC	-0.662	.005
SPM SOC	ABAS-II CON	-0.498	.05
SPM SOC	ABAS-II SOC	-0.701	.002
SPM SOC	ABAS-II PRA	-0.725	.001
SPM SOC	SRS-2 Social Awareness	0.551	.027
SPM SOC	SRS-2 Social Cognition	0.561	.024
SPM SOC	SRS-2 Social Communication	0.58	.018
SPM SOC	SRS-2 Social Motivation	0.586	.017
SPM SOC	SRS-2 Restricted Interests and Repetitive Behavior	0.677	.004
SPM SOC	SRS-2 Social Communication and Interaction	0.618	.011
SPM SOC	SRS-2 Total	0.629	.009
SPM VIS	SRS-2 Social Communication	0.512	.042
SPM VIS	SRS-2 Social Motivation	0.512	.043
SPM VIS	SRS-2 Restricted Interests and Repetitive Behavior	0.598	.014
SPM VIS	SRS-2 Total	0.504	.046
SPM HEA	SRS-2 Restricted Interests and Repetitive Behavior	0.506	.046
SPM BOD	CBCL 6-18 Social Problems	0.59	.016
SPM BOD	SRS-2 Social Motivation	0.52	.039
SPM BOD	SRS-2 Restricted Interests and Repetitive Behavior	0.596	.015
SPM BOD	SRS-2 Total	0.538	.032
SPM BAL	SRS-2 Total	0.502	.048
SPM PLA	SRS-2 Social Cognition	0.626	.01
SPM PLA	SRS-2 Social Communication	0.521	.039
SPM PLA	SRS-2 Restricted Interests and Repetitive Behavior	0.557	.025
SPM PLA	SRS-2 Social Communication and Interaction	0.555	.026
SPM PLA	SRS-2 Total	0.592	.016
SPM TOT	SRS-2 Social Cognition	0.525	.037
SPM TOT	SRS-2 Social Communication	0.507	.045
SPM TOT	SRS-2 Restricted Interests and Repetitive Behavior	0.567	.022
SPM TOT	SRS-2 Social Communication and Interaction	0.527	.036
SPM TOT	SRS-2 Total	0.568	.022
ABAS-II GAC	SRS-2 Social Cognition	-0.674	.004
ABAS-II GAC	SRS-2 Social Communication	-0.56	.024
ABAS-II GAC	SRS-2 Social Motivation	-0.554	.026
ABAS-II GAC	SRS-2 Restricted Interests and Repetitive Behavior	-0.498	.05
ABAS-II GAC	SRS-2 Social Communication and Interaction	-0.622	.01
ABAS-II GAC	SRS-2 Total	-0.592	.016
ABAS-II CON	SRS-2 Social Cognition	-0.576	.02
ABAS-II CON	SRS-2 Social Communication and Interaction	-0.517	.04
ABAS-II SOC	SRS-2 Social Awareness	-0.807	.0
ABAS-II SOC	SRS-2 Social Cognition	-0.559	.024
ABAS-II SOC	SRS-2 Social Communication	-0.636	.008
ABAS-II SOC	SRS-2 Social Motivation	-0.667	.005
ABAS-II SOC	SRS-2 Social Communication and Interaction	-0.686	.003
ABAS-II SOC	SRS-2 Total	-0.624	.01
CBCL 6-18 Anxious/Depressed	SRS-2 Restricted Interests and Repetitive Behavior	0.503	.047
CBCL 6-18 Withdrawn/Depressed	SRS-2 Social Communication	0.502	.047
CBCL 6-18 Withdrawn/Depressed	SRS-2 Social Motivation	0.656	.006
CBCL 6-18 Withdrawn/Depressed	SRS-2 Restricted Interests and Repetitive Behavior	0.534	.033
CBCL 6-18 Withdrawn/Depressed	SRS-2 Total	0.564	.023
CBCL 6-18 Somatic Complaints	SRS-2 Social Motivation	0.528	.036
CBCL 6-18 Social Problems	SRS-2 Social Motivation	0.614	.011
CBCL 6-18 Thought Problems	SRS-2 Social Communication	0.572	.021
CBCL 6-18 Thought Problems	SRS-2 Social Motivation	0.531	.034

CBCL 6-18 Thought Problems	SRS-2 Social Communication and Interaction	0.563	.023
CBCL 6-18 Thought Problems	SRS-2 Total	0.53	.035
CBCL 6-18 Internalizing Problems	SRS-2 Social Motivation	0.645	.007
CBCL 6-18 Internalizing Problems	SRS-2 Restricted Interests and Repetitive Behavior	0.554	.026
CBCL 6-18 Internalizing Problems	SRS-2 Total	0.532	.034
CBCL 6-18 Externalizing Problems	SRS-2 Social Cognition	0.532	.034
CBCL 6-18 Total Problems	SRS-2 Social Motivation	0.504	.047
CBCL 6-18 Total Problems	SRS-2 Restricted Interests and Repetitive Behavior	0.521	.039

SPM = Sensory Processing Measure; SOC = social participation; VIS = vision; HEA = hearing; BOD = body awareness; PLA = planning and ideas; TOT = total sensory score; CBCL 6-18 = Child Behavior Checklist for Ages 6-18; SRS-2 = Social Responsiveness Scale, 2nd Edition; ABAS-II = Adaptive Behavior Assessment System, 2nd Edition; GAC = Global Adaptive Composite. Only statistically significant correlations ($p < .05$) are reported.

Table A2 Supplementary Paired-Sample t-Test Results and Cohen's d Effect Sizes for Pre-Post Changes

	t (df)	***p*-value**	**Mean Difference**	**Cohen's d**
SPM Domain				
SOC T-score	-2.87 (15)	.012*	-3.75	-0.72
VIS T-score	-3.68 (15)	.002*	-3.19	-0.92
HEA T-score	-2.99 (15)	.009*	-2.87	-0.75
TOU T-score	-2.86 (15)	.012*	-1.81	-0.71
TAS raw score	-1.93 (15)	.073	-1.06	-0.48
BOD T-score	-2.10 (15)	.053	-1.25	-0.52
BAL T-score	-2.41 (15)	.029*	-2.50	-0.60
PLA T-score	-1.47 (15)	.161	-1.56	-0.37
TOT T-score	-0.89 (15)	.385	-1.12	-0.22
CBCL 6-18 Scale				
Anxious/Depressed	-3.57 (15)	.003*	-2.56	-0.89
Withdrawn/Depressed	-3.64 (15)	.002*	-2.87	-0.91
Somatic Complaints	-3.05 (15)	.008*	-3.94	-0.76
Social Problems	-3.78 (15)	.002*	-2.69	-0.94
Thought Problems	-2.96 (15)	.010*	-2.56	-0.74
Attention Problems	-3.48 (15)	.003*	-3.94	-0.87
Rule-Breaking Behavior	-4.00 (15)	.001*	-3.06	-1.00
Aggressive Behavior	-2.39 (15)	.030*	-1.87	-0.60
Internalizing Problems	-6.20 (15)	<.001*	-4.81	-1.55
Externalizing Problems	-3.04 (15)	.008*	-4.44	-0.76
Total Problems	-2.77 (15)	.014*	-3.81	-0.69
SRS-2 Scale				
Social Awareness	-4.34 (15)	< .001*	-4.75	-1.09
Social Cognition	-5.33 (15)	< .001*	-2.87	-1.33
Social Communication	-3.19 (15)	.006*	-3.25	-0.80
Social Motivation	-2.98 (15)	.009*	-4.50	-0.74
Restricted Interests and Repetitive Behavior	-4.70 (15)	< .001*	-3.31	-1.17
Social Communication and Interaction	-3.61 (15)	.003*	-3.62	-0.90
Total	-3.94 (15)	.001*	-3.875	-0.98
ABAS-II Scale				
Conceptual	2.92 (15)	.011*	5.25	0.73
Social	4.53 (15)	< .001*	4.87	1.13
Practical	0.15 (15)	.883	0.44	0.04
GAC	3.54 (15)	.003*	3.75	0.88

SPM = Sensory Processing Measure; SOC = social participation; VIS = vision; HEA = hearing; TOU = touch; TAS = taste and smell; BOD = body awareness; BAL = balance and motion; PLA = planning and ideas; TOT = total sensory score; CBCL 6-18 = Child Behavior Checklist for Ages 6-18; SRS-2 = Social Responsiveness Scale, 2nd Edition; ABAS-II = Adaptive Behavior Assessment System, 2nd Edition; GAC = Global Adaptive Composite. Negative Cohen's d values indicate reductions in symptom scores (e.g., CBCL 6-18, SRS-2, SPM), reflecting improvement. Positive values indicate increases in adaptive functioning (e.g., ABAS-II), also reflecting improvement. * $p < .05$.

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