



Sensory processing in preterm preschoolers and its association with executive function



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ABSTRACT

Background: Symptoms of abnormal sensory processing have been related to preterm birth, but have not yet been studied specifically in preterm preschoolers. The degree of association between sensory processing and other domains is important for understanding the role of sensory processing symptoms in the development of preterm children.

Aims: To test two related hypotheses: (1) preterm preschoolers have more sensory processing symptoms than full term preschoolers and (2) sensory processing is associated with both executive function and adaptive function in preterm preschoolers.

Study design: Cross-sectional study.

Subjects: Preterm children (≤ 34 weeks of gestation; $n = 54$) and full term controls (≥ 37 weeks of gestation; $n = 73$) ages 3–5 years.

Outcome measures: Sensory processing was assessed with the Short Sensory Profile. Executive function was assessed with (1) parent ratings on the Behavior Rating Inventory of Executive Function – Preschool version and (2) a performance-based battery of tasks. Adaptive function was assessed with the Vineland Adaptive Behavior Scales-II.

Results: Preterm preschoolers showed significantly more sensory symptoms than full term controls. A higher percentage of preterm than full term preschoolers had elevated numbers of sensory symptoms (37% vs. 12%). Sensory symptoms in preterm preschoolers were associated with scores on executive function measures, but were not significantly associated with adaptive function.

Conclusions: Preterm preschoolers exhibited more sensory symptoms than full term controls. Preterm preschoolers with elevated numbers of sensory symptoms also showed executive function impairment. Future research should further examine whether sensory processing and executive function should be considered independent or overlapping constructs.

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1. Introduction

Sensory processing is the organization and interpretation of sensory stimuli from the body and surrounding environment. Symptoms of atypical sensory processing manifest as abnormal behavioral reactions in response to sensory stimulation. Behavioral reactions that are greater than expected are referred to as hypersensitivity; a child with hypersensitivity may respond negatively to bright lights or loud noises. Behavioral reactions that are less than expected are referred to as hyposensitivity; a child with hyposensitivity may have decreased awareness of pain or temperature [1]. Differences in sensory processing have been thought

to cause children to exhibit sensation-seeking or sensation-avoiding behaviors [1], both of which could interfere with normal functioning. No consensus has been reached on whether symptoms of sensory processing problems constitute a unique disorder, or whether they represent behavioral characteristics coinciding with other conditions. Although no formal definition or diagnosis of sensory processing problems has been widely accepted in the medical and psychological fields, sensory processing symptoms are commonly identified in a wide range of clinical populations using a diverse set of methodologies, including neurophysiological testing and behavioral questionnaires [2–6].

Children born preterm (< 34 weeks gestational age) have been documented to have deficits spanning numerous cognitive domains [7], though sensory processing within the preterm population has not been thoroughly investigated. Research to date has found elevated levels of sensory symptoms to be associated with premature birth [8–10], and has primarily focused on preterm infants and toddlers. Sensory differences in preterm and late preterm (34–36 weeks of gestation) infants have been found to be modest to substantial, measured through

Abbreviations: BRIEF-P, Behavior Rating Inventory of Executive Function – Preschool Version; PT + S, preterm children with elevated numbers of sensory symptoms; PT – S, preterm children with typical numbers of sensory symptoms; SSP, Short Sensory Profile.

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both behavioral questionnaires and interactive sensory exams [11–13]. A study of preterm toddlers found impaired sensory profile patterns across all sensory modalities on a parent-report measure, including behaviors such as sensation seeking, sensation avoiding, sensory sensitivity, and low registration [8]. Atypical sensory profiles were also observed in a broad age range of preterm infants and children, ranging from 1 to 8 years of age [9]. A study of 9-year-old preterm children found reduced electrophysiological responses to auditory stimuli compared to the responses of full term children [14]. To our knowledge, sensory processing has not been evaluated specifically in preterm preschoolers, though the preschool period is important for consolidating development in multiple domains including communication, social development, and pre-academic skills.

Elevated levels of sensory symptoms in preterm children could be attributable to several factors associated with preterm birth. First, abnormal sensory exposure in the neonatal intensive care unit (NICU) during the critical period of sensory neurodevelopment has been postulated to alter and impair neural structures essential to processing sensory information [15,16]. In addition, brain injury, including periventricular leukomalacia (PVL), periventricular hemorrhage (PVH), and accompanying widespread neural and axonal disease, could disrupt the normal functioning of the sensory systems or association areas, leaving the preterm child with extreme or diminished reactions to sensory stimuli [17]. Finally, abnormal sensory processing could be part of a larger symptom complex of neurodevelopmental conditions that affect the preterm population. Measures of sensory processing have been found to correlate with measures of cognition and language in preterm toddlers [18].

The relationship between sensory processing in preterm preschoolers and other domains potentially impacted by sensory processing, specifically executive function and adaptive function, has not been investigated. Deficits in executive function and adaptive function have been well documented in preterm preschoolers and children [7,19]. Executive function is a composite of skills involved in higher order and goal-directed thinking; it includes skills such as working memory, inhibition, and planning [20]. Sensory processing may be associated with executive function because sensory processing has been shown to be influenced by higher order cognitive control [21,22]. Adaptive function describes how a child functions within the environment, completes personal tasks, and demonstrates social skills necessary for success in daily life [23]. Sensory processing may be associated with adaptive function because adverse behavioral reactions to sensory stimuli have been hypothesized to interfere with a child's ability to efficiently or effectively perform age-appropriate functional skills [1].

Associations between atypical sensory processing and impairment in either executive function or adaptive function have been found in several other clinical populations [2,5,24,25]. Reduced auditory sensory gating has been found to coincide with poorer performance on executive function tasks in adults with autism [25] and Alzheimer's disease [24]. In toddlers with autism, sensory scores significantly predicted adaptive behavior scores, over and above the severity of autism symptoms [2]. Finally, in a study of children with Williams syndrome, children classified as having high sensory impairment had poorer scores on both executive function and adaptive function measures than children classified as having low sensory impairment [5].

1.1. Study aims and hypotheses

The first aim of the current study is to evaluate sensory processing in preschool-aged children born preterm. We hypothesized that preterm children have more symptoms of abnormal sensory processing than full term children, and that a higher proportion of preterm compared to full term children meet the criteria for having elevated numbers of sensory symptoms, as defined by classification from the Short Sensory Profile.

The second aim of the current study was to investigate the association between sensory processing and both executive function and adaptive function within the preterm sample. We hypothesized that preterm children with elevated numbers of sensory symptoms have poorer executive function and lower adaptive function than do preterm children with typical numbers of sensory symptoms.

2. Methods

2.1. Participants

Participants were recruited from Palo Alto, California, and the surrounding communities. Preterm children were specifically recruited by letters sent to the families of children who were evaluated at High Risk Infant Follow-up Services at Lucile Packard Children's Hospital in Palo Alto, California. Full term children were recruited by distributing flyers in general pediatric clinics. Both groups were also recruited by postings on local parent message boards and by word of mouth. The sample consisted of 127 children, with 54 preterm and 73 full term participants, ranging from 3 to 5 years of age ($M = 4.3$ years). Participants were born from 2004 to 2009. Inclusion criteria for the preterm group required gestational age of 34 weeks or less and birth weight under 2500 g. Inclusion for the full term group required gestational age of at least 37 weeks, birth weight of over 2500 g, and no major medical complications. Exclusion criteria for both preterm and full term participants were genetic disorders, congenital heart disease, and major neurosensory impairment (i.e. blind or deaf). Medical complications and results from neonatal head ultrasound/MRI for the preterm sample are reported in Table 1. Ethical approval for the study was granted by the Stanford University Institutional Review Board. Informed consent was obtained from a parent or guardian on behalf of the children, and participants were compensated for participation.

2.2. Procedure

Parents completed a demographic questionnaire and standardized rating scales on site to assess child sensory symptoms, executive function, and adaptive function. Children ranged from ages 3–5 years of age at the time of testing, and completed a battery of executive function tasks that were administered by trained research assistants at a standard study unit.

2.3. Outcome measures and variables

2.3.1. Demographics and health information

A demographic and health questionnaire addressed child age, sex, race (white vs. non-white), maternal education, and parent report of services, including occupational therapy (Table 1). Maternal education (<4 years in college, 4 years in college, ≥Master's degree) was used as an indicator of socioeconomic status (SES). Health information, collected from parents and medical record review, included gestational age at time of delivery, birth weight, brain injury, and medical complications, such as respiratory distress syndrome, chronic lung disease, and necrotizing enterocolitis.

2.3.2. Parent-completed rating scales

1. Short Sensory Profile (SSP) [26]. The SSP is a parent-rated questionnaire used to discriminate children with sensory processing differences from children with typical sensory processing. It consists of 38 items that are classified into seven subscales, and an overall composite measure of sensory processing. The subscales are Tactile Sensitivity, Taste/Smell Sensitivity, Movement Sensitivity, Underresponsive/Seeks Sensation, Auditory Filtering, Low Energy/Weak, and Visual/Auditory Sensitivity. For each item, the parent determines the likelihood of the child responding in the manner listed using a 5-point Likert scale, with "always" scored the lowest and "never" the highest.

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