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ORIGINAL RESEARCH

Age as a factor in sensory integration function in Taiwanese children

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Objective: Sensory integration progresses along a normal developmental sequence. However, few studies have explored how age difference affects the way sensory integration functions in Taiwanese children as they develop. Therefore, this study aims to pinpoint the role of age in sensory integration.

Method: A purposive sampling plan was employed. The study population comprised 1,000 Chinese children aged 36 to 131 months (mean = 74.48 months, standard deviation = 25.69 months). Subjects were scored on seven subsets of the Test of Sensory Integration Function (TSIF). An analysis of variance (ANOVA) was used to identify differences between four age groups (ages 3–4, 5–6, 7–8, and 9–10 years), in the categories of the TSIF.

Results: ANOVA revealed that age is a significant factor in each of the seven tasks of sensory integration associated with various stages of development. The effect of age was significant in all four groups for the subscale of Bilateral Integration Sequences. The function of sensory integration for the children aged 5–8 years did not produce statistically significant results for the subscale of Postural Movement, Sensory Discrimination, Sensory Seeking, or Attention and Activity. For the subscale of Sensory Modulation and Emotional Behavior, the effect of age was significant in only group 1 (children aged 3–4 years) and group 2 (children aged 5–6 years).

Conclusion: There was significant difference between group 1 and group 2 for seven categories. Significant differences were contributed by the differences from group 1 (3–4 years) and group 4 (9–10 years) in five subscales (Postural Movement, Bilateral Integration Sequences, Sensory Discrimination, Sensory Seeking, and Attention and Activity). There were three developmental trends in the seven categories of the TSIF.

Keywords: age effect, sensory integration function, developmental trend

Introduction

Sensory integration refers to the neurological process by which the brain organizes sensory information from the body to produce an adaptive movement or behavior.[1,2] In the United States, the prevalence of children who typically develop sensory integration dysfunction is 5%–13%;[3] the estimated prevalence for children having symptoms of sensory processing disorder is 16%.[4] The prevalence of sensory integration dysfunction in preschool children in Taiwan is 21%–28%.[5] Thus, sensory integration dysfunction is a common developmental problem, with the "sensory integration treatment" approach most commonly employed in schools.[6] According to the model of sensory integration dysfunction described by Bundy et al, sensory integration disorders are heterogeneous problems that fall into several subtypes: postural movement; bilateral integration sequences; sensory modulation; sensory seeking; and sensory discrimination.[7]

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Postural movement may cause problems that include being barely able to engage in antigravitational activities, poor proximal joint stability, low postural tone, and poor balance and endurance.[8,9] Deficits in bilateral integration and bilateral integration sequence activity may cause inadequate coordination in the hands and feet, and poor performance in such sequencing actions as playing ball and athletic activities that require speed.[10] Sensory modulation refers to over-responsive reactions or under-responsive reactions, wherein the term under-responsive is understood as having too little response to sensory input, with awareness of a need for strong stimulus before the child can perceive sensory input.[11] Sensory seeking refers to an intensive craving for sensory stimuli in children.[8] Sensory discrimination primarily refers to difficulty in interpreting sensory inputs. Sensory integration dysfunction may lead to other issues, such as lack of attention, excessive activity,[12] or emotional behavior problems.[13] The aforementioned problems may affect a child's performance in school and daily life.

Underlying the study of sensory integration is the understanding that integration relies on a normal developmental sequence. A spiral process of self-actualization is based on the conceptual model of sensory integration proposed by Bundy et al,[7] which describes a new, complex upper loop that is established dependently on top of an old, simple lower loop in the model of sensory integration. Ayres posited that children older than 9 years still benefited from intervention despite the fact that plasticity of the central nerve system had decreased.[7] According to Dunn and Westman,[9] the ability of sensory processing continues to grow after the age of 8 years. There has been much research carried out in America on the effect of age on sensory integration, using such tools as the Test of Sensory Functions in Infants,[14] the Degangi–Berk Test of Sensory Integration,[15] the Sensory Profile,[16] the Sensory Experiences Questionnaire,[17] the Tactile Defensiveness and Discrimination Test,[18] the Touch Inventory for Elementary School-Aged Children,[19] and the Touch Inventory for Preschoolers.[20] However, little data has been collected (nor further statistical analysis performed) on the effects of age on the function of sensory integration in Taiwanese preschoolers.

Differences in children's responses to sensation may be attributed to the fact that some children feel pleasure in an activity requiring more vestibular stimulus, whereas other children seem to feel overwhelmed. The features of sensory processing and physiological responses in American children could be different from those in Taiwanese children as a result of their respective societal backgrounds.

Tseng and Cheng[21] collected sensory profile data from Taiwanese children divided into two groups: preschool (3–6 years old) and school-aged (7–10 years old). According to Sensory Integration theory, age difference should affect preschool children; however, the study by Tseng and Cheng did not provide enough information on preschool children to warrant the application of the practice of early intervention for children below the age of 6 years in Taiwan. Thus, the participants in this study were subdivided into two groups, including group 1 that comprised preschoolers (aged 3–4) and group 2 that comprised the kindergarteners (aged 5–6).

This study posed two questions and compared four groups. The first question was whether there were differences in the function of sensory integration among preschool, kindergarten, and school-aged children. The second question was whether there were different developmental trends in each of the seven categories of the Test of Sensory Integration Function (TSIF).[22] We expected to obtain more age information, and more detailed information, about the effect of age on sensory integration among Taiwanese children than was found in the Tseng and Cheng study.[21] We tested the hypothesis that the improvement of sensory integration function will be significantly greater in the older groups than in the younger groups (ie, group 4 better than group 3, group 3 better than group 2, and group 2 better than group 1) in the seven categories of the TSIF. Sensory integration is an important developmental process, which must develop in a normal sequence to be successful.[8] Understanding the role of age in development will greatly enhance the ability to identify effective strategies at suitable ages and support appropriate intervention during developmental stages.

Method

Participants

Participants were typically developing children, aged 3 to 10 years. A total of 1,000 children were selected for statistical analysis using normative sampling, for developing the Test of Sensory Integration. The 1,000 children were selected from mainstream Taiwanese kindergartens and elementary schools. The exclusion criteria for participants were: (1) receiving special education services or other related services or (2) having developmental disabilities or any neurological dysfunctions, such as seizures, physical disorders, autism, cerebral palsy, or traumatic brain injury. The 1,000 participants included 448 girls (44.8%) and 552 boys (55.2%), (Mean = 74.48 months, standard deviation = 25.69 months). Study participants were divided into four groups: group 1 included the 343 (34.3%) children aged

36 to 59 months; group 2 included the 288 (28.8%) children aged 60 to 83 months; group 3 included the 227 (22.7%) children aged 84 to 107 months; and group 4 included the 142 children (14.2%) aged 108 to 131 months. Table 1 shows the demographics of all participants. Since the approach of collecting data was based on the questionnaires, the Ethics Committee of the University in the middle of Taiwan did not consider that their approval was needed before the study began. Parents or legal guardians of each child provided informed consent prior to participation, which included consent to publish.

Instrument

The TSIF was developed in 2004 to determine sensory integration dysfunction in children aged 3 through 10 years. The TSIF subtests are as follows: (1) Postural Movement (12 items); (2) Bilateral Integration Sequences (16 items); (3) Sensory Discrimination (eleven items); (4) Sensory Modulation (21 items); (5) Sensory Seeking (nine items); (6) Attention And Activity Levels (18 items); and (7) Emotional Behavior (eleven items).[22] Each of the 98 items was scored on a five-point Likert scale and took approximately 20 minutes to complete. Teachers of the participants scored each behavior, as follows: 1 = never (the child never responds in this fashion when presented with the opportunity [0% of the time]); 2 = seldom (the child responds occasionally in this fashion [25%]); 3 = occasionally (the child responds sometimes [50%]); 4 = frequently [≥75%]; 5 = always (the child responds in the manner noted every time when presented with the opportunity [100%]). The range of possible raw scores on the total scale was 98 to 490, with higher scores indicating poorer performance. Internal consistency for the subtests demonstrated a Cronbach's alpha ranging from 0.80~0.94; test-retest reliabilities for the subtest scores ranged from 0.82~0.94. The seven subscales have good construct validity.[23]

Table 1 Demographics of study participants

	Gender				Total
	Females		Males		N
	N	%	N	%	
Group 1					
3–4 yrs	150	33.48	193	34.96	343
Group 2					
5–6 yrs	126	28.13	162	29.35	288
Group 3					
7–8 yrs	101	22.54	126	22.83	227
Group 4					
9–10 yrs	71	15.85	71	12.86	142
Total	448	100	552	100	1000

Procedure

Taiwan was divided into northern, central, and southern areas, in this study. Major population cities used for recruitment were Taipei, Taichung, and Kaohsiung, the three most populous cities in the northern, central, and southern parts of Taiwan, respectively. Taipei has 16 administrative districts, based on the 1990 division criterion, while Taichung has eight and Kaohsiung has eleven. The study selected one kindergarten and one elementary school in each administrative district by purposive sampling. Hence, a total of 70 schools (35 kindergartens and 35 elementary schools) participated in this study. Administrators at all schools were telephoned in order to assess their level of enthusiasm for the project. The schools were recruited based on the respondent's interest during the call in which researchers explained the study. After the parents signed a consent form, the teachers received a packet with written instructions, questionnaires, and contact information for the researchers. The teachers were instructed to submit any questions during school hours. Each evaluator (teacher) had to have been familiar with the tested child for at least 6 months before being allowed to assess the performance of the child. The teachers helped with responses and returned the completed questionnaires. In total, 1,600 children were sampled during school screening for sensory symptoms. Of the total sampling, 1,280 questionnaires (80%) were returned, of which 1,000 (62.8%) were valid (with complete answers to questionnaires).

Data analysis

The study used the Statistical Package for the Social Science (SPSS 13.0; SPSS, Inc, Chicago, IL, USA) to conduct data analysis. An analysis of variance (ANOVA) was used to identify possible differences among the four age groups (ie, 3−4, 5−6, 7−8, and 9−10 years) in the categories of the TSIF. First, the assumption of homogeneity of variance was examined using Levene's test. Follow-up univariate analysis F tests of the categories were used to identify which categories contributed to differences between the groups if the variances were homogeneous; otherwise, two robust tests of equality of means, the Welch Test and the Brown−Forsythe test, were conducted if the variances were heterogeneous. Finally, the Games−Howell tests were used for multiple post hoc comparisons if the variances were not homogeneous. Least significant difference (LSD) tests were used for multiple post hoc comparisons if the variances were homogeneous. The criterion for the level of statistical significance was set at 0.05.

Results

The test of homogeneity of variance

The result of the Levene test showed that there were four categories that did not meet the assumption of homogeneity of variance, including: Postural Movement (Levene statistic = 3.78, $P = 0.01$); Bilateral Integration Sequences (Levene statistic = 17.61, $P = 0.00$); Sensory Discrimination (Levene statistic = 6.46, $P = 0.00$); and Attention and Activity (Levene statistic = 7.16, $P = 0.00$). Games−Howell tests were used for multiple post hoc comparisons for those four categories. LSD tests were used for multiple post hoc comparisons for Sensory Modulation, Sensory Seeking, and Emotional Behavior.

Age comparisons

The ANOVA indicated a significant effect of age on the following subcategories of the TSIF: Postural Movement ($F_{3,996} = 8.48$, $P < 0.001$); Bilateral Integration Sequences ($F_{3,996} = 60.85$, $P < 0.001$); Sensory Discrimination ($F_{3,996} = 18.13$, $P < 0.001$); Sensory Modulation ($F_{3,996} = 17.35$, $P < 0.001$); Sensory Seeking ($F_{3,996} = 9.39$, $P < 0.001$); Attention and Activity ($F_{3,996} = 6.68$, $P < 0.001$); and Emotional-Behavioral Reactivity ($F_{3,996} = 13.95$, $P < 0.001$) (Table 2).

In post hoc comparisons of Bilateral Integration Sequences, group 4 performed better than group 3, group 3 performed better than group 2, and group 2 better than group 1; older children performed better than younger children.

The post hoc comparisons of Postural Movement, Sensory Discrimination, Sensory Seeking, and Attention and Activity indicated that group 4 performed better than group 2 and group 3, and that group 2 and group 3 performed better than group 1, but there was no significant difference between group 2 and group 3.

The post hoc analysis of Sensory Modulation and Emotional Behavior showed that the performance of children aged 3−4 years was poorer than those in any other group (Table 2).

Discussion

Age comparison and developmental trend

In this study, no significant difference was found in postural movements among the children aged 5−6 (group 2) and 7−8 (group 3). The children aged 9−10 years (group 4) had significantly better performance than the three younger groups. Dunn and Brown used the Sensory Profile to survey and found significant differences in body position and movement between younger (3−6 years) and older subjects (7−10 years), although the effect sizes were very small.[24] Tseng and Cheng showed similar results to Dunn and Brown, in the performance of body position and movement. The factor of Low Endurance Tone produced no significant difference between younger (3−6 years) and older subjects (7−10 years), in Taiwanese children.[21] Wu found that subjects aged 5−6 performed better in Postural Movement performance than subjects aged 4.[5] However, significant differences were found between children aged 4−5 years and those aged 6−8 years, in the study by Gregory-Flock and Yerxa.[25] The results of both of these studies[5,25] were inconsistent with our study. Gregory-Flock and Yerxa utilized clinical observation and Wu utilized computerized clinical observation, both of which can be subjective, to explore children's prone extension. Our study employed a widely-used survey scale that evaluated performance according to responses from teachers about the children.

Table 2 Comparison of age with TSIF

	Age groups								*F* value	Score comparison
	Group 1		Group 2		Group 3		Group 4			
	M	SD†	M	SD†	M	SD†	M	SD†		
PM	22.34	7.33	21.07	5.98	20.78	7.05	19.02	6.25	8.48*	$1 > 2 = 3 > 4^a$
BIS	33.80	11.80	27.43	8.52	25.07	8.91	22.70	7.71	60.85*	$1 > 2 > 3 > 4^a$
SD	20.85	6.85	18.74	5.37	18.29	6.14	16.77	5.40	18.13*	$1 > 2 = 3 > 4^a$
SM	41.51	11.31	37.43	9.94	35.94	10.45	35.94	10.12	17.35*	$1 > 2 = 3 = 4^b$
SS	18.53	5.80	17.18	5.14	16.96	5.54	15.86	4.91	9.39*	$1 > 2 = 3 > 4^b$
AA	40.71	12.67	38.32	11.66	38.68	14.42	35.15	11.29	6.68*	$1 > 2 = 3 > 4^a$
EB	23.52	7.21	21.34	6.75	20.70	7.54	19.51	6.43	13.95*	$1 > 2 = 3 = 4^b$

Notes: Group 1: 3–4 yrs; group 2: 5–6 yrs; group 3: 7–8 yrs; group 4: 9–10 yrs. *$P < 0.001$. [a]Games–Howell tests were used for multiple post hoc comparisons; [b]LSD tests were used for multiple post hoc comparisons.

Abbreviations: AA, Attention and Activity; BIS, bilateral integration sequences; EB, Emotional Behavior; LSD, least significant difference; M, mean; PM, Postural Movement; SD, Sensory Discrimination; SD†, standard deviation; SM, Sensory Modulation; SS, Sensory Seeking; TSIF, Test of Sensory Integration Function.

Magalhaes et al examined children's ability to perform three bilateral motor coordination tasks: jumping jacks, symmetrical stride jumps, and reciprocal stride jumps.[26] Huh et al found that older children moved faster than younger children, when performing both unilateral and bilateral aiming movements.[27] The result of our study concurred with results of the aforementioned studies, in that the performance of bilateral integration sequences tended to improve as age increased.

The content of Sensory Discrimination in the TSIF includes: proprioception (posture and movement) and vestibular, tactile, olfactory, and thermal discrimination. Previous studies focused on the discriminative function of a single sensory system, such as tactile or auditory.[28,29] The overall performance of various sensory systems of discrimination lacked attention in previous studies, especially the research and analysis of age effect on sensory discrimination in children. The items in the Poor Sensory Registration test in the Sensory Profile[21] were similar to those in Sensory Discrimination; however, age did not have an effect on performance at Poor Sensory Registration. The value of this study lies in the result that as children grow from age 3−4 years to 5−6 years or from 7−8 years to 9−10 years, they will develop better ability at sensory discrimination, but further development of the ability becomes a flat trend for children from 5−6 years old to children aged 7−8 years.

Much of the research concerning sensory modulation has focused on the effect of treatment, comparison of different disabilities, the relationship between emotion and sensory modulation, or anxiety and sensory modulation. In Dunn's research,[16] there was a very small difference in the mean scores for sensory modulation across age groups. Though the performance of the scoring of oral sensitivity for preschoolers was significantly higher than that of elementary school children, there was no significant difference of the sensory sensitivity between the two groups.[21] In a research sample of Israeli children, neither age nor gender was found to be significantly different in the hypo- or hyper-responsive responses of the tactile and vestibular systems, between the 3-year-old and 4-year-old participants.[30] In this research, 3-year-olds and 4-year-olds were classed into one group, and the children in that group did significantly less well in sensory modulation than those aged 5−6 years. Yet, no significant difference was shown among children of the three oldest groups (ie, those aged 5−6, 7−8, and 9−10 years).

Early studies of sensory deprivation investigated the sensory seeking behavior of children.[31] There has been little study examining sensory seeking by age. It showed that children aged 3−6 years sought sensory stimulus more than the elementary school children.[21] However, there was no age effect in Dunn's study.[16] In this study, children aged 3−4 years had a significantly higher frequency of seeking stimulus than did children aged 5−8 years, and children aged 5−8 years had a significantly higher frequency than children aged 9−10 years.

Previous studies have shown that inhibition will be attained by the age of 6 years.[32] The age of 10 may be too mature a stage at which to develop focused attention.[33] Research indicates that activity level decreases with age, and sustained attention increases with age.[34] The subscale of Attention and Activity of the TSIF includes motor inhibition, impulse control, selective and sustained attention, and executive functions. In this study, children aged 9−10 years scored better than children aged 5−8 years, and children aged 5−8 years scored better than children aged 3−4 years. Tseng and Cheng demonstrated there was no significant difference in inattention and distraction between preschool and elementary school children.[21] Our results are more similar to those of Klenberg et al[33] which showed a rapid increase in attention between the ages of 8 and 10 years.

Significant differences in emotions and social responses were found between younger (3−6 years) and older subjects (7−10 years) in the research of Dunn and Brown,[24] and Tseng and Cheng.[21] Elementary school children had more positive emotion reaction than did preschool children. Those results differed from this research in that in the current work, the frequency of emotional behavior problems in children aged 3−4 years was significantly higher than in those aged 5−10 years. This difference might be caused by the differences in how the age groups were divided.

The implications of this study

From the findings of the seven categories in the TSIF, age effects resulted in three developmental trends: (1) an age effect was significant in the four age groups for the subscale Bilateral Integration Sequences; (2) for children aged 5−8 years, the function of sensory integration did not present significant progress except Bilateral Integration Sequences. However, there was better development, from group 1 (aged 3−4 years) to group 2 (aged 5−8 years) and from group 3 (5−8 years) to group 4 (aged 9−10 years), at the subscales of Postural Movement, Sensory Discrimination, Sensory Seeking, and Attention and Activity; (3) an age effect was only present between group 1 (aged 3−4 years) and group 2 (aged 5−6 years) for the subscales Sensory Modulation and Emotional Behavior.

Although the observations and results were not dramatic, they were predictable, and they provided further confirmation regarding the effect of age on the sensory integration of developing preschool and elementary school children of age 3−10 years.

The implications of this study involve screening for sensory integration dysfunction. The results of this study provide "age effect" information for the early identification of sensory integration dysfunction in children in Taiwan. Using these results, the therapist could screen for the problem of sensory integration dysfunction based on different criteria at different ages and in different categories in the function of sensory integration. For an effective strategy, the therapist could design treatment according to different levels of difficulty for different ages.

The limitation of this study was that the three geographical areas selected as representative may be special municipalities, in that they have large populations, and therefore, they may not be representative for all the cities in Taiwan. However, they do represent the three geographical areas of Taiwan. Another limitation of this study was that we did not evaluate interrater reliability, to minimize the effect of bias from teachers. We therefore suggest future studies examine the potential role of gender or socioeconomic status in the development of sensory integration.

Conclusion

There was significant difference between group 1 and group 2 for seven categories of the TSIF. Significant differences were contributed by the differences from group 1 (3−4 years) and group 4 (9−10 years) in five subscales (Postural Movement, Bilateral Integration Sequences, Sensory Discrimination, Sensory Seeking, and Attention and Activity). There were three developmental trends in the scoring of seven categories of the TSIF.

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Disclosure

The authors report no conflict of interest in this work.

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