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Altered sensory integration from body and language development in children with autism spectrum disorder

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Abstract

Aim: Although atypical sensory motor processing has been investigated in children with autism spectrum disorder (ASD), whether or not atypical sensory motor processing is related to altered language function in children with ASD remains unclear.

Methods: This study examined the relationship between sensory motor processing and language conceptual inference ability in 3–10-year-old children with ($n = 61$) and without ($n = 114$) ASD. Language performance was assessed using the language conceptual inference task of the Kaufman Assessment Battery for Children (K-ABC). Sensory processing was assessed using the Caregiver Sensory Profile.

Results: In children with ASD, altered processing of the fine motor/perceptual factor scored by sensory profile was found to be significantly related to language conceptual inference ability in the K-ABC, representing the integrated abilities of language comprehension and language expression, which reflect language semantic concept formation.

Conclusions: For children with ASD, the results suggest a relationship between difficulties of integrating sensory information perceived from the body adjusting fine movement and deficiencies of language semantic conceptual formation.

KEYWORDS

autism spectrum disorder, language conceptual inference ability, sensory integration, sensory motor processing, sensory profile

INTRODUCTION

Autism spectrum disorder (ASD) is characterized by deficits of social interaction and communication, restricted interests, and repetitive behaviors.[1] Atypical sensory motor processing is also evident early in the development of individuals with ASD. Several studies have demonstrated that 60%–90% of children with ASD exhibit atypical reactivity such as hypersensitivity or hyposensitivity to sensory stimuli.[2–6] Results of numerous results of studies suggest that changes in primary sensory processing are associated with aspects of higher cognition in ASD.[7,8]

Language issues are also prominent features affecting quality of life and long-term outcomes of ASD.[9] Our previous study demonstrated that 5–7-year-old ASD children without intellectual disability had significantly lower ability for language conceptual inference tasks than age-matched typically developing (TD) children.[10] Language conceptual inference ability is not merely language receptive and expressive language ability; it integrates them and reflects the development of semantic concept formation.

Some reports have described a link between atypical sensory processing and language function (i.e., receptive and expressive ability) in individuals with ASD.[2,11–13] As described earlier, preschool children with ASD particularly show malfunction in language conceptual inference ability.[10] To date, debate persists about the role that the sensory motor system plays in processes of constituting concepts in humans.[14] In contrast to the classical view that conceptual representations differ from the representation in the sensory-motor system of the brain, recent notions that the processing of language concepts is accompanied by activation in modality-specific brain areas are supported by results obtained from numerous studies. This modality-specific approach relies on the assumption that language concepts are fundamentally grounded in perception and action.[15,16] Moreover, the approach proposes close links between sensory motor brain systems and language conceptual systems.[17,18] Although earlier studies have often specifically examined relationships between characteristics of atypical sensory motor processing and language receptive and expressive functions in ASD, the relationship between the sensory motor system and semantic concept formation in children with ASD remains unknown.

This study was conducted to clarify relationships between language conceptual inference ability and sensory motor features in children with ASD. Atypical sensory motor functions are expected to be related to language conceptual inference ability in children with ASD.

METHODS

Participants

For examination in this study as a clinical group, 80 children with ASD (19 girls, 61 boys) at 70.9 mean months of age were recruited from Kanazawa University and prefectural hospitals in the Kanazawa or Toyama area. The ASD diagnosis was made for this study by a psychiatrist and a clinical speech therapist. The speech therapist, who is well trained, with an Autism Diagnostic Observational Schedule (ADOS) research license and more than 10 years of experience in ASD treatment, employed the Autism Diagnostic Observational Schedule, Generic (ADOS-G)[19] and ADOS-2.[20] The definitive diagnosis of ASD was made by a psychiatrist with more than 15 years of experience in ASD using the Diagnostic Interview for Social and Communication Disorders (DISCO),[21] the DSM-IV criteria,[22] and the DSM-5 criteria.[1] In the clinical group, 68 children satisfied the diagnosis of childhood autism (n = 52), atypical autism (n = 15), or Asperger's syndrome (n = 1) using the DISCO. Children who were below the DISCO cutoff levels were included in this study if they met the criteria for ASD using ADOS (i.e., 10 children). Two children who did not meet the diagnostic criteria for ASD in either DISCO or ADOS were excluded from analyses. As participants in this study, we included children with a mental processing scale score in the Kaufman Assessment Battery for Children (K-ABC) of 70 and more and <130, therefore data from 61 children with ASD (16 girls, 45 boys) were used for analyses. As control subjects, 114 TD children (42 girls and 72 boys with mean age 71.8 months) participated in this study. The TD children were matched to children with ASD according to age in months. All TD children were native Japanese children with no prior or existing developmental, learning, or behavioral problems according to information obtained from a questionnaire completed by their parents. All participants had normal hearing ability according to available medical records. The relevant data of participants are presented in Table 1.

Cognitive and language performance measurements

The Japanese adaptation of the K-ABC[23] was used to assess the cognitive skills of the children. To confirm the standardized score of mental processing scales in the children, we used subtests of this battery that were complementary to the age (in months) of the children. Because we found significantly lower language conceptual inference ability (i.e., a subtest of the K-ABC “riddles” task) in young children with ASD in an earlier study by the authors,[10] this “riddles” subtest was used for this study as the language index. For the “riddle” task, children were asked to respond to the examiner's questions, such as “Which fruit has a rounded shape with a depression at the top where the stem is attached? The color of the skin can be either red, green, yellow, or a combination of these colors.” In this case, “an apple” is the answer. The “riddle” task consists of 32 questions, which are presented in ascending order of difficulty. The linguistic level is defined by the child's degree of achievement. The K-ABC “riddles” subtest reflects language conceptual inference abilities in addition to the degree of language semantic conceptual formation. To clarify that atypical sensory motor processing is particularly associated with the language conceptual inference, we also investigated the relationship between sensory motor characteristics and nonverbal ability, such as visual inference, as a complementary analysis. As an index of

TABLE 1 Participant data

	ASD	TD	*t*	*P*
Number of participants	61	114		
Gender (female/male)	16/45	42/72		ns
Chronological age (months)(mean)	72.8 (9.9)	71.8 (13.3)		ns
K-ABC				
Mental processing scale (±SD)	93.4 (13.9)	104.6 (12.6)	−5.388	<0.05
"Riddles" task (±SD)	89.4 (14.5)	96.9 (13.5)	−3.419	<0.05
Matrix analogies (±SD)	8.6 (3.1)	9.5 (2.5)	−2.028	<0.05

Note: *t* value is the result of two sample *t*-test and is the value obtained by dividing the mean value by SE (standard error).
Abbreviations: ASD, autism spectrum disorder; K-ABC, Kaufman Assessment Battery for Children; ns, not significant; SD, standard deviation; TD, typically developing.

nonverbal ability (visual inference), the score of the subtest Matrix Analogies in the K-ABC was used.

Sensory profile

The Japanese version of the Caregiver Sensory Profile (SP) questionnaire was used to assess atypical sensory characteristics in all children. This questionnaire includes 125 questions that quantify the frequency of abnormal behavioral responses to various sensory experiences.[24] For this study, we specifically examined the nine factor subscales of the SP. The nine factors are "sensation seeking," "emotionally reactive," "low endurance/tone," "oral sensory/sensitivity," "inattention/distractibility," "low registration," "sensory sensitivity," "sedentary," and "fine motor/perceptual." We examined differences across groups separately for each score (Table 2).

Statistical analyses

Statistical analyses were conducted using software (Statistical Package for the Social Sciences, SPSS for Windows, ver. 20.0; IBM Corp.). First, Spearman's rank correlation coefficient was calculated to assess the relationship between the nine factor subscales of the SP and language conceptual inference ability for all children: children with ASD and TD children. The α level was adjusted to 0.05/9 = 0.0056 (for the nine subscales of the SP). Then Spearman's rank correlation analysis was applied separately for the ASD and TD groups to clarify group differences in the relationship between significantly correlated factor subscales of the SP and language conceptual inference. The α level was adjusted to 0.05/2 = 0.025 (for the number of SP subscales [i.e., 2] that were found to be significant in the analysis described above). To contrast "verbal" conceptual ability with "nonverbal" conceptual ability, Spearman's rank correlation analysis was applied as a complementary analysis with the standard score of matrix analogies (nonverbal conceptual ability in the K-ABC) and factors in SP that were related to language inference ability (verbal conceptual ability in the K-ABC).

TABLE 2 Factor scores of the sensory profile

	ASD (*n* = 61)	TD (*n* = 114)	*t*	*P*
Sensory seeking	33.6 (11.8)	24.0 (6.0)	5.863	<0.0056
Emotionally reactive	43.8 (14.3)	25.6 (8.6)	9.008	<0.0056
Low endurance/tone	15.6 (7.7)	10.3 (3.1)	5.362	<0.0056
Oral sensory sensitivity	14.6 (6.7)	10.9 (3.1)	4.067	<0.0056
Inattention/ distractibility	17.0 (4.8)	11.0 (3.2)	8.747	<0.0056
Low registration	14.1 (4.9)	9.3 (2.1)	7.255	<0.0056
Sensory sensitivity	4.9 (1.5)	4.6 (1.3)	1.365	ns
Sedentary	11.3 (4.3)	8.4 (3.5)	4.813	<0.0056
Fine motor/ perceptual	7.2 (3.3)	4.7 (1.8)	5.464	<0.0056

Note: Mean scores and standard deviations are presented for children with autism and control TD children along with the statistics of two-sample *t*-tests. Italicized *P* values were found to be significant after Bonferroni correction ($P < 0.0056$). *t* value is the result of two sample *t*-test and is the value obtained by dividing the mean value by SE (standard error).
Abbreviations: ASD, autism spectrum disorder; ns, not significant; SD, standard deviation; TD, typically developing.

RESULTS

Comparison of factor subscales of sensory profiles between children with ASD and TD children

Children with ASD scored significantly higher than control group children in eight factor subscales of theSP, but not for the factor of

"sensory sensitivity" (Table 2). The sensory sensitivity factors between TD children and children with ASD were not significantly different.

Relationship between language performance and sensory processing characteristics

We examined the relationship between the language conceptual inference ability and nine factor subscales of the SP for all children: children with ASD and TD children. For these nine SP factors, significant negative correlation was found for two factors: low registration ($n = 175$, $\rho = -0.259$, $P < 0.001$; Table 3) and fine motor/perceptual ($n = 175$, $\rho = -0.270$, $P < 0.001$; Table 3).

TABLE 3 Factor scores of the sensory profile and language ability for all children

	n	*ρ*	*P*
Sensory seeking	174	−0.098	ns
Emotionally reactive	174	−0.085	ns
Low endurance/tone	174	−0.097	ns
Oral sensory sensitivity	175	−0.066	ns
Inattention/distractibility	174	−0.091	ns
Low registration	175	−0.259*	<0.001
Sensory sensitivity	175	−0.012	ns
Sedentary	175	−0.136	ns
Fine motor/perceptual	175	−0.270*	<0.001

Note: *n* is the number of participants. *ρ* is the Spearman's rank correlation coefficient.

*$P < 0.0056$.

Regarding the results of the relationship between language conceptual inference ability and sensory factors, which were significant in the analysis of all children, we investigated each group separately, but only the relationship between language conceptual inference ability and the factor of fine motor perceptual was found to be significant for children with ASD ($n = 61$, $\rho = -0.288$, $P = 0.024$; Figure 1). For example, the item related to the factor of fine motor perceptual is "Has trouble staying between the lines when coloring or when writing." For TD children, no significant correlation was found between the two factor subscales of the sensory profile and language conceptual inference performance (i.e., "riddles" task) (Table 4).

Relationship between matrix analogies (nonverbal ability in the K-ABC) and sensory processing characteristics

The relationship between the two factors (low registration and fine motor/perceptual) of the SP and Matrix Analogies (i.e., visual

TABLE 4 Factor scores of the sensory profile and language ability for each group

	ASD (*n*)	TD (*n*)	ASD (*ρ*)	TD (*ρ*)
Low registration	61	114	−0.255	−0.125
Fine motor/perceptual	61	114	−0.288*	−0.107

Note: *n* is the number of participants. *ρ* is the Spearman's rank correlation coefficient.

Abbreviations: ASD, autism spectrum disorder; ns, not significant; TD, typically developing.

*$P < 0.025$.

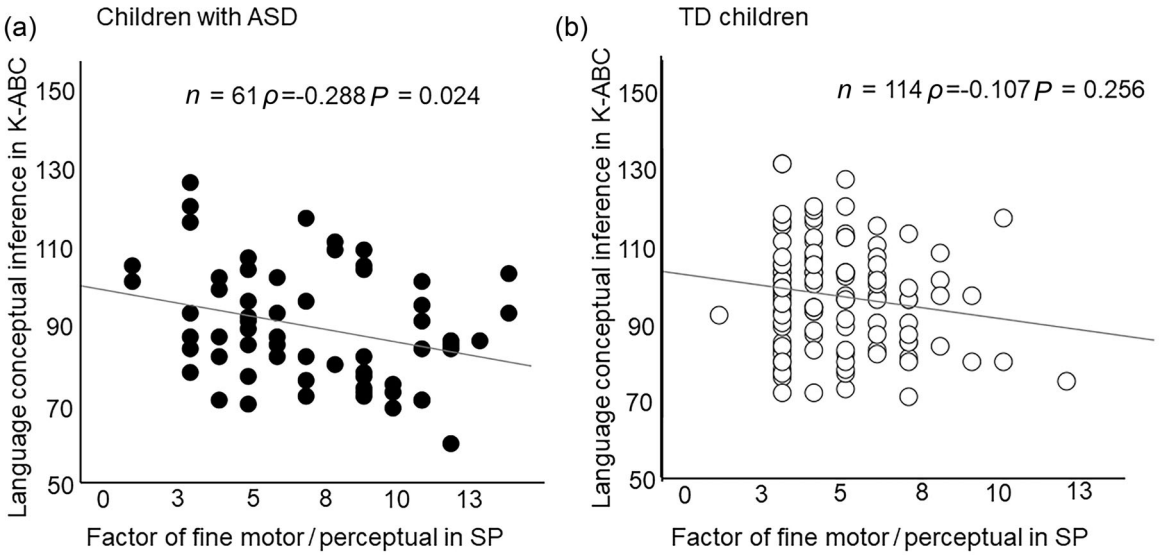

FIGURE 1 Relationship between language performance and the factor of fine motor and perceptual in the Caregiver Sensory Profile (SP): (a) children with autism spectrum disorder (ASD) and (b) typically developing (TD) children. K-ABC, Kaufman Assessment Battery for Children

TABLE 5 Factor scores of sensory profiles and visual inference ability for each group

	ASD (*n*)	TD (*n*)	ASD (*ρ*)	TD (*ρ*)
Low registration	61	108	−0.095	0.094
Fine motor/perceptual	61	108	−0.150	−0.041

Note: No factor was found to have $P < 0.025$. *n* is the number of participants. *ρ* is the Spearman's rank correlation coefficient.
Abbreviations: ASD, autism spectrum disorder; TD, typically developing.

inference performance in the K-ABC) was not significant either for children with ASD children or for TD children (Table 5).

DISCUSSION

The current study was undertaken to examine the relationship between the characteristics of sensory motor processing and language conceptual inference ability in 3–10-year-old children with ASD. Our results indicated a significant negative correlation between the factor of fine motor/perceptual in the SP and language conceptual inference ability in children with ASD, but not in TD children, therefore difficulties in fine motor and perceptual function are associated with lower language conceptual abilities in children with ASD. This report is the first of a study suggesting that the sensory motor system is involved in language concept formation and semantic memory in young children with ASD without intellectual disabilities.

Earlier studies have examined relationships between sensory difficulties and language function.[2,11–13] Language development involves sensory characteristics such as sensory hyporesponsiveness characterized by absence of the expected response to a stimulus, and sensory seeking characterized by actions that perpetuate or intensify a sensory experience. The results of a longitudinal study indicated that sensory characteristics (i.e., sensory hyporesponsiveness and sensory seeking) and joint attention behavior at 1 year of age are associated with language development during preschool.[12] For children with ASD, the scores of sensory hyporesponsiveness and sensory seeking, which were assessed by combining parent reports and observational evaluations, were found to be associated with the severity of receptive and expressive language difficulties.[13,25] Moreover, existing evidence supports an association of sensory seeking characteristics with language receptive and expressive ability in 8–18-year-old children with ASD.[11] The results of the current study indicated no significant association between earlier reported sensory characteristics (i.e., hyporesponsiveness and sensory seeking) and language conceptual inference ability. One reason for these divergent findings might be differences of children with ASD. In earlier studies, children with cognitive developmental delay[13,25] and children older[11] than those in our study were examined. Moreover, issues of fine motor function related to sensory system were not addressed in earlier studies, therefore a novel finding from our study is the involvement of sensory-related fine motor function assessed using the SP in language conceptual inference ability in children with ASD without intellectual disability.

Regarding child language development, Gonzalez et al. concluded from a systematic review of the literature that gross and fine motor skills help to foster language development from infancy to early childhood.[26] Regarding language development in high-risk infants with ASD, some follow-up studies have demonstrated that early fine motor skills predicted expressive language at 36 months.[27,28] The findings obtained from this study support results of earlier studies suggesting that fine motor capability is important for language development. Furthermore, it is noteworthy that this study demonstrated that fine motor development is involved in the development of language semantic conceptual formation for children with ASD who are older than 3 years.

Another explanation for the relationship between sensory-related fine motor function and language conceptual inference ability in children with ASD is that more than half of the items of the "riddle" task in the K-ABC included questions that asked children to give responses about artificial objects. According to the research view that manipulability and motion are more involved in the concept of artificial objects than with natural objects,[29] more opportunities for children to infer and respond about artificial objects than natural objects might have influenced this result. However, this study found no relationship between language conceptual ability and atypical sensory characteristics related to visual, auditory, and somatosensory systems. The language conceptual inference task of the K-ABC used for this study might have been insufficient to detect the relationship between other sensory traits (i.e., vision, touch, hearing) and the language conceptual abilities in children. Alternatively, in children with ASD, the relationship between the concept of artificial objects and the sensory motor system might be stronger than the relationship between the concept of natural objects and the sensory systems of vision, touch, and hearing.

This study has some limitations. First, the children with ASD examined for this study were without intellectual disability, therefore they might not represent children with Kanner-type autism. Second, the analysis included only participants who scored 70 or more and less than 130 in the K-ABC mental processing scale. However, a significant difference was found between TD children and children with ASD, therefore we have not sufficiently considered the influence of mental processing scale on the association between the factor of fine motor perceptual and language conceptual inference that we found in this study. These limitations demand some caution. In the complementary analysis contrasting the "verbal" conceptual ability with the "nonverbal" conceptual ability, our results underscore that language conceptual inference ability is particularly related to fine motor perceptual factors in the SP. Third, the SP was used for this study to examine sensory abnormalities specifically. However, it is desirable to use a more detailed assessment that is specialized for atypical sensory motor characteristics in children with ASD.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Yuko

Yoshimura. Data collection and investigation were performed by Chiaki Hasegawa, Sanae Tanaka, Takashi Ikeda, Ken Yaoi, Sumie Iwasaki, and Kyung-min An. The first draft of the manuscript was written by Yuko Yoshimura. Supervision was performed by Mitsuru Kikuchi. All authors commented on earlier versions of the manuscript. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST

The authors declare that the research was conducted with no commercial or financial relationship that could be construed as a potential competing interest or conflict of interest.

DATA AVAILABILITY STATEMENT

Datasets collected during or analyzed during the current study are available from the corresponding author upon reasonable request.

ETHICS APPROVAL STATEMENT

The Ethics Committee of Kanazawa University Hospital approved the methods and procedures, all of which were performed in accordance with the Declaration of Helsinki.

PATIENT CONSENT STATEMENT

Parents, with full knowledge of the experiment characteristics for this research, agreed to participation of the children in the study. Written informed consent was obtained before participation in the study.

CLINICAL TRIAL REGISTRATION

Clinical trial registration information is not available.

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REFERENCES

1. American Psychiatric Association. Diagnostic and statistical manual of mental disorders (DSM-5®). 5th ed. Washington, DC: American Psychiatric Association; 2013.
2. Baranek GT, David FJ, Poe MD, Stone WL, Watson LR. Sensory Experiences Questionnaire: discriminating sensory features in young children with autism, developmental delays, and typical development. J Child Psychol Psychiatry. 2006;47(6):591–601.
3. Ben-Sasson A, Carter AS, Briggs-Gowan MJ. Sensory over-responsivity in elementary school: prevalence and social-emotional correlates. J Abnorm Child Psychol. 2009;37(5):705–16.
4. Tavassoli T, Miller LJ, Schoen SA, Nielsen DM, Baron-Cohen S. Sensory over-responsivity in adults with autism spectrum conditions. Autism. 2014;18(4):428–32.
5. Tomchek SD, Dunn W. Sensory processing in children with and without autism: a comparative study using the short sensory profile. Am J Occup Ther. 2007;61(2):190–200.
6. Zachor DA, Ben-Itzchak E. The relationship between clinical presentation and unusual sensory interests in autism spectrum disorders: a preliminary investigation. J Autism Dev Disord. 2013;44:229–35.
7. Robertson CE, Baron-Cohen S. Sensory perception in autism. Nat Rev Neurosci. 2017;18(11):671–84.
8. Cascio CJ, Woynaroski T, Baranek GT, Wallace MT. Toward an interdisciplinary approach to understanding sensory function in autism spectrum disorder. Autism Res. 2016;9(9):920–5.
9. Billstedt E, Carina Gillberg I, Gillberg C. Autism in adults: symptom patterns and early childhood predictors. Use of the DISCO in a community sample followed from childhood. J Child Psychol Psychiatry. 2007;48(11):1102–10.
10. Kikuchi M, Yoshimura Y, Shitamichi K, Ueno S, Hirosawa T, Munesue T, et al. A custom magnetoencephalography device reveals brain connectivity and high reading/decoding ability in children with autism. Sci Rep. 2013;3:1139.
11. Feldman J, Cassidy M, Liu Y, Kirby A, Wallace M, Woynaroski T. Relations between sensory responsiveness and features of autism in children. Brain Sci. 2020;10(11):775.
12. Nowell SW, Watson LR, Crais ER, Baranek GT, Faldowski RA, Turner-Brown L. Joint attention and sensory-regulatory features at 13 and 22 months as predictors of preschool language and social-communication outcomes. J Speech Lang Hear Res. 2020;63(9):3100–16.
13. Watson LR, Patten E, Baranek GT, Poe M, Boyd BA, Freuler A, et al. Differential associations between sensory response patterns and language, social, and communication measures in children with autism or other developmental disabilities. J Speech Lang Hear Res. 2011;54(6):1562–76.
14. Kiefer M, Pulvermüller F. Conceptual representations in mind and brain: theoretical developments, current evidence and future directions. Cortex. 2012;48(7):805–25.
15. Barsalou LW, Kyle Simmons W, Barbey AK, Wilson CD. Grounding conceptual knowledge in modality-specific systems. Trends Cogn Sci. 2003;7(2):84–91.
16. Gallese † V, Lakoff G. The Brain's concepts: the role of the sensory-motor system in conceptual knowledge. Cogn Neuropsychol. 2005;22(3):455–79.
17. Pulvermüller F, Hauk O, Nikulin VV, Ilmoniemi RJ. Functional links between motor and language systems. Eur J Neurosci. 2005;21(3):793–7.
18. Binder JR, Desai RH. The neurobiology of semantic memory. Trends Cogn Sci. 2011;15(11):527–36.
19. Lord C, Risi S, Lambrecht L, Cook, EH Jr., Leventhal BL, DiLavore PC, et al. The autism diagnostic observation schedule–generic: a standard measure of social and communication deficits associated with the spectrum of autism. J Autism Dev Disord. 2000;30(3):205–23.
20. Lord C, Rutter ML, PC D, S R, K G, SL B, editors. Autism diagnostic observation schedule–2nd ed. California: Western Psychological Services; 2012.
21. Wing L, Leekam SR, Libby SJ, Gould J, Larcombe M. The diagnostic interview for social and communication disorders: background, inter-rater reliability and clinical use. J Child Psychol Psychiatry. 2002;43(3):307–25.
22. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4rth ed. Washington, DC: American Psychiatric Association; 1994.
23. Kaufman A, Kaufman N editors Kaufman Assessment Battery for Children. Circle Pines, MN: American Guidance Service; 1983.
24. Dunn W. Sensory profile user's manual. San Antonio: Psychological Corp.; 1999.

25. Baranek GT, Watson LR, Boyd BA, Poe MD, David FJ, McGuire L. Hyporesponsiveness to social and nonsocial sensory stimuli in children with autism, children with developmental delays, and typically developing children. Dev Psychopathol. 2013;25(2):307–20.
26. Gonzalez SL, Alvarez V, Nelson EL. Do gross and fine motor skills differentially contribute to language outcomes? A systematic review. Front Psychol. 2019;10:2670.
27. LeBarton ES, Iverson JM. Fine motor skill predicts expressive language in infant siblings of children with autism. Dev Sci. 2013;16(6):815–27.
28. Choi B, Leech KA, Tager-Flusberg H, Nelson CA. Development of fine motor skills is associated with expressive language outcomes in infants at high and low risk for autism spectrum disorder. J Neurodev Disord. 2018;10(1):14.
29. Tranel D, Logan CG, Frank RJ, Damasio AR. Explaining category-related effects in the retrieval of conceptual and lexical knowledge for concrete entities: operationalization and analysis of factors. Neuropsychologia. 1997;35(10):1329–39.

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