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Sensory processing profile among a sample of Egyptian children with different types of delayed language development: correlations of different variables

Hassnaa Othman Mohammed[1*], Shimaa Abd Allah Elsayed[1] and Nesreen Fathi Mahmoud[2]

Abstract

Background Research on sensory processing, particularly its association with language disorders, has been increasing in recent years, aiming to understand the correlation between language and sensory processing. This study aimed to determine sensory profiles among children aged 36 and 120 months with language disorders (autism spectrum disorders (ASD), attention deficit hyperactivity disorders (ADHD), specific language impairment (SLI), and intellectual disability (ID)) and correlate their language ages with their sensory profile responses.

Results The study involved 120 children with language disorders (ASD, ADHD, SLI, and ID), and 30 typically developing children. All children were subjected to assessment by the Sensory Profile and the Preschool Language Scale Fourth Edition (PLS-4) Arabic edition. Based on their sensory profile, children with language disorders are distinguished from typically developing peers. The former has a higher prevalence of sensory modulation disorders as well as atypical emotional and behavioral responses to sensory inputs compared to typically developing children. Children with ASD have the highest atypical sensory responses, followed by those with SLI, ADHD, and ID. A negative correlation was found between some sensory profile scores and receptive language scores. Expressive language was related to oral processing in some subtypes of language disorders.

Conclusions The study indicates that detailed sensory processing assessment in children reveals different faces for different types of language disorders.

Keywords Sensory processing disorders, ASD, ADHD, SLI, Intellectual disability, Sensory profile, Neurodevelopmental disorders

Background

A child's developmental aspects in academic achievement, social and emotional regulation, motoric development, and cognitive and language development are high brain functions that require intact sensory processing [1]. In typically developing children sensory feeding from the surrounding world passes in a trajectory of appropriate recording, regulation, organization, integration, and interpretation. Decision-making and child interaction with the environment are the final stations in this processing trajectory [2].

There are two well-known sensory processing theories. The first theory was by Ayers [3]. She emphasized that the eight senses we have should not only be intact but also integrate in action with each other for proper processing. The second was by Dunn [4]. She established

*Correspondence:
Hassnaa Othman Mohammed
hasnaa.osman@chi.asu.edu.eg; hassnaaphoniatrics@gmail.com
[1] Medical Studies Department for Children, Faculty of Postgraduate Childhood Studies, Ain Shams University, Cairo, Egypt
[2] Phoniatric Unit-Department of ENT, Faculty of Medicine, Beni-Suef University, Beni-Suef, Egypt

what is known as "Dunn's sensory processing framework". The framework described how sensations from the body itself and the environment are categorized, understood, and coordinated. Ayers [3] described "the sensory diet" in which the child receives adequate sensory input for certain senses the child is seeking, and accommodations and adaptations for the sensory input the child is avoiding. Adequate sensory processing develops when the brain makes connections as a result of environment and learning. Sensory processing is divided into sensory modulation, habituation, and sensitization. A balance between habituation and sensitization guarantees appropriate daily functioning. This balance is responsible for the neurological threshold continuum which is specific for each child [3]. Authors [5, 6] defined sensory processing disorder (SPD) as a dysfunction affecting the adequate reception, modulation, integration, discrimination, or organization of stimuli coming from senses, and the behavioral responses to this sensory input. These dysfunctions compromise functional performance in areas related to cognitive, motoric, behavioral, emotional, and attentional responses for environmental adaptation [7].

Sensory processing disorders may manifest as one or more of three distinct disorders. They included (a) sensory modulation disorder (SMD); (b) sensory discrimination disorder (SDD); and (c) sensory-based motor disorder (SBMD) [8]. Children with SMD may face challenges in grading the intensity and type of responses to the surrounding sensory input. These grading difficulties may be in the form of sensory overresponsivity (SOR), sensory underresponsivity (SUR), and sensory craving or (sensory seeking). Each type is characterized by its unique interaction with everyday life situations [7, 9]. Children with SBMD showed inadequacy in their physical condition and voluntary movements. In response to incoming sensory stimuli, inappropriate motor planning, praxis, sequence, smoothness, and control of movements may manifest as postural dysfunction and dyspraxia.

Children with SDD typically show discrimination difficulty in the temporal and spatial features of the sensory input [10]. There are debates regarding the origin of sensory processing disorders. It is not yet known whether SPDs are the primary disorder from which other disabilities emerge or if they are mere comorbidities [11].

Language development is considered a highly functioning cognitive process and the end product of adequate and appropriate sensory processing operations. Smith and Yu [12] and Casey et al. [13] determined that the reciprocal relation between language and sensory development guarantees the appropriate development of each. Language disorders are commonly associated with SPDs. SPDs are responsible for challenging outcomes among children with language disorders. Van der Linde et al. [10] determined that more than 80% of children with developmental language disorders demonstrated difficulties with SPDs. Taal et al. [14] reported that the sensory profiles of up to 60% of children with specific language impairment (SLI) differed significantly from those of age-matched controls. Simposon et al. [15] claimed that SPDs are the accused risk factor for the development of comorbidities among this category of children.

SPDs have been highly reported among children with neurodevelopmental disorders [1, 16]. SPDs are common findings among children with ASD and ADHD [17–21]. The prevalence ranges between 40 and 80% [22, 23] The sensory profile of these disorders interprets the diagnostic criteria among these children [24].

Literature specified certain SP for different types of delayed language development. For example, in children with ASD, Van der Linde et al. [10] described oral cavity and touch processing disorders as well as modulation deficits of emotional and social interaction. For children with SLI, multisensory processing and modulation of movement are compromised sectors in their sensory profile. For children with ADHD, Jung et al. [25] claimed that deficits in visual and vestibular processing are specific for this category of children. For children with ID, Tomchek et al. [26] supported the presence of sensory-seeking behaviors among this category of children.

Isralowitz et al. [24] compared the sensory profile among children with developmental intellectual disability, ASD children, and children with Down syndrome. The results indicated the specificity of the SP according to the clinical population.

Discussions of the presentation of sensory processing disorders among Egyptian children with delayed language development (DLD) and the legibility of including the sensory profile as a diagnostic and severity index tool in their assessment are deficient. Alsaedi et al. [27] claimed that the neurological manifestation of neurodevelopmental disorders remained constant between different cultures but, sensory processing manifestation was specific for each culture. For this purpose, SP was translated and culturally adopted from its original language (English) to different languages and cultures for example (Brazilian Portuguese language [28], Persian language [29] Jordanian culture and language [30], for Arabic Golf region culture and language [27] and Egyptian culture and language [31]). Their application resulted in different results [27, 31]. The current work took advanced steps toward these goals.

The aim of the work

The aim of this study is to (1) illustrate the specific sensory pattern in detail for different causes of delayed language development compared with typically developing children and (2) correlate the sensory profile with language age (receptive and expressive) to determine the challenging sensory areas that should take priority in the therapeutic program. The current work hypothesized that the different types of delayed language development are differentiated on the sensory profile.

Methods

The current work was conducted according to the World Medical Association Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. Parents of children assented to participate in the study.

Design and setting of the study

This study is an observational cross-sectional study in which participated children were randomly selected according to the inclusion and exclusion criteria in the following section.

Participants

One hundred and fifty Arabic-speaking Egyptian children aged between 36 and 120 months of both genders were classified into 5 groups as follows: 30 children with attention deficit hyperactivity disorder, 30 children with autism spectrum disorder, 30 children with specific language impairment, and 30 children who received a diagnosis of intellectual disability (ID) (mild degree). The fifth group included 30 typically developing (TD) children who worked as a control group. All participants were previously diagnosed by a multidisciplinary team of pediatric psychiatrists, neurologists, phoniatricians, and psychologists. Participants were recruited from the phoniatric unit of the Special Needs Center of Post Graduate Childhood Studies at Ain-Shams University and Beni-Suef University Hospital and selected by simple random sampling.

ASD group

The ASD group was composed of 22 males and 8 females who had a clinical diagnosis of ASD. They were diagnosed according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-V) [32]. The severity rating was determined by a more specific instrument, the Childhood Autism Rating Scale (CARS) (Arabic version) [33]. The CARS is the most widely used standardized behavioral rating scale of autistic characteristics in children over the age of two. They scored ≥ 70 on (the nonverbal domain) of the Stanford Binet 5th Edition (SB-5th). Cognitive assessment was used to exclude ID [34]. Children included in the ASD group did not receive any medical treatment or sensory integration therapy for at least 6 months prior to inclusion in the study.

ADHD group

The ADHD group was composed of 22 males and 8 females who had been clinically diagnosed according to the criteria of the DSM-V [32]. All of them showed the presence of six or more inattention symptoms and six or more hyperactivity/impulsivity symptoms, based on information provided by both parents and teachers; persistence of symptoms for more than 6 months; and the appearance of symptoms before the age of 12. Children included in the ADHD group did not receive any medical treatment or sensory integration therapy for at least 6 months prior to inclusion in the study.

SLI group

The SLI group was composed of 22 males and 8 females who had been clinically according to Ziegenfusz et al. [35]. Children with SLI scored two standard deviations on the PLS4-Arabic Edition [36] and gained intelligence quotient (IQ) greater than 89 on the nonverbal sector of Stanford Binet-5th. These children were free from any audiological, neurological, or psychiatric disorders.

ID (mild degree) group

The ID (mild degree) group was composed of 22 males and 8 females who had been clinically diagnosed according to the criteria of the DSM-V [32]. Children with ID obtained an IQ between 49 and 69 according to the nonverbal domain of the Stanford Binet-5th. They were chosen without any associated comorbidities.

Typically developing (TD) group

Fifty participants and their parents were initially invited to participate. The parents of 45 participants (90%) consented to participate in the research, while the parents of 5 (10%) declined to participate. The initial TD sample, therefore, comprised 45 participants. Five participants (11.1%) with learning difficulties and four participants (8.89%) with a family history of ASD were excluded from the study, while six participants (13.33%) were excluded due to incomplete assessments. This resulted in a total of 30 TD participants being included in the study (22 males and 8 females). The TD participants were all recruited from nursery and mainstream primary schools. To be included in the analyses, the TD participants had to have (a) no parental concern about their children's motoric development, no complaints of language or speech disorders, no prior language or speech therapy, with adequate performance in the Modified Preschool Language Scale [36]. (b) TD children did not demonstrate significant difficulties with social (eye contact, lack of social interaction) or repetitive behaviors and were free of any neurological or psychiatric disorders, psychotropic medication, audiological, or family history of ASD.

Procedures

Sensory profile (SP)

Sensory processing abilities were assessed by the long form of the Sensory Profile [37] which is composed of 14 sections (a total of 125 questions) focused on daily-life sensory responses in children aged three to 10 years. It is a caregiver questionnaire that measures the children's responses to daily sensory stimuli. The clinician demonstrated the purpose of the questionnaire. The questionnaire includes three sectors: (1) sensory processing, (2) modulation, (3) behavioral and emotional responses. Sensory processing contains six-item categories that reflect sensory processing (auditory, visual, vestibular, touch, multisensory, and oral sensory stimuli). The modulation sector contains five items and measures the child's ability to sustain performance and to move effectively in response to sensory stimuli. The emotional/social section of the Sensory Profile measures the child's psychosocial coping strategies. The questionnaire was translated and culturally adapted from English to Arabic [37] in a study involving 100 typically developing children aged 3 to 10 years. The SP-Arabic was a valid and reliable tool to be applied in Egyptian culture according to Zidan [37]. Factor analysis was not completed in the current work.

Parents were instructed to respond according to the frequency of the behaviors listed in the profile. The test lasted approximately 40–50 min for each child. The principal researcher illustrated that each question is scored on a 1-to 5-point scale (Likert scale). 1 = always; (i.e., the child always responds in this manner 100% of the time). 2 = frequently (i.e., 75% of the time your child frequently responds in this manner). 3 = occasionally (i.e., 50% of the time your child responds in this manner). 4 = Seldom (i.e., child always responds in this manner, 25% of the time). Last, never = 5 (i.e., your child always responds in this manner, 0% of the time). A lower raw score indicated an atypical sensory response, while high scores indicated typical responses. The raw score is then converted according to the conversion table into a descriptive score. Descriptive scores were converted as numbers as follows: children were scored as 1 = for typical response, 2 = probable difference, and 3 = definite difference. Atypical scores in the current work described children who received probable and definite differences. The mean and SD were calculated according to the final conversion.

Modified preschool language scale-4 (Arabic Edition) (PLS-4) [36]

PLS-4 is a valid and reliable scale to assess language in age range of (2 months and 7 years and 5 months). It has two standardized subscales and two supplemental measures. The two standardized subscales are the auditory comprehension subscale (the auditory comprehension subtest is composed of 62 items that are distributed in different age groups), and the expressive communication subscale (the expressive communication subtest is composed of 71 items that are also distributed in different age groups). The two supplemental measures are the articulation screener and caregiver questionnaire. It contains a picture book, scores recording sheet, tools, and toys appropriate for different age groups, and a user's manual. Scoring: for each child the basic and the ceiling level are determined and the raw score is estimated by subtracting the ceiling score from the basal score. The raw score is converted into their equivalent language age in the conversion tables.

Statistical analysis

The data were entered, coded, and processed on a computer using Statistical Package for Social Science [38]. Quantitative data are displayed as the mean, standard deviation (SD), and range. Qualitative variables were described in the form of percentages. The chi-square test $\chi 2$ was used to compare qualitative variables between groups. The independent samples *t*-test was used to assess the statistical significance of the difference between two population means in a study involving independent samples. One-way ANOVA was used to assess the statistical significance of the difference in more than two population means in a study involving independent samples. The correlation coefficient method was used to relate different parameters, Pearson correlation for quantitative variables, and Spearman correlation for ordinal variables. Regression analysis was used to determine the most significant independent predictors affecting outcome, linear regression analysis for quantitative dependent variables, and logistic regression analysis for qualitative dependent variables. The significance of the results was determined in the form of a *P* value that was classified as non-significant when *P* value was > 0.05 and significant when the *P* value was ≤ 0.05.

The power of the sample size was estimated using g*power software based on an effect size of 0.5, an overall type I error rate (α) ≤ 0.05, and 150 subjects (120-case, 30-control) expected to achieve a power of more than 80%.

Results

Descriptive and comparative statistics

This work was carried out on 150 Egyptian children (110 males (73.3.%) and 40 females (26.6%)). Their mean ages ranged between 36 and 120 months. Their language age ranged between 17 and 96 months.

Children were divided into two main groups: group I (cases group) and group II (control group). Group I was further divided into 4 groups (group Ia: children with ADHD; group Ib: children with ASD; group Ic: children with SLI and Last group Id: children with mild ID). The mean age of the children in the four groups as well as their receptive and expressive language mean ages is also detailed in Table 1. Children in the case group and the control group were matched according to their chronological age and gender distribution. They were all from similar socioeconomic standards.

The percentage of children who responded as typical performance, probable difference, and definite difference was determined in Table 2.

Independent *t*-test compared children with ASD, ADHD, SLI, and ID on one side and children with h normal language development on the other side in different SP sectors (data are shown in Table 3). There is a significant difference between children with SLI and children with normal language development in emotional and social modulation of incoming sensory stimuli and *P* value was 0.002**. There is a significant difference between children with ADHD and children with normal language development in the modulation of visual input affecting emotional response and activity and emotional and social modulation of incoming sensory stimuli and *P* value was 0.023* and 0.012* respectively. There is a significant difference between children with ASD and children with normal language development in the modulation of movement affecting activity level and emotional and social modulation of incoming sensory stimuli and *P* value were 0.009** and 0.035* respectively. There is a significant difference between children with ID and children with normal language development in auditory processing, emotional and social modulation of incoming sensory stimuli, and thresholds for response and *P* value were 0.005**, 0.001**, and 0.018* respectively.

Independent *t*-test compared children with ASD, ADHD, and ID with children with SLI in different SP sectors (data are shown in Table 4). There is a significant difference between children with ASD and children with SLI in the modulation of movement affecting activity level and emotional and social modulation of incoming sensory stimuli and *P* value was 0.029* and 0.026* respectively.

Independent t-test compared children with ASD and ID with children with ADHD in different SP sectors (data are shown in Table 5). There is a significant difference between children with ASD and children with ADHD in modulation of movement affecting activity level *P* value was 006**.

Independent *t*-test compared children with ASD and children with ID in different SP sectors (data are shown in Table 6).

Correlative statistics

Spearman correlation test correlated language ages and different sensory sectors of SP among the four main types of delayed language development.

Among ADHD children receptive and expressive language correlated negatively with auditory, visual, and vestibular processing scores ($r = -0.548$ *P* value was 0.004** $r = -0.677$, *P* value was < 0.001**, $r = -0.553$ and *P* value was 0.003** respectively).

Among ASD children receptive language correlated negatively with auditory processing scores ($r = -0.66$ *P* value was 0.027*).

Among SLI children receptive language age correlated negatively with modulation related to body position and movement, modulation of sensory input affecting emotional responses, emotional social responses, the behavioral outcome of the sensory responses, and items indicating thresholds for responses ($r = -0.477$ *P* value was 0.021*, $r = -0.518$ *P* value was 0.011*, $r = -0.437$ *P* value was 0.037*, $r = -0.537$ *P* value was 0.008** respectively). The expressive language correlated with oral sensory processing modulation related to body position and movement, modulation of sensory input affecting emotional responses,

Table 1 The mean and SD of the chronological age, the receptive language, and the expressive language ages among the studied groups

Types of DLD Mean age	ADHD		ASD		SLI		ID		Control	
	Mean ± SD	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean (± SD)	Range	Mean ± SD	Range
Chronological Age (months)	72.46 (± 26.0)	39–120	71.9 (± 20.17)	39–93	70.65 (± 24.7)	36–120	73.2 ± 29.05)	36–120	72.50 (± 27.48)	39–120
RA (months)	48.65 (± 23.52)	18–96	30.81 (± 8.40)	17–42	39.17 (± 13.65)	17–60	49.7 (± 30.9)	30–96	63.0 (± 24.9)	30–102
EA (months)	50.41 (± 21.83)	15–89	24.09 (± 5.62)	17–33	35.0 (± 12.74)	15–54	49.2 (± 39.4)	24–108	68.8 (± 26.89)	36–108

The mean age of the children in the four groups as well as their mean receptive and expressive language ages is also detailed in Table 1. Children in the 5 studied groups were matched according to their chronological ages and gender distribution

SD standard deviation, *DLD* delayed language development, *ADHD* attention deficit hyperactivity disorder, *ASD* autism spectrum disorders, *SLI* specific language impairment, *ID* intellectual disability

Table 2 The percentage of different responses plotted by children on the SP in cases group

The sensory modalities	ADHD group			ASD group			SLI group			ID group		
	1%[a]	2%[b]	3%[c]	1%[a]	2%[b]	3%[c]	1%[a]	2%[b]	3%[c]	1%[a]	2%[b]	3%[c]
S1 (auditory)	37%	35.3%	28.6%	27.2%	9.1%	63.6%	30.4%	21.7%	47.8%	55.5%	44.4%	0
S2 (visual)	53.8%	19.2%	26.9%	54.5%	18.2%	27.3%	73.9%	8.7%	17.4%	55.5%	44.4%	0
S3(vestibular)	38.4%	7.6%	53.8%	45.4%	0	54.5%	52.2%	4%	43.4%	44.4%	0	55.5%
S4(touch)	26.9%	42.3%	30.7%	63.6%	9%	27.2%	47.8%	13%	39%	44.4%	11.1%	44.4%
S5 (multisensory)	26.9%	23%	50%	18.2%	63.6%	18.2%	34.7%	26.1%	39%	44,4%	22.2%	33.3%
S6 (oral)	46.2%	15.4%	38.5%	54.5%	0	45.5%	34.7%	21.7%	43.5%	33.3%	33.3%	33.3%
M1(tone/endurance)	30.7%	15.4%	53.8%	27.3%	9%	63.6%	60.8%	4.3%	34.7%	22.2%	0	77.8%
M2(body position and movement)	26.9%	11.5%	61.5%	27.3%	45.5%	27.3%	21.7%	13%	65.2%	44.4%	22.2%	33.3%
M3(modulation of movement affecting activity level)	50%	34.6%	15.3%	18.2%	18.2%	63.6%	43.4%	34.7%	21.7%	55.5%	0	44.4%
M4 (modulation of sensory input affecting emotional response)	19.2%	11.5%	69.2%	0	36.4%	63.6%	13%	4.3%	82.6%	0	44.4%	55.5%
M5(modulation of visual input affecting emotional response and activity)	30.7%	50%	19.2%	45.4%	45.4%	9%	43.5%	30.4%	54.5%	22.2%	44.4%	33.3%
E1 (emotional/social)	30.7%	15.4%	53.8%	0	27.3%	72.2%	30.4%	30.4%	39.1%	44.4%	22.2%	33.3%
E2 (behavioral outcomes of sensory processing)	23.1%	23.1%	53.8%	0	27.2%	72.7%	13%	45.5%	65.2%	66.6%	0	33.3%
E3 (thresholds for response)	38.5%	26.9%	34.6%	27.2%	45.5%	27.2%	30.4%	21.7%	47.8%	66.6%	33.3%	0

The percentage of children who responded as typical performance, probable difference, and definite difference was determined

1[a] = children responded with typical performance, 2[b] = children responded with probable differences, and 3[c] = children responded with definite problem

Table 3 Comparison of different SP sectors between children with language disorders (ASD, ADHD, SLI, and ID) and children with normal language development

Lang. dis SP	control	SLI		ADHD		ASD		ID	
	M (SD)	M (SD)	*p* value	M (SD)	*p* value	M (SD)	*p* value	M (SD)	*p* value
S1	2.50 (±0.84)	2.2 (±0.8)	0.334	2.0 (±0.9)	0.137	2.4 (±0.9)	0.730	1.44 (±0.53)	0.005**
S2	2.1 (±0.73)	1.43 (±0.8)	0.030	1.7 (±08)	0.246	1.7 (±0.9)	0.317	1.44 (±0.66)	0.942
S3	2.6 (±0.69)	1.9 (±0.9)	0.058	2.2 (±0.9)	0.194	2.1 (±1)	0.210	2.11 (±1.0 5)	0.245
S4	1.9 (±0.73)	1.9 (±0.9	0.969	2.0 (±0.7)	0.629	16 (±0.9)	0.482	2 (±1)	0.8
S5	2.3 (±0.82)	2.04 (±0.9)	0.438	2.2 (±0.9)	0.829	2.0 (±0.6)	0.358	1.88 (±0.92)	0.320
S6	1.7 (±0.94)	2.1 (±0.9	0.273	1.9 (±0.9)	0.527	1.9 (±1.0	0.638	2 (±0.86)	0.483
M1	2.4 (±0.84)	1.7 (±0.9)	0.070	2.2 (±0.9)	0.613	2.4 (±0.9)	0.926	2.55 (±0.88)	0.699
M2	2.3 (±0.48)	2.4 (±0.8)	0.641	2.3 (±0.9)	0.878	2 (±0.8)	0.306	1.88 (±0.92)	0.235
M3	1.4 (±0.84)	1.8 (±0.8)	0.221	1.7 (±0.74)	0.383	2.5 (±0.8)	0.009**	1.88 (±1.05)	0.277
M4	2.2 (±1.03)	2.7 (±0.7)	0.117	2.5 (±0.8)	0.364	2.6 (±0.5)	0.227	2.55 (±0.55)	0.366
M5	1.3 (±0.48)	1.8 (±0.8)	0.073	1.9 (±0.7)	0.023*	1.63±0.7)	0.209	2.11 (±0.78)	0.14
E1	3.0 (±0.00)	2.1 (±0.8)	0.002**	2.2 (±0.9)	0.012*	2.7 (±0.5)	0.081	1.88 (±0.92)	0.001**
E2	1.726	2.5 (±0.7)	0.094	2.3 (±0.8)	0.347	2.7 (±0.5)	0.035*	1.7 (±1)	0.465
E3	1.726	2.2 (±0.9)	0.819	1.96 (±0.9)	0.660	2.0 (±0.8)	0.766	1.3 (±0.5)	0.018*

Independent *t*-test

S1 auditory processing, *S2* visual processing, *S3* vestibular processing, *S4* touch processing *S5* multisensory processing, *S6* oral processing, *M1* tone/endurance, *M2* body position and movement, *M3* modulation of movement affecting activity level, *M4* modulation of sensory input affecting emotional response, *M5* modulation of visual input affecting emotional response and activity, *E1* emotional/social, *E2* behavioral outcomes of sensory processing, *E3* thresholds for response, *SP* sensory processing lang, *dis* language disorders

Children with ASD, ADHD, SLI, and ID were significantly differentiated from children with normal language development in the SP sectors

* Significant

** Highly significant

Table 4 Comparison of the SP between children with SLI and that of ADHD, ASD, and ID

Language disorders SP	SLI	ADHD		ASD		ID	
	M (SD)	M (SD)	*p* value	M (SD)	*p* value	M (SD)	*p* value
S1	2.17 (±0.88)	2.0 (±0.89)	0.499	2.4 (±0.9)	0.569	1.44 (±0.53)	0.029
S2	1.43 (±0.78)	1.73 (±0.87)	0.222	1.7 (±0.9)	0.341	1.44 (±0.66)	0.973
S3	1.91 (±0.99)	2.15 (±0.96)	0.395	2.09 (±1)	0.635	2.11 (±1.05)	0.622
S4	1.91 (±0.94)	2.03 (±0.77)	0.613	1.63 (±0.9)	0.429	2 (±1)	0.820
S5	2.04 (±0.87)	2.23 (±0.86)	0.456	2.0 (±0.63)	0.884	1.88 (±0.92)	0.662
S6	2.08 (±0.90)	1.92 (±0.93)	0.536	1.9 (±1.04)	0.612	2(±0.86)	0.806
M1	1.73 (±0.96)	2.23 (±0.9)	0.072	2.36(±0.9)	0.083	2.55 (±0.88)	0.035
M2	2.43 (±0.84)	2.34 (±0.89)	0.723	2.0 (±0.78)	0.159	1.88(±0.92)	0.120
M3	1.78 (±0.79)	1.65 (±0.74)	0.561	2.5 (±0.82)	0.029*	1.88 (±1.05)	0.759
M4	2.69 (±0.70)	2.5 (±0.81)	0.375	2.63 (±0.5)	0.804	2.55 (±0.55)	0.594
M5	1.82 (±0.83)	1.88 (±0.71)	0.792	1.63 (±0.7)	0.516	2.11 (±0.78)	0.384
E1	2.08 (±0.84)	2.23 (±0.9)	0.571	2.7 (±0.46)	0.026*	1.88 (±0.92)	0.567
E2	2.52 (±0.73)	2.30 (±0.83)	0.348	2.7 (±0.46)	0.402	1.7 (±1)	0.012
E3	2.17 (±0.88)	1.96 (±0.87)	0.403	2.0 (±0.77)	0.582	1.3 (±0.5)	0.012

Independent *t*-test

S1 auditory processing, *S2* visual processing, *S3* vestibular processing, *S4* touch processing *S5* multisensory processing, *S6* oral processing, *M1* tone/endurance, *M2* body position and movement, *M3* modulation of movement affecting activity level, *M4* modulation of sensory input affecting emotional response, *M5* modulation of visual input affecting emotional response and activity, *E1* emotional/social, *E2* behavioral outcomes of sensory processing, *E3* thresholds for response. *SP* sensory processing lang., *dis* language disorders, *M* mean, *SD* standard deviation

The table showed the significance of the difference between the mean of responses among children with SLI and children suffering from other types of DLD

* mean significant difference

Table 5 Comparison between the SP of children with ADHD and that of ASD and ID

Lang. dis SP	ADHD	ASD		ID	
	M (SD)	M (SD)	*p* value	M (SD)	*p* value
S1	2.0 (±0.89)	2.36±0.92	0.271	1.44 (±0.53)	0.89
S2	1.73 (±0.87)	1.72±0.90	0.991	1.44 (±0.66)	0.364
S3	2.15 (±0.96)	2.09±.1.04	0.861	2.11 (±1.05)	0.912
S4	2.03 (±0.77)	1.63±0.92	0.181	2 (±1)	0.906
S5	2.23 (±0.86)	2.0±0.63	0.430	1.88 (±0.92)	0.322
S6	1.92 (±0.93)	1.90±1.04	0.968	2 (±0.86)	0.830
M1	2.23 (±0.90)	2.36±0.92	0.688	2.55 (±0.88)	0.358
M2	2.34 (±0.89)	2.00±0.77	0.271	1.88 (±0.92)	0.198
M3	1.65 (±0.74)	2.45±0.82	0.006**	1.88 (±1.05)	0.470
M4	2.50±0.81)	2.63±0.50	0.611	2.55 (±0.55)	0.850
M5	1.88 (±0.71)	1.63±0.67	0.332	2.11 (±0.78)	0.824
E1	2.23 (±0.9)	2.72±0.46	0.096	1.88 (±0.92)	0.340
E2	2.30 (±0.83)	2.72±0.46	0.129	1.7 (±1)	0.068
E3	1.96 (±0.87)	2.0±0.77	0.900	1.3 (±0.5)	0.050

Independent *t*-test

S1 auditory processing, *S2* visual processing, *S3* vestibular processing, *S4* touch processing, *S5* multisensory processing, *S6* oral processing, *M1* tone/endurance, *M2* body position and movement, *M3* modulation of movement affecting activity level, *M4* modulation of sensory input affecting emotional response, *M5* modulation of visual input affecting emotional response and activity, *E1* emotional/social, *E2* behavioral outcomes of sensory processing, *E3* thresholds for response, *SP* sensory processing lang, *dis* language disorders, *M* mean, *SD* standard deviation

The table showed the significance of the difference between the mean of responses among children with ADHD and children suffering from other types of DLD

** highly significant changes

Table 6 Comparison between the SP of children with ASD and that of children with ID

Language disorders Sensory profile	ASD	ID	
	M (SD)	M (SD)	*p* value
S1	2.36 (±0.92)	1.44 (±0.53)	0.016
S2	1.72 (±0.9)	1.44 (±0.66)	0.419
S3	2.09 (±1.04)	2.11	0.966
S4	1.63 (±0.92)	2 (±1)	0.41
S5	2.0 (±0.63)	1.88 (±0.92)	0.754
S6	1.90 (±1.04)	2 (±0.86)	0.837
M1	2.36 (±0.92)	2.55 (±0.88)	0.643
M2	2.00 (±0.77)	1.88 (±0.92)	0.774
M3	2.45 (±0.82)	1.88 (±1.05)	0.193
M4	2.63 (±0.50)	2.55 (±0.55)	0.731
M5	1.63 (±0.67)	2.11 (±0.78)	0.162
E1	2.72 (±0.46)	1.88 (±0.92)	0.017
E2	2.72 (±0.46)	1.7 (±1)	0.006
E3	2.0 (±0.77)	1.3 (±0.5)	0.039

Independent *t*-test

S1 auditory processing, *S2* visual processing, *S3* vestibular processing, *S4* touch processing, *S5* multisensory processing, *S6* oral processing, *M1* tone/endurance, *M2* body position and movement, *M3* modulation of movement affecting activity level, *M4* modulation of sensory input affecting emotional response, *M5* modulation of visual input affecting emotional response and activity, *E1* emotional/social, *E2* behavioral outcomes of sensory processing, *E3* thresholds for response, *SP* sensory processing lang., *dis* language disorders, *M* mean, *SD* standard deviation

The table showed the significance of difference between the mean of responses among children with ASD and children suffering from other types of DLD

emotional social responses, behavioral outcome of the sensory responses, and items indicating thresholds for responses ($r = -0.513$ and P value was 0.012*, $r = -0.422$ and P value was 0.045*, $r = -0.584$ and P value was 0.003**, $r = -0.553$ and P value was 0.006** $r = -0.503$ and P value was 0.015* respectively).

Among ID children receptive language grew independent of the sensory profile. While expressive language age correlated negatively with vestibular sensory score, multisensory processing scores, modulation of sensory input affecting emotional responses, and behavioral outcome of the sensory responses ($r = -0.664$ P value was 0.051, $r = -0.706$ P value was 0.033, $r = -0.664$ P value was 0.051, $r = -0.706$ P value $= 0.033$ respectively).

Logistic regression analysis of factors that may affect language age showed that behavioral/emotional responses to incoming sensory stimuli are the independent predictors affecting outcome.

Discussions

Sensory processing is crucial for language development and academic achievement. Atypical language development and sensory processing are related and considered as two aspects of the same coin. Sensory processing disorders cause problems in perceptual, motor, behavioral, and academic skills [22]. Each neurodevelopmental disorder has a specific sensory profile, which helps physicians understand the aspects of the disorder [10].

The current work found that children with typical language development have compromised sensory profiles in certain areas. In agreement with these findings, Galiana-Simal et al. [20] reported similar results. They demonstrated the presence of 5–19% idiopathic SPDs among children without psychiatric disorders. Boogert et al. [39] determined that SPDs may be related to anxiety as well as depression among young and old-aged children. A considerable prevalence was reported among other disorders.

This study revealed that children with and without delayed language development (DLD) are differentiated on SP. Children with DLD showed atypical responses in areas related to modulation of movement-affecting activities, emotional and social responses, and behavioral outcomes of sensory processing. Mirazakhani and Sahriyarpour [1] determined that sensory modulation disorders are the most common form of SPDs linked to brain damage disorders, particularly in children with ASD, ADHD, and learning disability.

Sensory profile specific for each type of delayed language development

The current work uniquely described the SP specific to each type of language disorder (ASD, ADHD and SLI, and ID) and correlated this profile to language age (receptive and expressive). Our findings determined that the prevalence of atypical sensory processing was in the following order: ASD followed by SLI, ADHD, and finally that of the children with ID. Children with ASD had the highest prevalence of SPDs. The literature has determined that children with ASD suffer from the highest prevalence of SPDs among children with neurodevelopmental disorders, reaching up to 95% [40].

The study reveals that in comparison to children with normal language development, children with ASD exhibit atypical sensory processing in various aspects of their SP, including modulation of movement and behavior outcomes. The frequency of sensory modalities that were affected was as follows: modulation of movement affecting emotional response (99%), multisensory processing disorders, modulation of movement affecting activity level (81%), auditory processing, sensory processing in relation to endurance, modulation related to body movement (72% for each), vestibular processing (54.5%), visual processing (45%), oral sensory processing among (45%), and touch processing (36%). Modulation of sensory input affecting emotional responses and activity, emotional and social responses, and behavioral outcomes were affected by up to 99%.

Like data found in the current work (Table 3), Van der Linde et al. [10] found significant differences in areas related to emotional/social responses between children with ASD and typically developing children. This type of SPD is responsible for emotional outbursts following inappropriate transitioning from one activity to the next. Weimer et al. [41] supported the idea that ASD patients responded similarly to the control group provided that visual aid is considered. Their performance is affected in nonvisual tasks. Jasmine et al. [42] agreed with the current work. They found that children with ASD have atypical sensory responses that are manifested by impaired gross and fine movement activities that compromise daily life activities (even in the absence of cognitive impairment). Oral sensory processing disorder was reported by Provost et al. [43] as a compromised sensory input among children with ASD. In the other direction, Thy et al. [44] hypothesized that SPDs may not be involved in social dysfunction among ASD children. The explanation of the diversity of findings was determined by Elsaedi et al. [27]. They concluded that SP among children with ASD changes with the age of presentation.

Gal et al. [45, 46] demonstrated that stereotyped movements (among 72% of ASD cases) are features of atypical SPDs in which the body responds atypically to over or understimulation.

Similar to the current work, Sobhy et al. [31] showed that 80% of children with ASD responded atypically to the short sensory profile in comparison to the control in the area of auditory processing, multisensory processing, and emotional and social responses. Alsaedi et al. [27] supported our results and concluded that there is an age-related decline in sensory processing difficulties among their participants.

The current work determined that children with SLI were differentiated from children with normal language development in areas related to modulation of sensory input affecting emotional response (82.6%), auditory processing (68.9%), behavioral outcomes of sensory processing and body position and movement (65.2% each), modulation of visual input affecting emotional response and activity (54.5%), threshold for response (47.8%), vestibular processing, and oral sensory processing (43.4% each). Visual processing differed only among 26% of participants (Table 3).

In the same line with the current work, Van der Linde et al. [10] determined that children with SLI had a unique pattern of sensory responsiveness. They utilized the same tool and determined that (81.8%) of children with SLI had difficulty with all areas of sensory processing (multisensory processing). Our results approached their results in areas related to vestibular, oral processing, behavior, and emotional response patterns. Both studies reported nearly the same prevalence of auditory processing disorder. In modulation sectors, a higher prevalence of difficulty with modulation of movement affecting activity levels was reported among their work.

Taal et al. [14] approximated our results in auditory processing and vestibular processing deficits among SLI children. They related the high prevalence of oral processing disorders in SLI to apraxia of speech which affects language learning, and therefore multisensory modalities may improve outcomes (Table 2).

Brumbach et al. [47] found the answer to high comorbidity between SLI and motor disorders. Neuroanatomical studies revealed that Broca's area is responsible for both syntax development and motoric development. Jäncke et al. [48] determined that white matter deficits in the left hemisphere are responsible for comorbidities of language, motor, and behavioral disorders.

The current work showed a higher prevalence of SPDs in the modulation of sensory input affecting emotional response than that reported by LeBarton and Iverson

[49]. Both works reported typical performance in visual processing in most participants.

Despite using different tools (i.e., short sensory profile) [50], Simpson et al.'s [51] data were in accordance with those of the current work. The authors claimed that 60% of children with developmental language disorders (SLI) exhibit sensory differences, auditory filtering deficits, low energy/weakness, under responsiveness, behavioral outcomes, and threshold for response.

Tactile sensory processing was an area of difference between the current work and Simpson et al.'s work. This item was significantly compromised among their sample. This could be due to the inclusion of children with below-average cognitive skills in their work. Abu-Dahab et al. [31] determined that tactile defensiveness in young children is an indicator of the severity of developmental impairment.

Cunha et al. [52] reported that auditory processing disorder is related to cognitive profile (poor vocabulary and spatial reasoning). Sangani and Ramak [53] have another point of view; they claimed that auditory processing disorders are related to working memory deficits (a common deficit among children with SLI).

Tallal and Piercy [54], Szelag et al. [55], and Vatakis and Allman [56] supposed that deficits in temporal information processing (TIP) are an accused factor for the development of SPDs among children with ADHD, SLI, and ASD. Szelag et al. [57] claimed that implementation of TIP rehabilitation (nonverbal information) may boost the communicative outcome in SLI children.

This study found that children with ADHD had a distinct sensory profile compared to the control group, specifically in terms of visual input modulation affecting emotional responses and activities. The prevalence of atypical sensory processing was in the following order: modulation of sensory input affecting emotional responses (80%), multisensory processing (73%), behavioral outcome of sensory processing (76%), modulation of visual input affecting emotional response and activity (69.2%), emotional and social responses and sensory processing related tone/endurance (68% for each), auditory processing (63%), in vestibular processing (61%), and oral sensory processing (54%). These findings were supported by Jung et al. [25] They concluded that visual perception and vestibular processing were distinct sectors that differentiated children with ADHD from typically developing children. The short version of the Sensory Profile of participating children in Mimouni-Bloch et al. [20] showed that approximately 50% of children with ADHD have atypical SP. This may be due to hyperactivity and impulsivity among ADHD associated with poor social interaction and motor planning. [58] Hilton et al. [59] specified that this atypical sensory processing in emotional and sensory responses is the accused domain.

The prevalence of SPDs among children with ADHD was in agreement with Sobhy et al. [31]. The young age of their sample was attributed to the presence of significant differences in most of the examined domains of the short version of the SP. The lowering of SPDs in older children was also supported by Kern et al. [60]. Significant differences found may be attributed to the young age of the sample, not the other way around.

Our work compared SP in children with intellectual disabilities (ID) and a control group. There is a significant difference in auditory processing and modulation of sensory input, impacting emotional responses and activity among children with ID. Wuang et al. [61] determined that SPDs are prevalent among children with ID and contribute to their maladaptive behaviors.

This study found that the highest rate of SPDs in children with ID is related to tone/endurance (in 77.8%). Similarly, Engel-Yeger et al. [62] found that boys with mild ID had atypical sensory performance in domains related to low energy/weakness. They reported a similar prevalence of SPDs in touch processing and oral processing as the current work. Ulla et al. [63] explained that ID severity impairs motor abilities due to severe brain damage and a lack of motivation to develop motor learning.

In accordance with the current work, Engel-Yeger et al. [62] determined that children with all severities of ID seem to experience atypical sensory processing but to a lesser degree than ASD children. The common comorbidities between ASD and ID make it difficult to distinguish each disorder on the sensory profile alone. Mazurek et al. [64], Bitsika et al. [65], Fetta et al. [66], and Schulz and Stevenson [67] specified that the SP among ASD children without ID is related to internalizing and externalizing processing. The results in this area are contradictory [68]. Some studies supported that the sensory profile of children with low-functioning ASD is much affected [69], whereas another study reported a high prevalence of sensory processing problems in high-functioning ASD individuals [70].

The relation between language and sensory processing

The current work determined that among ASD children receptive language correlates negatively with auditory processing scores. Sobhy and his colleagues [31] did not find a correlation between language age and SP. No one can deny the role played by auditory processing especially the central one for language comprehension. Again the young age of children Sobhy et al. study was responsible for contradicting results.

Among children with SLI, receptive language was correlated with modulation of the sensory input in areas related to (body position, body movement, emotional and social responses, behavioral outcomes, and thresholds for responses). The reciprocal relation between social interaction and language understanding and usage could explain this negative correlation. Expressive language was correlated with oral sensory processing. More than 80% of children with SLI are presented with phonological disorders. These phonological disorders have sensory processing deficits and motor bases in the background [71].

Georgopoulo et al. [72] and Leyfer OT et al. [73] went with the current work. They supported the correlation of oral sensory processing with expressive language abilities in SLI children.

McIntosh et al. [50] and Simpson et al. [51] suggested that there is no correlation between language age and the sensory profile. The difference between the two studies could be related to the higher intelligence quotient and younger age of children in the current work (5 years and 5 months (± 24.7) compared to 6 years in Simpson et al.'s [51] work.

Among children with ADHD, the receptive and expressive language age of children with ADHD correlates negatively with auditory, visual, and vestibular processing scores. These results were in accordance with Watson et al. [74]. They determined that atypical sensory processing patterns correlated negatively with language scores. However, Sobhy et al. [31], Liss et al. [75], and Lane et al. [76] found no correlation. The low language age of their participants (3.23 ± 1.1) compared to ~ 7 years in the current work could be the cause.

Among children with ID, the expressive language abilities among children with ID are related to the multisensory processing score, vestibular sensory processing, modulation of sensory input affecting emotional responses, and behavioral outcome of the sensory responses. Similarly, Ikeda et al. [77] and Engel-Yeger et al. [62] found that the sensory profile (auditory memory) is not correlated with the intelligence quotient.

Similarities and differences between SPs of different types of language disorders

The current work determined that the sample of children with SLI was differentiated from children with ASD in the area of modulation of movement affecting activity level, and emotional/social responses. Modulation was more compromised among children with SLI and emotional and social responses were more compromised among children with ASD.

Simpson et al. [51], Little et al. [78], and DeBoth and Reynolds [79] supported the idea of the presence of well-differentiated subtypes of children with neurodevelopmental disorders (including SLI, ADHD, and ASD) on SP within groups.

In agreement with the current work Van der Linde et al. [10] compared the sensory profile among children with SLI, ASD, and ADHD. They found that the sensory profile among SLI children was differentiated from that of children with ASD and ADHD.

Touch processing disorders were not common among children with ASD in the current work due to higher male numbers. Br¨oring et al. [80] claimed that touch processing deficits were related to the female gender. Many studies [26, 81] have found that auditory processing and touch processing deficits are the most affected and differentiating sensory modalities among children with ASD, while others have claimed that evidence is nonconclusive [79].

Georgopoulos et al. [72] and Leyfer OT et al. [73] went with the current work. They agreed with considering modulation related to body position and movement scores as a discriminating score for children with SLI and touch processing score for children with ASD.

Children with (SLI) exhibited a sensory profile mimicking that of children with ADHD. Van der Linde et al. [10] results supported our findings.

Children with SLI and children with ASD were differentiated from children with ID in auditory processing and social and emotional responses. Hulslander et al. [82] and Owens [83] agreed on the role played by auditory processing disorders in manifesting the poor sensory regulation observed among SLI and ASD children. McArthur and Bishop [84] supported these findings by highlighting the important role played by auditory processing disorders and modulation of the amount in the development of speech and language disorders. Cunha et al. [52] have another point of view. They claimed that auditory processing disorder is related to cognitive profile (poor vocabulary and spatial reasoning).

The current study found that children with ASD and ADHD exhibit similar sensory profiles, except for modulation of input affecting activity level. Children with ASD have a higher deficit in this domain.

Sobhy et al. [31] agreed with a similarity between these disorders. They determined that children with ASD and ADHD were differentiated in the proprioceptive processing domain (more compromised in ADHD) and emotional/social response (more compromised in ASD). High comorbidity between ADHD and ASD makes it difficult to differentiate between them.

Camarata et al. [85] agreed with the current work in the aspect that children with ID were differentiated from those with ADHD in areas related to the threshold of the sensory stimuli. They determined that children with ADHD with SPDs responded to stimulation more quickly, more intensely, and for a longer duration.

Patten et al. [86], Tomchek et al. [87], and Watson et al. [74] found that sensory-seeking behaviors have been associated with low language and communication. These behaviors are linked to emerging verbal skills [86] and receptive language skills [87]. Many studies have declined the idea of the specificity of SP to certain disorders. Researchers such as Ashburner et al. [74], Lane et al. [88], and Mimouni-Bloch et al. [19] found that auditory processing disorders are areas of overlap. They claimed that it is a common presentation of SPDs in children with neurodevelopmental disorders, rather than being specific to a diagnostic condition.

Camarata and his colleagues [85] and Cheung and Siu [89] concluded that SPD is not exclusive to ASD, ADHD, or any other developmental condition and that ASD should not be diagnosed using SP.

Limitations and recommendation

This study explores brain connectivity and its impact on children's development and behaviors, providing comprehensive features for different categories of DLD and potentially aiding in the development of specific intervention programs. Communicative assessment should not be limited to the language domain only and the SP should be added to address different aspects of daily behavior and the interaction severity index.

The current study's limitations may be due to the small sample size. Future research should include a larger, representative sample and develop a screening tool to address specific sensory processing deficits. Language assessment should incorporate a specific tool that addresses different aspects of daily behavior and interaction. An intervention program addressing sensory processing deficits specific to each disorder is recommended to improve daily living performance, facilitate integration into regular school settings, and enhance children's development.

Conclusion

Sensory processing deficits are common among different types of DLD, and that sensory profiles could be used as a complementary tool during the evaluation of these cases and in guiding tailored intervention.

Abbreviations

ASD	Autism spectrum disorders
ADHD	Attention deficit hyperactivity disorders
SLI	Specific language impairment
ID	Intellectual disability
SPDs	Sensory processing disorders
SMD	Sensory modulation disorder
SDD	Sensory discrimination disorder
SBMD	Sensory-based motor disorder
SOR	Sensory overresponsivity
SUR	Sensory underresponsivity
DLD	Delayed language development
CARSS	Childhood Autism Rating Scale
DSM-V	Diagnostic and Statistical Manual of Mental Disorders 5th Edition
SB-5TH	Stanford Binet 5th edition
TD	Typically developing
PLS-4	Modified Preschool Language Scale-4 (Arabic Edition)
IQ	Intelligent quotient
SP	Sensory Profile
SD	Standard deviation
TIP	Temporal information processing

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Authors' contributions
HOM made a substantial contribution to the study concept and the intellectual content. She constructed the study design and performed the clinical study. She makes a substantial contribution to the literature review. She organized the data and performed the statistical analysis. She participated in result interpretation. She wrote the manuscript. She agreed to be the corresponding author and the guarantor of this work. SAE has a substantial contribution to constructing the study design and making the clinical study. She participated in organizing data and performing statistical analysis. She has a substantial contribution to the manuscript writing and editing. She participated in the data interpretation. She has a substantial effort in manuscript submission. She revised the manuscript and made a valuable editing. NFM made a substantial contribution to the design of this work. She participated in the literature review and made the scientific interpretation of the data. She organized the data into statistical form. She performed the statistical analysis. She contributed to data analysis and interpretation. She has a substantial contribution to manuscript writing. She has a substantial contribution to manuscript submission. She revised the manuscript and performed valuable editing. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The current work was conducted in accordance with the guidelines of the ethical committee of the Faculty of Post-graduate Childhood Studies, Ain Shams University, Cairo, Egypt. Parents of participating children were informed about the objectives of the study and written consent was taken. It received the approval No: FPGCS-ASUREC/ RHDIRB2020110401/MSDFC-S1.

Consent for publication
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Competing interests
The authors declare that they have no competing interests.

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