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Sensory processing difficulties in school-age children born very preterm: An exploratory study

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ABSTRACT

Background: Very preterm birth has a detrimental impact on the developing brain, including widespread white matter brain abnormalities that threaten efficient sensory processing. Yet, sensory processing difficulties in very preterm children are scarcely studied, especially at school age.
Aims: To investigate somatosensory registration, multisensory integration and sensory modulation.
Participants: 57 very preterm school-age children (mean age = 9.2 years) were compared to 56 gender and age matched full-term children.
Methods: Group differences on somatosensory registration tasks (Registration of Light Touch, Sensory Discrimination of Touch, Position Sense, Graphestesia), a computerized multisensory integration task, and the parent-reported Sensory Profile were investigated using *t*-tests and Mann-Whitney *U* tests.
Results: In comparison to full-term children, very preterm children are less accurate on somatosensory registration tasks, including Registration of Light Touch (d = 0.34), Position Sense (d = 0.31) and Graphestesia (d = 0.42) and show more sensory modulation difficulties (d = 0.41), including both behavioral hyporesponsivity (d = 0.52) and hyperresponsivity (d = 0.56) to sensory stimuli. Tactile discrimination and multisensory integration efficiency were not affected in very preterm children. Aspects of sensory processing were only modestly related.
Conclusion: Very preterm children show sensory processing difficulties regarding somatosensory registration and sensory modulation, and preserved multisensory (audio-visual) integration. Follow-up care for very preterm children should involve screening of sensory processing difficulties at least up to school age.

1. Introduction

Worldwide, around 1.6 million children are born very preterm (< 32 weeks of gestation) each year [1]. An estimated 24% of very preterm children show neurodevelopmental impairments [1], including motor, cognitive and behavioral problems [2–5]. These functional impairments arise from the detrimental impact of very preterm birth on the developing brain, with widespread white matter abnormalities [6–8] that threaten the efficient processing of sensory information as a consequence [9]. The current study aims to elucidate the effects of very preterm birth on sensory processing at school age.

The neuropathology of very preterm birth is thought to be caused by a complex constellation of primary pathological mechanisms [10] and secondary harmful environmental influences related to treatment and stay at the neonatal intensive care unit (NICU) [8]. Very preterm infants tend to develop hypoxia-ischemia and inflammation, leading to damage to oligodendrocyte progenitors resulting in disrupted maturation of myelin forming oligodendrocytes and ultimately diffuse white matter damage and periventricular leucomalacia (PVL) [10–12]. In addition, environmental factors of the NICU further compromise normal brain development [8,13,14], through early exposure of the rapidly developing immature preterm brain to extra-uterine sensory experience [15–17]. More specifically, sensory overstimulation (e.g. bright lights, noise, nursery handling, repetitive pain) [18,19] may cause excitotoxic

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neural damage, while sensory understimulation (e.g. tactile, vestibular and kinesthetic deprivation due to parental separation during unavoidable stay in the incubator) is suggested to cause apoptotic damage [8,13,20,21].

Consistent with these findings, children born very preterm show deviant brain development as compared to their term born peers [17,22]. The available body of research has shown reduced brain volume [23,24], abnormal white matter integrity and disrupted structural and functional brain connectivity in children born preterm [25,26]. Since very preterm birth threatens the connectivity of brain networks that facilitate efficient integration of sensory information throughout the brain [9,27], children born very preterm are at risk of sensory processing difficulties.

Sensory processing difficulties concern impaired processing of sensory information and/or ineffective responses to sensory information that affect participation in daily life activities [28,29] Sensory processing includes *registration*, *integration* and *modulation* of sensory stimuli [28,29]. Sensory *registration* difficulties comprise disturbances in identification, discrimination and interpretation of sensory stimuli [30]. The burden on the tactile sense (i.e. somatosensory processing) in particular is significant for very preterm children, because of early exposure to frequent and painful somatosensory stimuli (e.g. nursery handling, heel lancing, venipunctures, nasal suctioning, inflammatory pain) and early deprivation of parental stimulation [15,16,18]. Sensory *integration* difficulties include disturbances in the integration of information from multiple sensory modalities [30,31]. The integration of multisensory information is crucial for the reconstruction of a full representation of the multisensory environment and efficient interaction with this environment [31]. Sensory *modulation* difficulties pertain to an impaired regulation of the intensity of responses to sensory stimuli, resulting in behavioral hyporesponsivity and/or hyperresponsivity with subsequent maladaptive emotional, attentional, and motor responses to sensory stimuli [29,30,32]. Sensory processing abilities relate to neurocognitive and academic functioning [33–35] in school-age children. For example, efficient sensory processing in one year old infants has even been found to predict intelligence at age six [36]. In addition, sensory processing difficulties hamper normal development by interfering with social activities, play and leisure [35,37] and have been found implicated in neurodevelopmental disorders, including attention-deficit hyperactivity disorder (ADHD) and autism spectrum disorders (ASD) [31,38–40]. These findings indicate that adequate sensory processing is pivotal for normal child development.

Sensory processing difficulties have scarcely been studied in very preterm children. In the domain of somatosensory registration, thermal sensitivity was found to be affected in extremely preterm children [41] and in very preterm children less effective manual form perception, kinesthesia, finger identification, graphesthesia and localization of tactile stimuli were found [42]. However, this last study was an uncontrolled study that compared very preterm children to norm referenced scores. In the integration domain, visual-motor integration problems have been observed in preterm children [43,44], and have been shown to persist up to adult age [45]. However, multisensory integration involving other modalities has not received much attention, with only one study showing poor visual-proprioceptive integration in very low birth weight adolescents [46] and one study showing no difference between very preterm and full-term children in visual-tactual integration [36]. Yet, early multisensory interventions during NICU stay have been studied more extensively in the past decades [47–52] and have recently been reviewed by Pineda and colleagues [53]. These authors concluded that multisensory interventions resulted in better infant development and lower maternal stress, but also warned that results were inconsistent and that interventions were implemented for only short periods of time. In the modulation domain, our recent systematic review reported evidence in 14 out of 16 studies for sensory modulation difficulties in preterm children across all sensory modalities and both behavioral hyporesponsivity and hyperresponsivity to sensory stimuli [54]. Moreover, it was found that sensory modulation difficulties were related to lower social participation in one-year-old late preterm infants [55], neurodevelopmental delay in two-year-old very preterm children [56], executive functioning in 3–5-year-old extreme preterm children [57] and symptoms of ASD in two year old very preterm children [54,58]. Yet, only one study has included children at school age, using an uncontrolled design [59]. All other studies in this review included children below age five and mostly around one or two years of age [54]. Taken together, the available studies on sensory processing difficulties after preterm birth are scarce, frequently use uncontrolled designs or focus on children at infant or preschool age.

This study aims to explore the effects of prematurity on somatosensory registration, multisensory integration and sensory modulation in very preterm school-age children in comparison to full-term children, using a multimodal assessment battery including behavioral somatosensory registration tasks [60], a computerized multisensory integration task [61] and the parent-reported Sensory Profile [62] to assess sensory processing difficulties. The results of this exploratory study may contribute to a better understanding of the multifaceted problems occurring in the developmental trajectory of very preterm children and may additionally target sensory processing as an important domain for follow up care in this large group of children.

2. Methods

2.1. Participants

A sample of 57 very preterm children and 56 gender and age matched full-term children participated in the current study. The very preterm children had participated in a randomized controlled trial (RCT) evaluating the effects of postdischarge formula on growth and body composition between term age and six months corrected age [63]. Eligible for inclusion in the current study were all very preterm children admitted between August 2003 and July 2006 to the neonatal intensive care unit (NICU) of the VU University Medical Center, Amsterdam, The Netherlands. Inclusion criteria were a gestational age less than or equal to 32 weeks or a birth weight less than or equal to 1500 g and at least one main caretaker understanding the Dutch or English language. Exclusion criteria were: infants with congenital malformations or conditions known to affect growth and/or body composition (i.e. severe bronchopulmonary dysplasia, inborn errors of metabolism, cardiac or renal disease, necrotizing enterocolitis with substantial gut loss, grade IV intraventricular hemorrhage). Baseline characteristics of the sample have previously been reported [63]. Of the 152 infants included in the original RCT, 139 completed the study at six months corrected age. For the current study at 8–9 years of age, 17 children were lost to follow up and 10 children were additionally excluded because they could not meet the test situation demands due to severe physical/neurosensory disabilities. All other 112 children were contacted and invited to participate, to which 57 (51%) agreed. No differences were found between the group of participants and the total group of non-participants ($n = 95$) on sex, parental education, gestational age (GA), birth weight, PVL, and the presence of perinatal infections (all $p \geq 0.14$).

The gender and age matched full-term control group was recruited from primary schools located in the same provinces as schools attended by the very preterm children, and included children without histories of prematurity (GA > 37 weeks), perinatal complications, neurological disorders, and diagnoses of ADHD and/or ASD as reported by parents.

Socio-economic status (SES) was determined by classifying the highest level of parental education in a household on a four-point scale (low, low intermediate, high intermediate, and high) with higher scores indicating higher levels of education and corresponding higher SES [64]. Medical characteristics of the very preterm group were obtained from medical files and included GA (weeks of gestation), birth weight (grams), small for GA (SGA, defined as either birth length or weight < 2 SD), length of stay in a hospital (defined by the total