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ORIGINAL ARTICLE

Social Interaction and Atypical Sensory Processing in Children with Autism Spectrum Disorders☆

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KEYWORDS
autism spectrum disorder;
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Summary *Objective/Background:* Many children with autism spectrum disorders (ASDs) have sensory processing disorders (SPDs), which may limit many facets of daily life, including social interaction, an important domain of occupational therapy. Therefore, we examined the relationship between social interaction deficits and SPD in 4—6-year-old children with ASD without intellectual disorders.
Methods: The Social Responsiveness Scale (SRS) and the Japanese Sensory Inventory-Revised (JSI-R) questionnaires were administered to parents of children with ASD and children in the control group ($n = 42$ each).
Results: Response analyses revealed significant intergroup differences in scores for the questionnaires, with more atypical sensory processing patterns and social interaction deficits observed in children with ASD. Significant correlations were observed between the SRS total raw scores and subcategory scores of all sensory modalities of the JSI-R in the entire experimental group. The SPD symptoms were significantly associated with social interaction deficits in children with ASD.
Conclusion: It is important that occupational therapists consider SPD symptoms in children with ASD to provide early intervention for social interaction deficits.

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Introduction

Autism spectrum disorders (ASDs) are characterized by deficits in social interactions and communication, as well as by the presence of stereotyped behaviours and restricted interests. In addition, previous studies have also reported that there are significant differences between the sensory experiences and responses of individuals with ASD and those of their normally developing peers (Baker, Lane, Angley, & Young, 2008; Baranek, David, Poe, Stone, & Watson, 2006; Tomchek & Dunn, 2007).

The symptoms of sensory processing disorders (SPDs) are common in children with ASD, with incidence rates ranging from 45% to as high as 95% (Baker et al., 2008; Baranek et al., 2006; Ben-Sasson et al., 2009b; Maskey, Warnell, Parr, Le Couteur, & McConachie, 2013). SPD refers to sensory processing challenges and deficiencies, and the condition interferes with higher level functions such as social participation (Bundy, Lane, & Murray, 2002; Cosbey, Johnston, Dunn, & Bauman, 2012).

Previous studies on SPD in children with ASD indicate the presence of interrelationships between sensory processing pattern and social, emotional, and behavioural functions (Ashburner, Ziviani, & Rodger, 2008; Baker et al., 2008; Jasmin et al., 2009; Lane, Young, Baker, and Angley, 2010a; Reynolds, Bendixen, Lawrence, & Lane, 2011). In addition, stereotypical and repetitive behaviours are also commonly related to SPD in children with ASD and intellectual disability (Joosten & Bundy, 2010). The draft of the *Diagnostic and Statistical Manual of Mental Disorders-5* (DSM-5) also includes "unusual sensory behaviour" as one type of "restricted repetitive pattern of behaviour." Considering the relationship between SPD and social behaviours, SPD may hinder the ability of children with ASD to participate in primary social interactions (Caminha & Lampreia, 2012). Children with ASD may seek sensations later on when it is not appropriate, and there is a delay in exploring the social environment (Ben-Sasson et al., 2009b).

Occupational therapists have provided practices and interventions to children with SPD based on the sensory integration theory (SIT) since it was introduced by Ayres (1963). The primary postulate of this theory is that learning occurs when a person has the ability to receive accurate sensory information, process it, use it to organize behaviours, and adapt responses (Bundy et al., 2002). Many children with ASD exhibiting SPD have difficulties in modulating their responses to sensory input, and occupational therapists assume that the child's behaviour reflect the central processing of sensory input from environment (Miller, Anzalone, Lane, Cermak, & Osten, 2007). Case-Smith and Miller (1999) reported that more than two-thirds of 292 occupational therapists provided service to children with ASD. Occupational therapists used various kinds of intervention approach such as child-centred play, environment modification, and fine motor intervention, and approach based on SIT were most frequently used by them (Case-Smith & Miller, 1999; Kim, Bo, & Yoo, 2012; Pfeiffer, Koenig, Kinnealey, Sheppard, & Henderson, 2011). Occupational therapists also work with individuals with ASD to improve their daily life and facilitate their development throughout life. In particular, qualitative impairment of social interaction is a core symptom of ASD and occupational therapists need to consider this domain, because social interactions are necessary for occupational engagement (Simmons & Griswold, 2010). Therefore, studies are needed to examine the association between SPD and social interaction deficits.

There are a few studies on the relationship between social interaction and sensory processing in children with ASD; however, thus far, these studies using different chronological age participants have reported different results. Baker et al. (2008) reported a significant relationship between SPD and social, emotional, and behavioural responsiveness in 2—8-year-old children with ASD. Other previous studies have shown a strong correlation between atypical sensory processing and the severity of social impairments in 6—10-year-old children with high-functioning ASDs (HFASDs) (Hilton et al., 2010). By contrast, Rogers, Hepburn, and Wehner (2003) reported that atypical sensory responses were unrelated to social communicative symptoms in 2—4-year-old children with ASD. No similar study has investigated social behaviour in 4- and 6-year-old children with ASD and atypical sensory processing. The early childhood patterns of sensory sensitivity can change during the typical developmental transition that occurs after the age of 2, during which children figure out ways to regulate their response to sensations and the development and manifestations of sensory processing patterns. These developmental processes are likely influenced by both biologic and environmental experiences throughout the toddler and early preschool years (Ben-Sasson, Carter, & Briggs-Gowan, 2010). Improvements in language and cognitive development during the preschool period (3—5 years of age) are dramatic changes in the social, emotional, and moral domains (Bredekamp & Copple, 1997). Although different instruments were used in each of these previous studies, it is important to investigate the influence of age on this issue when considering appropriate early intervention. Early intervention is necessary to address developmental issues and minimize the risk of development of co-morbid anxiety disorders in individuals with ASD (White, Oswald, Ollendick, & Scahill, 2009). More children with ASD are being diagnosed at earlier ages (around 3 years of age), and early intervention program are provided to them. However, many children without intellectual disorders are not diagnosed until after they reach the age of 5 (Pringle, Colpe, Blumberg, Avila, & Kogan, 2012). In addition, previous research reported that autism severity and symptoms increase with decreasing age and intellectual quotient (IQ) in children with autism (Mayes & Calhoun, 2011). Thus, we also need to consider the influence of cognitive function such as intellectual ability.

A relationship between SPD and diminished sociability has been suggested in Japanese children, especially in the occupational therapy practitioners. A few studies have reported that children with ASD had difficulty in sensory processing (Tsuji et al., 2009), but no study has directly addressed the relationship between SPD and sociability in Japanese children with ASD using standardized assessment tools created or modified for Japanese children. Previous research on SPD used the sensory profile (SP) (Dunn, 1999). The SP measures children's sensory processing, modulation, behavioural, and emotional responses. The Sensory Experiences Questionnaire has also been used to evaluate behavioural responses to common everyday sensory experiences (Baranek et al., 2006). In previous studies performed in Japan, the Japanese Sensory Inventory-Revised (JSI-R) was used as a standardized questionnaire to assess behaviours related to SPD (Ota, Tsuchida, & Miyajima, 2002). There is no quantitative assessment tool for assessing the severity of social impairment in individuals with ASD; however, the Social Responsiveness Scale (SRS) has recently been cross-culturally translated to Japanese by Kamio et al. (2009). These assessment tools were used in this study.

The purpose of this study was to examine the association between SPD and social interaction deficits in Japanese children with ASD, especially (a) to research SPD symptoms in young Japanese children with ASD; (b) to examine correlation between behaviours related to SPD and social interaction deficits in 4- and 6-year-old children; and (c) to determine whether SPD symptoms are predictive of social impairment severity in children with ASD without intellectual disorders.

Methods

Participants

Eighty-four children aged 48–72 months were enrolled in the study, including 42 children with ASD (36 male, 6 female) and 42 typically developing (TD) children (32 male, 10 female) who served as a control group that was matched for age and sex (Table 1). All children were recruited from six special education institutions and four preschools. Parental consent was obtained prior to study initiation. Individuals with ASD were evaluated by licensed psychiatrists having extensive experience with children with ASD, and diagnosis of ASD was confirmed with the clinical judgement based on the standard diagnostic criterion of the DSM-IV-text revision (2000). All children with ASD were attending special educational institutions for early intervention. Cognitive function of children with ASD was assessed by psychologists with extensive experience. Of the 42 children in the ASD group, full-scale IQ of 10 children was assessed using the Wechsler Intelligence Scale for Children-III or the Tanaka–Binet Intelligence Scale (V) (Matsubara, Fujita, Maekawa, & Ishikuma, 2005) and developmental quotient (DQ) was assessed in 32 children using the Kyoto Scale of Psychological Development (Ikuzawa, Matsushita, & Nakase, 2001). The Kyoto Scale of Psychological Development is another criterion to measure cognitive functioning, which comprises cognitive–adaptive (nonverbal reasoning or visuospatial assessed using materials) and language–social (interpersonal relationships, socializations, and verbal abilities) domains. Koyama, Osada, Tsujii, & Kurita (2009) reported that DQ were highly correlated with IQ ($rs = .88$, $p < .01$). In general, an IQ and DQ test score of around 70 indicates a limitation in cognitive functioning. Inclusion criteria for all participants consisted of IQ or DQ of at least 70 [mean = 87.7; standard deviation (SD) = 10.4], no history of cerebral palsy, epilepsy, any other diagnosed major neurological condition, and no uncorrected hearing or sight problems. The children in the control group were recruited from regular preschools and were not receiving any special education services or taking any form of medication. Furthermore, they did not exhibit any developmental delays during the infant medical examination.

Table 1 Participant Characteristics (n = 84).

Character	ASD (n = 42)	Control (TD) (n = 42)	Z	p
Age (mo)				
Median	61.4	60.9	0.04	.96
Sex			chi-square	
Male	36	32	1.24	.27
Female	6	10		
DQ	87.7			
SD	10.4			

ASD = autism spectrum disorder; DQ = developmental quotient; SD = standard deviation; TD = typically developing.

Measures

SRS

The SRS (Constantino, 2005) is a 65-item Likert scale questionnaire to be completed by a parent, teacher, or caregiver who has routinely observed the child in his/her natural social settings for a minimum of 2 months. The five SRS Treatment subscales were developed to provide a differentiated approach and include social awareness, social cognition, social communication, social motivation, and autistic mannerisms. Item response scores range from 1 (not true) to 4 (almost always true). The SRS assesses the behaviour of children or adolescents aged between 4 years and 18 years. The SRS total score and the treatment subscale score are expressed in two ways: SRS raw scores (from 1 to 195) and normalized SRS T-score [mean = 50; standard deviation (SD) = 10]. In both cases, higher scores indicate a greater severity of social impairment. Permission to use the author-approved Japanese research translation of the SRS was granted by the Western Psychological Service (Torrance, USA).

JSI-R

The JSI-R is a standardized assessment tool (Ota et al., 2002; Ota, 2004) comprising 147 items grouped into eight subcategories that are used to describe the behavioural responses of 4–6-year-old children to specific sensory stimuli. The JSI-R items were selected based on a review of the literature on atypical sensory processing (Ayres, 1979). The subcategories probe behaviours related to SPD, including vestibular (30 items), tactile (44 items), proprioception (11 items), auditory (15 items), visual (20 items), olfactory (5 items), taste (6 items), and other (16 items) (Table 2). The percentiles of the normal distribution are calculated for Japanese TD 4–6-year-old children (n = 320; Ota et al., 2002). Test–retest reliability coefficients showed good stability, ranging from 0.34 to 1.0 (Ota, 2004). The item that gained the lowest test–retest reliability was the "other" item "is always sloppy whatever he/she does," which was excluded from analysis. It is completed by

Table 2 Sample JSI-R Items.

Vestibular items
1. Tends to fall or lose his/her balance
5. Avoids jumping down from a higher surface to a lower surface even though it is not so high
26. Jumps a lot on the floor
Tactile items
1. Is sensitive to be touched on the body
8. Dislikes it when people touch his/her hands, and give him/her hug
24. Avoids going barefoot
30. Prefers long-sleeved shirt and long pants
Proprioception items
1. Shows habits of nail biting and teeth grinding
5. Grasps and throws objects with too much force
7. Chews inedible objects having hard and tough texture
Auditory items
3. Seems distracted by background noises, such as refrigerator, ventilating fan, and vacuum cleaner
8. Does not pay attention to people talking
9. Occasionally does not turn around, even when his/her name is called
Visual items
1. Becomes easily distracted when there are many things to look at
14. Has difficulty finding the object of his/her search
20. Seems to look at objects out of the corner of his/her eye
Olfactory items
2. Is under-responsive to smell, and seems to ignore or not notice odours
4. Dislikes specific smells
5. Prefers strong smells
Visual items
1. Notices even small changes in taste
3. Dislikes specific taste of foods
5. Dislikes mixtures of different tastes

JSI-R = Japanese Sensory Inventory-Revised.

parents, who report the frequency of responses to specific sensory events using a Likert scale (0 = never, 1 = unusual, 2 = sometimes, 3 = frequently, and 4 = always). Scoring is performed such that the items in each subcategory are added to obtain a subcategory score. Higher each subcategory score and total scores indicate that the child may have atypical sensory processing patterns related to SPD symptoms. Percentiles are used to clarify the interpretation of the JSI-R raw score, which is classified into the following three ranges: 5th percentile, 20th percentile, and 75th percentile. The 5th percentile is classified as definite SPD symptoms. The distribution of frequent atypical behaviours related to SPD is calculated based on a normal distribution.

Procedures

Ethical approval was granted by the Medical Ethics Committee of the Faculty of Medicine, Kyoto University (Kyoto, Japan). Information about this study was provided by the first author and each preschool teacher, and one parent gave written informed consent for each participant. Parents completed both the SRS and the JSI-R and submitted their questionnaires to the preschool (for the control group) or the special institution attended by the ASD children.

Data analyses

The SRS total raw score, SRS Treatment subscale scores, JSI-R total score, and JSI-R subcategory scores were used for data analysis. The SRS raw scores were used rather than the SRS T-scores because the latter tended to cluster at the highest score range for many of the children with autism (Hilton et al., 2010). This study used seven of the eight subcategories of JSI-R. The "others" subcategory was excluded because many items were related to several sensory modalities in this subcategory. Data were analyzed using SPSS version 20 (IBM, Armonk, NY, USA).

The Mann–Whitney *U* test was used to compare the JSI-R subcategory scores and the SRS Treatment subscale scores of the ASD group with those of the control group. The percentiles of the JSI-R subcategory score in both groups were calculated and they were classified into three ranges. We compared the number of children classified in each range between the ASD group and the control group using the chi-square test.

Spearman rank correlation was used to examine the correlations between the SRS total raw scores and each JSI-R subcategory score in both the entire experimental group and the ASD group or the control group.

A multiple regression analysis was used to identify behaviours based on SPD, which were described by the JSI-R, cognitive function (DQ or IQ), and chronological age (months) that were most closely related to social responsiveness in the ASD group. The Durbin–Watson (DW) test was used to detect correlations between errors; DW values close to 2 means that the residuals are independent, whereas DW values of <1 or >3 suggest the presence of autocorrelations between prediction errors, which creates uncertainty in tests of statistical significance. This study also calculated the variance inflation factor (VIF) to measure the impact of multicollinearity among variables in the regression model.

Results

The ASD group comprised 36 boys and 6 girls. The ratio of boys to girls was higher than 4:1, which was consistent with the sex ratio for ASD currently reported by the Ministry of Health, Labour and Welfare in Japan (2010).

Comparative analysis between the ASD group and the control group

There were significant differences in the JSI-R subcategory scores between the ASD group and the control group, with the exception of the olfactory subcategory ($p = .15$). Significant differences between the groups were also detected for the SRS total raw score and five SRS Treatment subscale scores (Table 3).

Table 3 Comparative Analysis Between ASD and TD: JSI-R and SRS.

	Median value (ASD)	Median value (TD)	Z[a]
JSI-R			
Vestibular	26.5	18.0	3.04**
Tactile	29.5	21.5	2.40*
Proprioception	9.5	5.5	2.60**
Auditory	16.0	6.5	5.25***
Visual	18.5	8.0	3.25**
Olfactory	1.5	1.0	1.45
Taste	3.5	2.0	2.21*
Total score	129.5	75.5	4.27***
SRS			
Awareness	11.0	7.0	4.94***
Cognition	14.0	7.0	5.80***
Communication	25.0	10.5	5.85***
Motivation	10.5	7.0	4.29***
Mannerism	13.5	3.0	5.88***
Total raw score	73.5	34.0	6.24***

Note. ASD = autism spectrum disorder; JSI-R = Japanese Sensory Inventory-Revised; SRS = Social Responsiveness Scale; TD = typically developing.
*$p < .05$, **$p < .01$, ***$p < .001$.
[a] The p values were calculated by Mann–Whitney U test.

Table 4 presents the percentile of the JSI-R subcategory score and total score in the ASD group and in the control group. Significantly more atypical sensory processing patterns were observed in the ASD group than in the control group.

Correlation analysis between the SRS score and the JSI-R score

The JSI-R total scores significantly correlated with the SRS total raw scores for both groups. Strong correlations were also found between the SRS total raw scores and each JSI-R subcategory score for the entire experimental group. When the ASD and the control groups were examined separately, significant correlations were also detected between subcategories within each group, with the exception of the olfactory modality in both groups and taste subcategories in the ASD group (Table 5).

Multiple regression analysis

A multiple regression analysis was performed to test for independent predictors of the SRS total raw scores in children with ASD. The regression equation obtained using data from the ASD group ($R^2 = 0.47$, adjusted $R^2 = 0.46$, F [1, 40] = 36.01, $p < .001$ level, DW = 1.65) provided a model of the relationship between social responsiveness (as measured using the SRS) and SPD (as measured using the JSI-R total scores; Table 6). The VIF values did not exceed 10 for any dependent variable, indicating that the results were not biased by high multicollinearity.

Discussion

The results of this study demonstrate the presence of atypical patterns of sensory processing in children with ASD, which is consistent with the results of previous studies (Baker et al., 2008; Baranek et al., 2006; Ben-Sasson et al., 2009b; Maskey et al., 2013). The moderate-to-significant differences in the JSI-R subcategory scores observed between the ASD group and the control group reflected differences in sensory processing symptoms in each sensory modality among these groups; however, the olfactory subcategory was an exception. Tavassoli and Baron-Cohen (2012) reported that adults with and without ASD did not differ overall in olfactory detection thresholds, and adults with ASD also showed normal adaptation to an olfactory stimulus. Regarding the olfactory system, sensory information goes directly from this system to a specific cortical region, without transmission at the thalamus, which is essential for the cortical functions that mediate attention and arousal and is the gateway to the cortex for all sensory systems (Lane, Lynn, & Reynolds, 2010b). Feeding problems observed in many Japanese children with ASD, and feeding

Table 4 Percentile of JSI-R.

JSI-R subcategories	ASD			TD			Chi-square	p
	5th percentile [%, (n)]	20th percentile [%, (n)]	75th percentile [%, (n)]	5th percentile [%, (n)]	20th percentile [%, (n)]	75th percentile [%, (n)]		
Vestibular	29 (12)	26 (11)	45 (19)	0 (0)	24 (10)	76 (32)	15.4	<.001**
Tactile	26 (11)	19 (8)	55 (23)	0 (0)	17 (7)	83 (35)	13.5	<.001**
Proprioception	21 (9)	29 (12)	50 (21)	2 (1)	21 (9)	76 (32)	9.1	.01*
Auditory	43 (18)	36 (15)	21 (9)	2 (1)	24 (10)	74 (31)	28.3	<.001**
Visual	45 (19)	12 (5)	43 (18)	0 (0)	21 (9)	79 (33)	24.6	<.001**
Olfactory	12 (5)	29 (12)	60 (25)	0 (0)	29 (12)	71 (30)	5.5	.07**
Taste	12 (5)	31 (13)	57 (24)	0 (0)	19 (8)	81 (34)	7.9	.02*
JSI-R Total score	31 (13)	31 (13)	38 (16)	0 (0)	12 (5)	88 (37)	24.9	<.001**

Note. ASD = autism spectrum disorder; JSI-R = Japanese Sensory Inventory-Revised; TD = typically developing.
*$p < .05$, **$p < .01$.

Table 5 Correlation Analysis Between JSI-R Scores and SRS Total Raw Score.

	SRS total raw score[a]		
	Total	ASD	TD
JSI-R score			
Vestibular	0.56**	0.69**	0.38*
Tactile	0.60**	0.63**	0.53**
Proprioception	0.48**	0.44**	0.39*
Auditory	0.73**	0.62**	0.56**
Visual	0.48**	0.53**	0.43**
Olfactory	0.25*	0.08	0.30
Taste	0.40**	0.27	0.46**
Total score	0.74**	0.72**	0.64**

Note. ASD = autism spectrum disorder; JSI-R = Japanese Sensory Inventory-Revised; SRS = Social Responsiveness Scale; TD = typically developing.
*$p < .05$, **$p < .01$.
[a] The p values were calculated using Spearman rank correlation.

symptoms may relate to olfactory sensitivity. The current study, however, did not show olfactory sensitivity in children with ASD, and thus, other factors may relate to these problems. Emond, Emmett, Steer, and Golding (2010) reported feeding problems reflecting neophobia and sensory sensitivity to the colours, tastes, and textures of food.

We found strong correlations between the SRS total raw score and the JSI-R subcategory scores in 4–6-year-old children. This finding confirms previous results that atypical patterns of sensory processing seem to be related to social interaction deficits in children with ASD, even though our participants were in a different age group (Baker et al., 2008; Hilton et al., 2010). It is noteworthy that this relationship was investigated in 4–6-year-old children because of the lack of similar research in this age group; this relationship was not confirmed in a study of 2–4-year-old children (Rogers et al., 2003). Children in the 4–6-year age group are capable of engaging in associative play and cooperative play (Parten, 1932). Children in the age group of 4 years begin to learn to play well with other children and need greater ability to participate in social interactions (Bredekamp et al., 1997). Throughout this period, the social interaction deficits in children with ASD are likely to surface, even if SPD symptoms affect social interaction prior to the age of 3 years.

In addition, the results of the multiple regression analysis confirmed the association between atypical sensory responsiveness and the severity of social interaction deficits in 4–6-year-old children, and that the severity of social interaction deficits correlated significantly with the total JSI-R score rather than cognitive function and chronological age in the ASD group. This result is relevant in that it is consistent with the results of previous studies that full-scale IQ was unrelated to the SRS score in children without intellectual disabilities (Constantino et al., 2003; Constantino, 2005); however, this relationship may exist in children with moderate-to-severe intellectual disability (Constantino, 2005). The current research could not identify patterns of sensory responsiveness and specific sensory modalities because of its sample size, which was too small to allow multiple regression analysis. Several previous studies have reported that the overall severity of SPD is positively associated with ASD symptom severity (Ben-Sasson et al., 2009b; Kern et al., 2007). In addition, Lane et al. (2010a) suggested that sensory under- and over-responding behaviours co-occur and that these patterns co-exist in children with ASD. Conversely, Watson et al. (2011) found that patterns of hyporesponsiveness and seeking, but not of hyper-responsiveness, are linked to the core ASD severity, including social communicative symptoms.

Here, the auditory subcategory score showed the most significant difference ($Z = 5.25$, $p < .001$ level) between the ASD group and the control group and exhibited a strong correlation with the SRS total raw score in the entire cohort ($rs = .73$, $p < .01$), even though a causal relationship as a predictive factor of social interaction deficits was not identified. By contrast, previous research has shown that auditory responsiveness might play a less prominent role as a predictor of social severity among children with HFASD (Hilton et al., 2010). This finding supports the results of several previous studies of auditory sensory processing patterns in individuals with ASD (Baker et al., 2008; Lane et al., 2010a; Tomchek & Dunn, 2007). Dunn (2008) suggested that children with autism were less likely to respond to changes in the sonic environment compared with their neurotypical counterparts, with the exception of instances when they were actively attending to a sound stimulus. Under-responsiveness is a common clinical symptom in children with ASD, and auditory under-responsiveness may impede social responsiveness (Baker et al., 2008; Watson et al., 2011). The auditory items in the JSI-R address behaviours related to poor social responsiveness, including "does not pay attention to a person talking" and "occasionally does not turn around, even when his/her name is

Table 6 Results of Multiple Regression Analysis.[a]

		β	t	p	VIF	R^2	Adjusted R^2	F	p	DW
ASD group	JSI-R Total raw score	**0.68**	5.73	***	1.00	0.47	0.46	36.10	***	1.65
	DQ	−0.13	−1.05		1.11					
	Months	0.21	1.88		1.01					

Note. ASD = autism spectrum disorder; DQ = developmental quotient; DW = Durbin–Watson test; JSI-R = Japanese Sensory Inventory-Revised; VIF = variance inflation factor.
*$p < .05$, **$p < .01$,***$p < .001$.
[a] The p values were calculated using multiple regression analysis.

called." Conversely, atypical behaviours related to hearing also include hyper-reactivity to sounds. Marco, Hinkley, Hill, and Nagarajan (2011) reviewed the studies available on auditory processing in individuals with ASD. This review found that several neurophysiologic studies suggest that individuals with autism show atypical neural activity as early in the processing stream as the primary auditory cortex, and atypical auditory processing may be related to top—down inhibitory process. Children with SPD may be distressed and inattentive in busy environments, such as a classroom. In addition, atypical auditory processing in children with ASD may affect the foundation of language and communication. In the next step of this research, it will be important to consider the different developmental mechanisms and conditions that underlie different patterns of sensory responsiveness and modality-specific profiles (Foss-Feig, Heacock, & Cascio, 2012). Responsiveness to tactile stimuli may have a close relationship with social interaction ($rs = .60$, $p < .01$). Hilton et al. (2010) reported on atypical responses to tactile stimuli as one of the strongest predictors of social interaction deficits. In addition, Blakemore et al. (2006) suggested that tactile hypersensitivity in individuals with ASD was linked to processing of rapidly changing dynamic stimuli, and social interaction is expected to process and modulate their stimuli.

This study had several limitations. First, participants were recruited from a limited region of Japan. Thus, further consideration of culture differences may be necessary. Second, the sample size was small. Third, the data reported in the present study were obtained from questionnaires completed by parents; thus, our conclusions are dependent on the accuracy of parental reporting, which may be influenced by a variety of uncontrolled factors. Finally, DQ and IQ evaluations and diagnoses were made by various professionals; therefore, we could not confirm all the documented results.

Finally, the results of the present investigation demonstrated the presence of a relationship between social interaction deficits and overall SPD symptoms in both the ASD and the control groups. Cosbey et al. (2012) reported that children with SPD appeared to participate in less mature play and that their play was characterized by more solitary and less complex activities than were those of their peers. The symptoms of SPD and social interaction deficits were more severe in the ASD group than in the control group; the association between SPD and social interaction deficits may be a great concern in intervention for children with ASD. In a previous study, children with elevated sensory over-responsivity had more social-emotional problems during school age (Ben-Sasson, Carter, & Briggs-Gowan, 2009a). Thus, earlier intervention and treatment of SPD, especially in 4—6-year-old children with ASD, may enhance social participation in the school environment. Dawson (2008) suggested that earlier intervention enrichment may alter the abnormal development trajectory of children with ASD and help guide brain and behavioural development back towards a normal pathway. We suggest that occupational therapists should consider SPD symptoms when providing early intervention including SIT and adaptations to their home/school environment to enhance social interaction in children with ASD. Future research should determine the specific causal relationships between SPD symptoms and ASD features in reciprocal social behaviours.

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