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Sensory processing in young children with visual impairments: Use and extension of the Sensory Profile

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ABSTRACT

Background: Children with visual impairments (VI) are at risk for sensory processing difficulties. A widely used measure for sensory processing is the Sensory Profile (SP). However, the SP requires adaptation to accommodate for how children with VI experience sensory information.
Aims: (1) To examine sensory processing patterns in young children with VI, (2) to develop VI-specific items to use in conjunction with the SP and to determine internal consistency and construct validity of these newly developed items, and (3) to examine the association between sensory processing and and emotional and behavioral problems.
Methods: Twenty-six VI-specific items were added to the SP. The SP and these items were completed by caregivers of 90 children with VI between 3 and 8 years old. The Child Behavior Checklist (CBCL) was used to assess emotional and behavioral problems.
Results: Three- to five-year-old children with VI have significantly more difficulties in three quadrants of the SP as compared to the norm group. Six- to eight-year-old children with VI have more difficulties in all quadrants. A reliable and valid VI-specific set of 15 items was established following psychometric evaluation. Age-related differences were found in the associations between the SP and CBCL.
Conclusion: Although further validation is recommended, this evaluation of the VI-specific item set suggests it has the potential to be a useful measure for children with VI.

What this paper adds

A better understanding of the sensory processing patterns of children with visual impairments (VI) is needed to ensure their optimal participation in daily activities. This is the first study to examine sensory modulation in children with VI. As part of this study, VI-

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specific items were created to be used in conjunction with the Sensory Profile. These items fill a gap in the assessments available for therapists of children with VI by addressing behaviors of children with VI that may be related to their responses to sensory stimuli. Our results showed that 3- to 5-year-old children with VI are more sensitive so sensory stimulation and have a greater tendency to avoid sensory stimulation than their peers without VI. The 6- to 8-year-old children with VI experienced overall more problematic sensory processing: They are more sensitive, they miss, seek, and avoid specific sensory information more than their peers without VI. More sensory processing issues were associated with more severe emotional and behavioral problems. These findings highlight the need to routinely consider sensory processing issues in the treatment of young children with VI. Furthermore, this study demonstrated the need to further examine whether sensory processing difficulties increase over time in children with VI.

1. Introduction

Our senses enable us to stay attuned to the environment and allow us to interact with the world in a meaningful way. While there is some controversy in the literature with regard to which sensory modality is most efficient and effective in gaining access to relevant information, vision is generally considered to play a primary role in how we interact with the world around us (Ricciardi, Bonino, Pellegrini, & Pietrini, 2014). As children with visual impairments (VI) are not able to use vision as the primary sense for learning, they need to rely more on their other senses, such as touch and hearing, to stay in touch with their physical and social environment. Combining multiple sensory modalities to improve the speed and accuracy of perceptual judgments can have an important compensatory function for children with VI with regard to perception and action control (Dionne-Dostie, Paquette, Lassonde, & Gallagher, 2015; Eimer, 2004; Garcia, 2016). Lack of adequate vision may, however, interfere with the integration of multiple sensory modalities in children with VI (Wallace, Perrault, Hairston, & Stein, 2004).

Professionals such as occupational therapists have reported that children with VI are at risk of being over-responsive or under-responsive in their intact senses (Jutley-Neilson, Greville-Harris, & Kirk, 2018). For example, some children do not adequately receive or process information from their muscles or joints resulting in insufficient feedback about movement and body position (Rosen, 2010). These children need information from the other senses to compensate for poor proprioception, but children with VI cannot or only partially rely on vision for compensation (Cuturi, Cappagli, Tonelli, Cocchi, & Gori, 2021). Children with VI may differ in their ability to attune to and adequately act upon information in the environment (Jutley-Neilson et al., 2018; Wallace et al., 2004), therefore, a better understanding of the heterogeneity of sensory features in children with VI is important to help identify behavioral risk signs as targets for early detection and effective intervention strategies (Bar-Shalita, Vatine, & Parush, 2008).

The capacity to regulate responses to sensory input in a graded and adaptive manner is generally referred to as sensory modulation (Champagne, 2011). According to Brown, Tse, and Fortune (2019) sensory modulation is 'a twofold process' that "originates in the central nervous system as the neurological ability to regulate and process sensory stimuli; this subsequently offers the individual an opportunity to respond behaviorally to the stimulus" (p.9). A widely established and frequently used model with regard to sensory modulation, referring to the interaction between neural sensitivity and self-regulation, is Dunn's model (Dunn, 1997, 2001). According to this model, sensory modulation patterns are a result of the interaction between the person's neurological threshold and behavioral responses to the environment. Neurological threshold refers to the threshold for a response to a sensory stimulus and ranges on a continuum from low (quick to detect) to high (slow to detect). Each child has unique thresholds for responding to sensory stimulation and thresholds may not be the same for all sensory modalities. The behavioral response construct refers to the child's behavioral strategy in response to sensory stimulation which can range from passive to active. Most children and adults have moderate responses to sensory stimuli in everyday life which support their participation. When responses are more extreme, then sensory modulation is more likely to interfere with daily activities (Dunn, 2007).

Children with VI display behavioral tendencies indicative of difficulties in grading or regulating responses to sensory stimuli, such as hyperresponsiveness to touch or engaging in stereotyped, repetitive behaviors, such as eye pressing, eye rubbing, and body rocking (Fazzi et al., 1999; Gal, Dyck, & Passmore, 2009, 2010; McHugh & Lieberman, 2003; Molloy & Rowe, 2011; Tröster, Brambring, & Beelmann, 1991a). From a functional point of view, these stereotyped, repetitive behaviors can be seen as strategies to maintain an optimal level of arousal and attention to process information (Molloy & Rowe, 2011; Tröster et al., 1991a). In a similar way, these behaviors may be seen as attempts by children with VI to replace the sensory information they are not getting by typical motor experiences (Molloy & Rowe, 2011; Rosen, 2010). Children with VI generally have fewer opportunities and incentives to engage in movement activities that provide the amounts and kinds of stimulation that children without VI generally experience (Brambring, 2006; Warren, 1994). Although self-stimulating behaviors may have a function for children with VI, they may also interfere with learning and socialization (Rosen, 2010). For example, repetitive behaviors such as body rocking or eye rubbing may appear odd to children without VI resulting for example in increased peer rejection, stigmatization, social isolation, and withdrawal (Tröster, Brambring, & Beelmann, 1991b; Verver, Vervloed, & Steenbergen, 2019). In addition, a parent may be confused by their child's reactions and experience parental stress (Gourley, Wind, Henninger, & Chinitz, 2013; Van den Broek et al., 2017). For these reasons, people in the social environment of a child with VI should have knowledge about the child's sensory modulation patterns so they can support this child in optimal participation. Hence, it is essential to assess these patterns in a child with VI.

Also, the degree of association between sensory processing and other domains is important for understanding the role of sensory processing in the development of children with VI. Although behavioral problems have been reported in children with VI (Alimovic, 2013; Sims, Celso, & Lombardo, 2021), little is yet known about the relationship between sensory processing and problem behavior. In both clinical and general child populations, significant associations have been found between atypical sensory processing and emotional and behavioral problems (e.g., Dean, Little, Tomchek, & Dunn, 2018; Gourley et al., 2013). For example, a study concerning a sample of children with a wide range of developmental and behavioral diagnoses found that the presence of sensory processing

difficulties was associated with more internalizing and externalizing behavioral problems (Gourley et al., 2013). Although the exact mechanisms of the relationship between sensory processing difficulties and behavioral problems are not clear yet, one hypothesis is that sensory processing difficulties may lead to difficulties managing emotions and behavior (Dunn, 2007). Another hypothesis is that children with sensory processing difficulties may have fewer opportunities for positive peer interactions and, consequently, to develop social-emotional skills (Benarous et al., 2020; Dunn, 2007).

A widely used measure in both clinical practice and research with the aim of identifying sensory modulation difficulties in children is the Sensory Profile (SP), which uses parent- and/or self-reports about sensory experiences (Dunn, 1999). Items of the SP referring to visual processing may not be appropriate for most children with VI but it is not known to date how their parents will answer those questions. Next to this, some sensory responses that are frequently reported by parents of children with VI, such as eye poking or rocking, are not included in the SP. Consequently, the SP may not optimally account for the full range of sensory and behavioral features in children with VI. Therefore, the present study had the following aims: (1) To examine sensory processing patterns in 3- to 8-year-old children with VI, (2) to develop VI-specific items to be used in conjunction with the original SP and to assess the internal consistency and construct validity of these newly developed items, and (3) to examine the relationship between sensory processing and emotional and behavioral problems.

2. Method

2.1. Participants

For the present study, children were selected from the two largest expertize centers for people with VI in the Netherlands. Selection was based on the following criteria: (a) visual acuity of at least 0.05 and $\leq$ 0.3 (Snellen notation) or a visual field of $\leq 20^{\circ}$ around the central fixation point; World Health Organization, 2016), (b) between 3 and 8 years of age, (c) an IQ-score $\geq$ 70, and (d) sufficient understanding of Dutch language (parents). Exclusion criteria were: (a) central neurological disorders (i.e., congenital or acquired brain lesion or deformities, including cerebral visual impairment) and (b) hearing impairment.

Based on criteria of the WHO (2016), the severity of the participants' visual impairment could be classified into two categories: a moderate VI (visual acuity between 6/18 and 6/60) and a severe VI (visual acuity between 6/60 and 3/60).

2.2. Instruments

2.2.1. Sensory Profile

The SP is a standardized questionnaire with behavioral statements in which caregivers rate their children's responses to sensory events that occur in daily life (Dunn, 1999). The SP was published in its Dutch version in 2006 (Dunn, 2006) and in 2013 norms of the Dutch normative sample were published (Dunn & Rietman, 2013). Responses to each of the 125 items of the SP are rated on a 5-point Likert scale, in which 1 = always: when presented with the opportunity, the child responds in the manner described 100% of the time, and 5 = never: when presented with the opportunity, the child never responds in this fashion, or 0% of the time. Children can be classified as fitting into one of the four behavioral patterns of sensory modulation, each representing one of the extremes of the threshold and response continua: (1) low registration (high threshold with a passive response) – lack of, or low awareness of sensations, (2) sensory sensitivity (low threshold with a passive response) – discomfort and distractibility caused by intense stimuli, (3) sensation seeking (high threshold with an active response) – enjoyment of sensations and interest in increasing them, and (4) sensation avoiding (low threshold with an active response) – controlling or limiting the amount and type of sensations. Next to this, section scores can be obtained regarding each sensory modality (auditory, visual, vestibular, oral, touch, and multisensory).

Cronbach's alpha, as reported in the manual, ranged from .71 to .90 across different sections and quadrants for 4- and 5-year-old children (except for the sections 'Modulation of sensory input affecting emotional responses', 'Modulation of visual input affecting emotional responses & activity level', and 'Items indicating thresholds for response') and from 0.71 to .91 for 6- to 10-year-old children (Dunn & Rietman, 2013). Good inter-rater reliability (ICC =0.87) and test-retest reliability (ICC =0.90) have been reported for 3- to 10-year-old children (Benjamin et al., 2014). Another study reported good test-reliability for quadrant scores (ICC =0.80 − 0.90) and moderate to good test-reliability for section scores (ICC =0.50 − 0.87) (Ohl et al., 2012).

2.2.2. Additional items related to sensory processing of children with VI

An expert group of 14 occupational therapists, physical therapists, and psychologists familiar with VI and sensory modulation participated in the development of VI-specific items as an addition to the SP. Based on clinical experience and on literature on specific behavioral characteristics of children with VI (Gal et al., 2009, 2010; McLinden, 2004; Tröster et al., 1991a), additional items were formulated to optimally represent behaviors that may be related to the responses of children with VI to sensory stimuli. These items were discussed and after processing comments, consensus was reached about 26 items that were added to the SP (see SI-Table 1). The items are scored using the same interval scale as the original items of the SP.

2.2.3. Child Behavior Checklist

To assess emotional and behavioral problems, parents completed validated Dutch versions of the Child Behavior Checklist (CBCL) using either the preschool version, the CBCL/1½–5 (Achenbach & Rescorla, 2000), or the school-aged version, CBCL/6-18 (Achenbach & Rescorla, 2001). Both these forms differ in items and scales but both report summary scales for internalizing, externalizing, and total problems. Scores were converted to T scores (mean 50, SD 10), with higher scores corresponding to more problems. Summed scores

result in three broadband scales for Internalizing, Externalizing, and Total Problems. The Internalizing Problems scale comprises anxious/depressed behavior, withdrawn/depressed behavior, and somatic complaints. The Externalizing Problems scale comprises rule-breaking behavior and aggressive behavior. The Total Problems scale is a combination of both the Internalizing and Externalizing Problems scales, together with scales for Social Problems, Thought Problems, and Attention Problems. The Dutch translation has adequate psychometric properties (Verhulst & Ende, 2013).

2.3. Procedure

The study was approved by the Ethical Committee of the Department of Psychology from the University of Groningen and adhered to the tenets of the Declaration of Helsinki (2013). The parents of the selected children were contacted by telephone or email to inform them about the study and to determine their interest in the study. If the parents showed interest, an information letter, informed consent form, and the questionnaires were emailed to them.

2.4. Data analysis

The statistical analyses were performed using the Statistical Package for Social Sciences for Windows (SPSS Version 27.0; Chicago, IL). Missing data on the SP and the VI-specific items were checked, and frequencies of missing values were calculated. Missing data were explored to find any recurrent pattern to suggest that data were missing in a nonrandom fashion. Data missing at random were imputed with a 2-way imputation technique (Bernaards & Sijtsma, 2000; Van Ginkel, Van der Ark, Sijtsma, & Vermunt, 2007). The mean was imputed for a subscale if no more than one item was missing on that subscale. For subscales that consisted of less than eight items, no mean was computed if an item was missing on that subscale.

Descriptive statistics were used to characterize the sample and study variables. With regard to the newly developed VI-specific items, we deleted items if $> 5\%$ of the scores were missing or if ≥ 2 of the five answer options were unutilized. Values above absolute skewness $= 2$ and kurtosis $= 7$ were considered problematic (Curran, West, & Finch, 1996).

One-samples t-tests were used to compare the SP results of the children with VI with the norm scores. This was done separately for both age groups: children aged 3–5 years and children aged 6–8 years. The data were checked for the assumptions of parametric techniques; the performances on most of the variables did not violate the assumptions. For variables that did not match well with normality, the nonparametric alternatives were conducted as well but the results did not change. Given the controversy over using the non-parametric methods (see, e.g., De Winter, 2013; Fagerland & Sandvik, 2009; Skovlund & Fenstad, 2001) we only reported the parametric outputs. The distribution of children's scores across the classifications of the SP sections (typical performance, probable difference, and definite difference) were calculated for both age groups according to the SP manual.

To find the underlying factor structure of the VI-specific items, a principal component analysis (PCA) with varimax rotation was performed for the remaining items, including inter-item correlations and followed by a reliability test. Kaiser-Meyer-Olkin (KMO) test for sampling adequacy needed to be ≥ 0.5 to proceed. Items were discarded based on predefined criteria: factor loading < 0.5 (Nunnally, 1994) on identified factors with an eigenvalue > 1 (Kaiser, 1960); or inter-item correlation > 0.8 indicating potential redundancy, retaining the highest Cronbach's alpha. The remaining factors were interpreted by using the factor loadings and all factors with an eigenvalue > 1 for initial interpretation. Internal reliability analyses of the found factors with Cronbach α, considered values above .60 to be minimally acceptable since this is a newly developed scale (Cho & Kim, 2015).

Finally, Spearman's rank correlations between the quadrant sections of the SP and the factors of the VI-specific items on one side and the Internalizing, Externalizing, and Total Problems scales of the CBCL on the other side were calculated for both age groups separately.

Effect sizes were expressed in terms of Cohen's d with values of 0.2, 0.5, and 0.8, referring to small, medium, and large effects and for correlations with values of 0.10, 0.30, and 0.50, referring to small, moderate, and large strength of relationships (Cohen, 1988). For all analyses α was set at 0.05. No corrections for multiple comparisons (e.g., Bonferroni) were made because we consider this an exploratory study (see Armstrong, 2014).

3. Results

3.1. Participants

The total sample consisted of 90 children (60 boys; 67%) with a mean age of 5.2 years (SD = 1.6). The children were divided into two different age groups for the analyses: 3- to 5-year-olds (n = 56; 37 boys, 66%) and 8- to 10-year-olds (n = 34; 23 boys, 68%). The mean visual acuity of the participants was 0.19 (SD =0.07). Based on criteria of the WHO (2016), 68 children had a moderate VI (49 boys; 72%) and 22 children (11 boys; 50%) had a severe VI. The participants' visual impairments were caused by a variety of different etiologies: albinism (n = 31), nystagmus (n = 15), congenital stationary night blindness (n = 7), aniridia (n = 5), achromatopsia (n = 5), high myopia (n = 5), Leber's congenital amaurosis (n = 4), retinal dystrophia (n = 3), congenital cataracts (n = 2), ocular albinism (n = 2), oculo-dento-digital dysplasia (n = 2), optic nerve atrophy (n = 1), optic nerve coloboma (n = 1), opticopathy (n = 1), high hypermetropia (n = 1), cone dystrophia (n = 1), retinitis pigmentosa (n = 1), retinoschisis (n = 1), congenital toxoplasmosis (n = 1), and Bornholm eye disease (n = 1).

3.2. Descriptives and comparison with normative values

Descriptive results for the scores on the SP are listed in Tables 1 and 2. For 8.8% of the children more than two items of the original dataset were missing and caregivers of 58.2% completed all items. In addition, no individual item was missing for more than 7.7% (n = 7) of the children, except for item 118 (34.1%). Surprisingly, all parents completed the items of the section for Visual processing.

Tables 1 and 2 also show comparisons with normative data and the effect size of the difference between the current sample and the normative data. The one-sample t-tests demonstrated a significant difference in mean scores for the 3- to 5-year-old children with VI compared to the norm group for five out of the 14 categories and three out of the four quadrants, with effect size ranging from small to large. Nevertheless, mean SP scores for this age group were in the typical range for every quadrant and section, except for Visual processing (> 2 SD from the mean of the norm group) and Modulation of sensory input effecting emotional responses (between 1 and 2 SD from the mean of the norm group).

For the 6- to 8-year-old children with VI, the one-sample t-tests showed significant differences in mean scores compared to the normative data for 11 out of the 14 sections and for all four quadrants, with effect sizes ranging from small to large. Scores were in the atypical range particularly for Visual processing (>2 SD). In addition, scores in the atypical range were found for the quadrant Low registration and the sections for Multisensory processing, Modulation related to body position and movement, Modulation of sensory input effecting emotional responses, and Modulation of visual input affecting emotional responses & activity level ($1 \leq SD < 2$).

To characterize the sensory processing difficulties in the SP profiles of children with VI, we established the actual percentage of children with sensory processing difficulties in the two VI age groups (see SI-Table 2 and SI-Table 3). Not surprisingly, the highest percentages of cases with scores ≥ 2 SD in the VI group were found on Visual processing in both age groups. The number of children with scores ≥ 2 SD on quadrant scores in the 3- to 5-year-old age group ranged from 5.9% (Sensation seeking) to 14.5% (Low registration and Sensation avoiding) and in the 6- to 8-year-old age group from 11.8% (Sensation seeking) to 29.4% (Low registration).

3.3. VI-specific items

Of the 90 participants, caregivers of three children did not complete this additional set of items, leaving us with a sample of questionnaires of 87 children. No items were deleted due to missing scores (see SI-Table 4 and SI-Table 5). There were two items with ≥ 2 unutilized answer options. Two additional items were discarded due to skewness > 2, one of which also had kurtosis > 7 (see SI-Table 4 and SI-Table 5). The PCA (KMO measure of 0.643) revealed four factors that were interpretable and had Cronbach's alpha coefficients > 0.60 (see Table 3). The remaining three factors had alpha's below .60 and the seven items in these factors were removed.

3.4. Relationship between sensory processing and behavioral problems

T-scores of the three Problem scales of the CBCL 1½– 5 and CBCL 6–18 are shown in Table 4. One-sample t-tests showed that only the mean T-score of the Total Problems scale for the younger children significantly differed from the normative value of 50, $t(53) = -2.06$, $p = .044$, and that the Externalizing Problems scale in that age group approached significance, $t(53) = -1.97$, $p = .055$.

Table 1
Scores on the sections and quadrants of the Sensory Profile for 3- to 5-year-old children with VI.

	Norm group (n = 667)		VI					
Sections	M	SD	*n*	M	SD	*t*	*p*	*d*
A. Auditory processing	32.00	4.15	55	30.40	5.08	-2.34	.023*	-0.31
B. Visual processing	38.16	4.39	56	29.02	6.75	-10.13	< .001***	-1.35
C. Vestibular processing	48.87	4.16	56	48.32	5.07	-0.81	.421	-0.11
D. Tactile processing	80.18	6.42	55	78.64	7.83	-1.46	.149	-0.20
E. Multisensory processing	29.54	3.42	55	28.49	3.93	-1.98	.053	-0.27
F. Oral sensory processing	53.08	6.59	53	53.66	6.85	0.62	.540	0.08
G. Sensory processing related to endurance/tone	42.59	3.41	56	41.66	4.12	-1.69	.097	-0.23
H. Modulation related to body position and movement	43.19	4.64	55	39.45	5.77	-4.80	< .001***	-0.65
I. Modulation of movement affecting activity level	25.76	4.14	56	26.29	4.13	0.95	.345	0.13
J. Modulation of sensory input affecting emotional responses	17.68	2.18	55	15.67	3.13	-4.76	< .001***	-0.64
K. Modulation of visual input affecting emotional responses & activity level	16.21	2.40	56	15.43	2.66	-2.20	.032*	-0.29
L. Emotional/Social responses	71.68	8.53	49	71.90	8.26	-0.20	.841	0.03
M. Behavioral outcomes of sensory processing	24.41	3.96	29	23.90	3.29	-0.84	.407	-0.16
N. Items indicating thresholds for response	13.49	1.44	54	13.28	1.62	-0.96	.340	-0.13
Quadrants								
1. Low registration	67.68	5.50	55	65.60	6.60	-2.23	.030*	-0.30
2. Sensation seeking	107.98	12.35	51	107.41	13.30	-0.31	.762	-0.04
3. Sensory sensitivity	88.07	7.64	54	82.72	9.53	-4.13	< .001***	-0.56
4. Sensation avoiding	122.32	11.74	55	115.53	13.16	-3.83	< .001***	-0.52

Note. The lower a score in an area, the greater the likelihood the child may be experiencing difficulties.
*$p < .05$. **$p < .01$. ***$p < .001$

Table 2
Scores on the sections and quadrants of the Sensory Profile for the 6- to 8-year-old children with VI.

	Norm group (n = 1257)		VI					
Sections	M	SD	*n*	M	SD	*t*	*p*	*d*
A. Auditory processing	32.94	4.41	34	30.00	5.76	-2.98	.005**	-0.51
B. Visual processing	39.09	4.31	34	30.12	6.72	-7.78	< .001***	-1.33
C. Vestibular processing	49.56	4.19	34	46.44	5.06	-3.60	.001**	-0.62
D. Tactile processing	82.02	6.51	34	77.26	8.74	-3.17	.003**	-0.54
E. Multisensory processing	30.26	3.40	34	26.74	4.61	-4.46	< .001***	-0.76
F. Oral sensory processing	54.12	6.23	34	54.88	5.10	0.86	.399	0.15
G. Sensory processing related to endurance/tone	42.49	3.67	34	39.09	6.18	-3.21	.003**	-0.55
H. Modulation related to body position and movement	44.88	4.38	34	39.79	5.55	-5.34	< .001***	-0.92
I. Modulation of movement affecting activity level	26.15	4.14	33	26.12	4.87	-0.03	.973	-0.01
J. Modulation of sensory input affecting emotional responses	17.80	2.25	34	15.32	3.35	-4.30	< .001***	-0.74
K. Modulation of visual input affecting emotional responses & activity level	16.69	2.45	34	14.50	3.07	-4.16	< .001***	-0.71
L. Emotional/Social responses	71.13	8.72	32	68.84	10.06	-1.29	.208	-0.23
M. Behavioral outcomes of sensory processing	25.13	3.65	29	22.21	5.28	-2.98	.006**	-0.55
N. Items indicating thresholds for response	13.84	1.31	33	13.12	1.78	-2.32	.027*	-0.40
Quadrants								
1. Low registration	68.12	5.78	34	61.76	9.26	-4.00	< .001***	-0.69
2. Sensation seeking	112.03	12.57	34	104.34	13.21	-3.44	.002**	-0.59
3. Sensory sensitivity	89.11	7.61	33	82.73	10.47	-3.50	.001**	-0.61
4. Sensation avoiding	124.22	11.27	34	116.35	15.83	-2.90	.007**	-0.50

Note. The lower a score in an area, the greater the likelihood the child may be experiencing difficulties.
*$p < .05$. **$p < .01$. ***$p < .001$

Table 3
VI-specific items after principal component analysis (PCA) and reliability analyses.

# Factor /Item	Former #	Mean (SD)	Factor: Alpha Item: IRC*	Name factor/Item
F1		**22.6 (2.7)**	**0.665**	**Self-regulation by touch and movement**
1.	4		0.340	Engages in rocking the head and/or body
2.	13		0.426	Wraps hair around finger(s) or pulls hairs
3.	14		0.450	Manipulates objects in a repetitive movement
4.	16		0.496	Rubs or sweeps hands or feet across surfaces
5.	20		0.394	Sniffs his/her nose constantly
F2		**16.5 (2.8)**	**0.688**	**Resistance to movement/auditory processing**
6.	5		0.454	Does not like to be lifted
7.	6		0.493	Remains seated or lying in the same place
8.	22		0.471	Keeps moving while listening to someone
9.	25		0.534	There is a delay between hearing the assignment and carrying out the assignment
F3		**17.3 (2.4)**	**0.649**	**Touching surfaces and materials**
10.	7		0.423	Finds it unpleasant to walk on an irregular surface, such as a dirt road
11.	8		0.384	Pushes with fingers against / or in the eyes
12.	11		0.490	Shuffles feet across the floor while walking
13.	23		0.435	Moves cautiously and slowly
F4		**8.6 (1.6)**	**0.631**	**Auditory hyporeactivity**
14.	2		0.461	Does not reach for toys with sounds or for other sound sources
15.	3		0.461	Does not focus on everyday noises

Note. IRC = Item Rest Correlation

Table 4
T-scores of the Problems scales of the CBCL 1½–5 (3- to 5-year-olds) and CBCL 6–18 (6- to 8-year-olds).

	3- to 5-year-olds (n = 54)				6- to 8-year-olds (n = 34)			
Problem scales	M	SD	BCR	CR	M	SD	BCR	CR
Internalizing problems	48.4	10.0	11.1	5.6	52.9	10.8	20.6	11.8
Externalizing problems	47.2	10.5	3.7	5.6	51.0	10.1	14.7	11.8
Total problems	47.1	10.4	5.6	5.6	52.5	11.0	0.0	20.6

Note. BCR = Percentage of children in the borderline clinical range, CR = Percentage of children in the clinical range.

Table 5 presents the Spearman correlation analysis of the three problem scales of the CBCL with the quadrants of the original SP and the four factors of the VI-specific items. Almost all correlations between the CBCL and the original SP were significant. For the VI-specific items, the associations with the CBCL are slightly different. For the younger children, all CBCL problem scales correlated moderately to strongly with three of the four factors. For the older children, correlations with some of the problem scales were found for almost all four factors. Notably, correlations with the factors 'Self-regulation by touch and movement' and 'Resistance to movement/auditory processing' were considerably weaker in this age group than for the younger children.

4. Discussion

4.1. Main findings

The aims of the present study were: (1) To examine sensory processing patterns in 3- to 8-year-old children with VI, (2) to develop VI-specific items to be used in conjunction with the SP and to assess the internal consistency and construct validity of these newly developed items, and (3) to examine the relationship between sensory processing and emotional and behavioral problems.

Our results showed that 3- to 5-year-old children with VI have significantly more difficulties in three of the four quadrants of the SP as compared to the norm group. Six- to 8-year-old children with VI have more difficulties in all four quadrants as compared to the norm group. In addition to the four quadrant scores, the current study found 3- to 5-year-old children with VI to score differently on about one-third (36%) of the sections compared to the norm group; for the 6- to 8-year-old children with VI this was 79%. Not surprisingly, visual processing was the highest rated sensory challenge for children with VI. A reliable and valid VI-specific set of 15 items was established following psychometric evaluation. Significant moderate-to-strong correlations were found between almost all quadrants of the SP and the Problem scales of the CBCL in both age groups. With regard to the VI-specific items, all CBCL problem scales correlated moderately to strongly with three of the four factors in the youngest age group. For the older children, correlations with some of the problem scales were found for almost all four factors. Although causality cannot be inferred from these correlations due to the cross-sectional design of the study, these results indicate that when children with VI have more sensory processing issues, they have more severe emotional and behavioral problems.

Although behavioral tendencies indicative of difficulties in regulating responses to sensory stimuli have been reported in children with VI (Fazzi et al., 1999; Gal et al., 2009, 2010; McHugh & Lieberman, 2003; Molloy & Rowe, 2011; Tröster et al., 1991a), we have found no studies on sensory modulation of these children. Compared to the norm group, the largest differences for the 3- to 5-year-old children with VI were found for Dunn's low neurological threshold sensory patterns, i.e., Sensory sensitivity and Sensory avoiding. The low neurological threshold is characterized by a person's notice of or annoyance with sensory stimuli, that may be regarded as hypersensitivity (Dunn, 1997, 2001). Put differently, children who score "more than others" in these patterns are more sensitive so sensory stimulation and have a greater tendency to avoid sensory stimulation. The 6- to 8-year-old children with VI scored significantly lower on all quadrants, suggesting more overall problematic sensory processing. Interestingly, our results showed similar occurrence of sensation-seeking behaviors in the 3- to 5-year-old children with VI compared to the normative data, whereas the 6- to 8-year-old children tend to experience increased sensation-seeking behaviors. This is consistent with the results of the meta-analysis concerning sensory processing patterns in children with autism spectrum disorders indicating that sensory-seeking behaviors may peak in middle childhood (6–9 years) (Ben-Sasson et al., 2009). One explanation for the increased frequency of certain behaviors may be that sensory features may become more expressed from the age of six years since children enter first grade in the Dutch school system around this age. The demands for independence increase, and the social and physical environment becomes more complex and less controlled which may lead to more stress in these children. However, there might also be a true increase in sensory features indicating a neurological mechanism (Ben-Sasson et al., 2009). It is important to note that the interpretation of the results is based on group data. Notably, all effect sizes for the significant differences indicated only small to moderate differences. Around 60% of the children with VI are typically performing with regard to sensory processing.

Table 5
Spearman correlations between the Problems scales of the CBCL (T-scores) and (1) the quadrant sections of the original SP, and (2) the four factors of the VI-specific items.

	3- to 5-year-olds			6- to 8-year-olds		
	CBCL Problem scales			CBCL Problem scales		
Quadrants Sensory Profile	Inter.	Exter.	Total	Inter.	Exter.	Total
Low registration	–.45***	–.41**	–.48***	–.65***	–.46**	–.66***
Sensation seeking	–.57***	–.71***	–.67***	–.46**	–.68***	–.64***
Sensory sensitivity	–.63***	–.62***	–.63***	–.43*	–.23	.–45**
Sensation avoiding	–.65***	–.60***	–.66***	–.64***	–.40*	–.63***
Factors VI-specificitems						
Self-regulation by touch and movement	–.63**	–.61**	–.64**	–.28	–.44*	–.38*
Resistance to movement/auditory processing	–.65**	–.65**	–.63**	–.41*	–.36*	–.54**
Touching surfaces and materials	–.46**	–.29*	–.40**	–.48**	–.16	–.40*
Auditory hyporeactivity	–.18	–.20	–.23	–.58**	–.17	–.49**

Note. Inter. = Internalizing problems, Exter. = Externalizing problems, Total = Total problems
*$p < .05$. **$p < .01$. ***$p < .001$

Measuring the nature and impact of sensory responses in children with VI is important to identify problems that require appropriate interventions. As we expected that the SP may not optimally account for the full range of sensory features in children with VI, 26 additional VI-specific items were formulated. These new items allow for the identification of behaviors associated with self-regulation, hyper- and hypo-reactivity specific to children with VI. Regarding further item analysis, four items were deleted, including item 17, 'Reacts evasively to perfume/deodorant scents', item 18, 'Bites himself', item 19, 'Sucks on thumb or fingers', and item 24, 'Avoids physical contact'. Findings indicate that these items showed little variability and are also less prevalent in these children than we expected. Not all VI-specific items passed the PCA fit test. Only 15 items were not redundant and were representative of four factors that were interpretable. The other items possibly measured a diversity of constructs, so they were eliminated to ensure that the remaining items were relevant and measured specific constructs.

Finally, the results showed relationships between sensory features and externalizing and internalizing behaviors, suggesting that sensory processing difficulties are associated with emotional and behavioral problems. These findings are consistent with studies in other groups of children, such as children from the general population and children with developmental and/or behavioral concerns (e.g., Dean et al., 2018; Gourley et al., 2013). Although one possible explanation for this high correlation could be that the SP produces "false positives" for children with behavioral problems, previous work with the shortened SP (SSP) has shown that even when this version in which items referring to temperament and emotional and behavioral problems are removed, there is a high correlation between sensory processing difficulties and psychopathology (Gouze, Hopkins, LeBailly, & Lavigne, 2009). Interestingly, the correlations between sensory processing and emotional and behavioral problems seemed stronger in the 3- to 5-year-old children, whereas the 6- to 8-year-old children showed more problematic sensory processing but not necessarily more emotional and behavioral problems. Possibly, older children have acquired coping and executive functioning skills to counteract unpleasant or overwhelming sensory experiences as they age (Little, Dean, Tomchek, & Dunn, 2018). It could also mean that older children attune to their social and physical environment differently. That is, they might have learned about the regularities of sensory experiences, making them less surprising and overwhelming, and also have learned to respond to them more appropriately. Clearly, this finding and what it means requires further research.

4.2. Limitations

Some limitations must be considered in the interpretations of the results of the current study. First, we used a convenience sample of children with VI which may limit the generalizability of the study results. In addition, the relatively small sample size limits the power and increases the chance of a type 1 error with regard to the performed analyses. Second, information was obtained via caregiver questionnaires and not through direct observation or testing of the child, which can cause observer bias. Moreover, both the SP and the CBCL were completed by the same person and this might introduce bias to the study results. Conversely, parents are the most likely source for obtaining a precise picture of a child's behavior and performance in response to sensory events in daily life (Taal, Rietman, Meulen, Schipper, & Dejonckere, 2013). A further limitation of this study is the fact that additional confounding child factors influencing the child's sensory processing and/or behavioral problems and their development, such as intellectual level, family context or fine and gross motor development, were not assessed. Despite these limitations, and because there are so few studies on this subject, we feel that these findings are important for clinicians who evaluate difficulties in sensory processing.

4.3. Future directions and practical implications

Based on the current results, we recommend further research into using the SP and the additional VI-specific items as an instrument for studying behavior of children with VI. An investigation with a larger sample as well as an increased age range is warranted. This study has been cross-sectional, therefore, findings related to chronological age and development must be interpreted with caution. Future research may use longitudinal designs to understand developmental trajectories of sensory features.

Sensory responses are interpreted based on the individual's behavioral response to the sensory input. The relationship or extent to which this behavior aligns with sensory processing in the brain requires further investigation through combining neurophysiological information with multi-informant reports. Further studies may also explore the significance and practical value of the link between sensory processing problems and behavioral problems in children with VI.

Better identification and acknowledgement of children's sensory processing difficulties may lead to more targeted treatment at home and at school. Given the relatively high prevalence of sensory processing difficulties found in our study, routine administration of the SP seems warranted. Using a sensory processing view in conjunction with best practices in developmental and behavioral assessment and intervention will likely better explain and address problem behavior and may result in more effective treatment outcomes.

CRediT authorship contribution statement

Suzanne Houwen: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Ralf Cox**: Conceptualization, Methodology, Formal analysis, Writing – review & editing. **Minette Roza**: Conceptualization, Investigation, Writing – review & editing. **Femke Oude Lansink**: Conceptualization, Investigation, Writing – review & editing. **Jannemieke van Wolferen**: Conceptualization, Investigation, Funding acquisition, Writing – review & editing. **André B. Rietman**: Conceptualization, Methodology, Formal analysis, Writing – review & editing, Supervision. All authors approved the manuscript submission.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ridd.2022.104251.

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