PERCEPTUAL WEIGHTING OF SYLLABLE-INITIAL FRICATIVES FOR NATIVE JAPANESE ADULTS AND FOR CHILDREN WITH PERSISTENT DEVELOPMENTAL ARTICULATION DISORDERS

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Background: Persistent developmental articulation disorder and language learning impairment are suspected to concur due to a speech processing deficit. The change in children's perceptual strategies is proposed as an indicator of development of speech processing ability (Nittrouer & Miller, 1997 b). To diagnose a speech processing deficit and intervene in it early, we examined perceptual weight in an attempt to identify a marker for the development of speech processing ability. **Methods:** Forty-two native Japanese adults without speech disorder and 2 native Japanese children with persistent developmental articulation disorder and language learning impairment participated the study. They identified tokens from a /ʃ/-/s/ continuum followed by vocalic portions with formant transitions changing continuously from ones appropriate for /ʃ/ to those for /s/. **Findings:** Most adults weighted to the spectrum of the fricative noise more than to formant transition in the same manner as the adults in Nittrouer and Miller. However, as compared with most adults, a small number of adults and the 2 children judged based more on the formant transitions than on the spectrum of the fricative noise like 3- to 4-year-old typically developing children in Nittrouer and Miller. **Interpretation:** The perceptual weight assigned by adults suggested that they did not perceive uniformly. The perceptual weight assigned by the 2 children indicated that their speech perception ability might develop differently from that of typically developing children because of speech processing deficits.

1. Introduction

1.1 Phonological processing deficits in children with developmental articulation disorder

Developmental articulation disorder is a communication disorder that involves incorrect speech production, including speech sound deletions and substitutions, and is characterized by a "failure to use developmentally expected speech sounds that are appropriate for age and dialect" (American Psychiatric Association, 2000) (see footnote). Developmental articulation disorders occur in absence of a physical disability, for example, hearing impairment, a deficit in structure and/or function of speech organs, and neuromotor disease, but its etiology has not been fully elucidated. More than one factor, such as phonological development, ability in speech perception and also in speech motor control, is implicated (Edwards, Fourakis, Beckman, & Fox, 1999).

Some children with developmental articulation disorder learn to articulate syllables easily but have great difficulty generalizing the sound in words, sentences, and conversation. Beyond the age of about 7 years old, when almost all children can articulate the very many speech sounds of their native language, these children have persistent articulation disorder and many also have language learning impairment. The concurrence of developmental articulation disorder and language learning impairment suggests that both problems derive from a phonological processing deficit (Hara, 2003).

Phonological processing refers to an individual mental operation that makes use of the phonological or sound structure of oral language in the encoding and decoding of speech, and requires certain abilities such as speech perception, phonological awareness and phonogical short-term memory (Torgesen, Wagner, & Rashotte, 1994). However, not all studies of speech perception have shown a direct relationship between developmental articulation disorder and speech perception disability (Shriberg, Gruber, Kwiatkowski, 1994; Shriberg & Kwiatkowski, 1994; Shriberg, Kwiatkowski, & Gruber, 1994; Winitz, 1984). In contrast to earlier studies using typical adult speech, recent studies using synthetic speech continua (Rvachew & Jamieson, 1989), natural speech recorded from children (Hoffman, Stager, & Daniloff, 1983) or speech electronically altered to remove cue redundancy (Edwards, Fox, & Rogers, 2002) have revealed that children with developmental articulation disorder are likely to have difficulty with categorical perception.

1.2 Developmental weighting shift (DWS) in speech perception

Most theories of speech perception propose that listeners perceive speech sounds using the linguistic system, based on integrating multiple acoustic properties of the speech signal (Baily & Summerfield, 1980; Borden, Harris, & Raphael, 2003), but they do not assign perceptual weight equally to each acoustic cue (Whalen, 1991). Moreover, many studies have reported that adults and children assign different perceptual weight to each acoustic property (Jusczyk, 1993; Morrongiello, Robson, Best, & Clifton, 1984; Nittrouer, 2004; Nittrouer & Studdert-Kennedy, 1987; Parnell & Amerman, 1978).

Nittrouer and Studdert-Kennedy (1987) showed that young children based phonetic judgment of syllable-initial fricatives on the formant transitions of the following vowel to a greater extent than did older children or adults. These results led them to the hypothesis that the young children's perceptual weight was different from older children or adults. Based on a series of studies, Nittrouer and colleagues proposed that children's perceptual strategies changed to those of adults as their experience of the native language increased (Nittrouer, 1992, 2002; Nittrouer & Miller, 1997a, 1997b), and they termed this developmental change the *developmental weighting shift* (DWS) (Nittrouer, Mannig, & Meyer, 1993; Nittrouer & Miller, 1997b).

Given that the DWS is one possible marker for the development of speech processing ability, children with developmental articulation disorder suspected to have phonological processing deficit might demonstrate different characteristics in DWS from those of children without those problems. Consequently, clarification of the nature of DWS in children with developmental articulation disorder who are suspected of having phonological processing deficit will help us not only to elucidate the mechanism behind both problems but also identify an effective treatment. Since the DWS has not been verified for native Japanese speakers, the purpose of the present study was to verify DWS for native Japanese adults and children without developmental articulation disorder and those children with developmental articulation disorder indicative of having a phonological processing deficit. We then discuss here the perceptual weighting of syllable-initial fricatives for a group of adults and a group of children with the disorder.

2. Method

2.1 Participants

2.1.1 Adults

Forty-two adults (6 men and 36 women) between the ages of 20 and 36 participated the study. All of them were native Japanese and had no histories of speech, language or hearing problems. The hearing screening test was performed at Sophia University in a sound-attenuated booth (Rion AT-80) using a Rion AA-77 audiometer and Telephonics TDH-39P headphones.

2.1.2 Children with developmental articulation disorder

Two children (child A and child B in the follow section) were referred to the study by teachers of a special class for children with speech and language handicaps. Teachers were requested to refer children on their caseload who met the following criteria: (a) IQ within average limits (defined as 70 or over), (b) persistent articulation disorder, (c) no physical problems causing the speech difficulties, (d) no hearing impairment, and (e) incorrect speech perception and production that occurred frequently and inconsistently.

Child A was a girl aged 9 years 11 months. She had developed speech typically until the age of 1 year 9 months, at which time she contracted herpes. Thereafter she did not speak at all. In 3 weeks she began to speak again, but she talked less than before and her speech was unintelligible. When she was 2 years old, her family consulted a doctor at a public health center, and when she was 5 years old, she was referred to a special class for children with speech and language handicaps at elementary school. From this time she received speech therapy about once a week from then to until the time of the study. She showed frequent and inconsistent speech sound substitutions that occurred more frequently in multisyllabic words than in mono- or disyllabic words. With regards to language development, her score on the Picture Vocabulary Test Revised in 1991(in Japanese) (Ueno, Utsuo, & Iinaga, 1991) at 6 years 6 months was equal to that of a child of 5 years 4 months, and that on the Wechsler Intelligence Scale for Children Revised (in Japanese) (Kodama, Shinagawa, & Mogi, 1989) at 8 years 3 months was 91 for full scale IQ, 100 for verbal IQ, and 83 for performance IQ. She acquired to read the Japanese Kana letters at about 6 years old, but in writing, she tended to confuse letters that have two sound forms (e.g., "は" has the sound /ha/ or /wa/ depending on the context). She learned to read and write Kanji letters but could not retain them long.

Child B was a girl aged 10 years 4 months. Her physical development was typical but delayed in the area of speech and language development. Her first word was seen at 12 months, but her vocabulary barely increased. At 3 years 10 months, she became able to use two-word sentences. She was extremely sensitive to sounds and was especially afraid of toilet flushing sound. When she was 6 years old, her family consulted a doctor in a local rehabilitation center for children. There she was diagnosed with language learning disability. After entering elementary school, she received speech and language training once a week in a special class for children with speech and language handicaps until aged 10 years old. Similar to Child A, she showed frequent and inconsistent speech sound substitutions. As to language development, she had IQ within average limits, but had difficulties with receptive and expressive language and with word retrieval. She became interested in reading and writing around 6 years old, but was not good at reading aloud. She could learn Kanji but could not retain long.

2.2 Experimental tasks

For adults, a hearing screening test was performed immediately before the speech identification task. For children, in addition to the speech identification task, the Articulation Test (The Japan Society of Logopedics and Phoniatrics, 1994) and several language development assessments were administered. To explore whether persistent articulation disorder is caused by a phonological processing deficit often accompanied by language learning impairment, we administered the Japanese language version of the Wechsler Intelligence Scale for Children-Third Edition (WISC-Ⅲ in Japanese) (Azuma, et al., 1998) and the Picture Vocabulary Test Revised in 1991 (in Japanese) (Ueno et al., 1991), and the National Standard Reading Ability Test type A (Okamoto & Muraishi, 1981). The speech identification task was administered on one day, separate from the other assessments.

2.3 Speech evaluation

The children's speech samples were recorded using a microphone (SONY ECM-MS957) and a digital audio tape recorder (SONY TCD-D100). The first author and two speech language pathologists who each had experience of at least 550 cases of articulation disorder evaluated the children's speech samples independently. Evaluation was determined by consensus among two or three speech language pathologists.

2.4 Speech identification task

The speech identification task was carried out as previously described (Hirai, Yasu, Arai, & Iitaka, 2005). Briefly, the methodology was as follows.

2.4.1 Devices

The speech identification task was carried out in a sound-attenuated booth (Rion AT-80). Stimuli stored on a computer were presented through the AD/DA converter (ONKYO SE-55) and the participants' responses were automatically recorded on the computer (Figure 1).

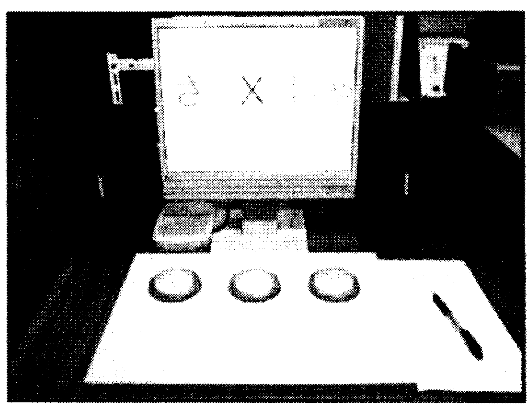

Figure 1 Experimental set up. Kana letters and alphabet letter *x* are shown on the monitor as presenting order of stimuli from left to right.

2.4.2 Stimuli

As described previously (Hirai et al., 2005), stimuli consisted of natural /s/ and /ʃ/ noises combined with synthetic /ɑ/ vocalic portions. In order to create the consonant portion, /s/ and /ʃ/ were separated from /ʃɑ/ and /sɑ/ syllables recorded by a native Japanese male speaker aged 36 years old. These fricative noises were varied along a nine-step continuum (C_1, C_2, ..., C_9), from one appropriate for /ʃ/ (C_1) to one appropriate for /s/ (C_9) (Figure 2). Duration of each consonant portion was 100 ms.

Nine synthetic vocalic portions were created using XKL (Klatt, 1984) to form a nine-step continuum (V_1, V_2, ..., V_9), varying from one most like /ʃ/ (V_1) to one most like /s/ (V_9) (Figure 3). Duration of each vocalic portion was 260 ms, and the characteristics of the fundamental frequencies are shown in Figure 4. The vocalic portion was always 11 dB greater in amplitude than the noise portion. That is, in 81 stimuli, C_1V_1 was most like /ʃɑ/ and C_9V_9 was most like /sɑ/.

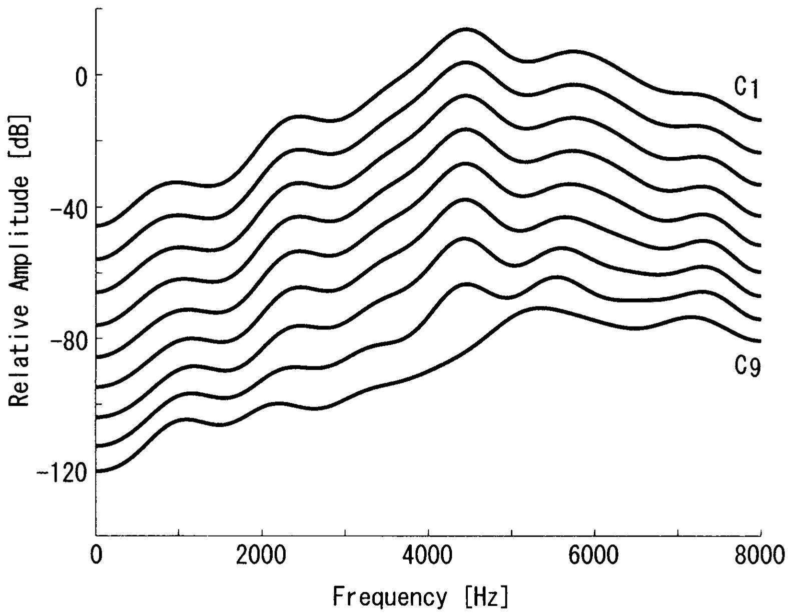

Figure 2 Outline of spectrum envelope of C_i (i = 1,2,...,9). These fricative noises are changed continuously from C_1 to C_9, but are plotted separately for ease of viewing.

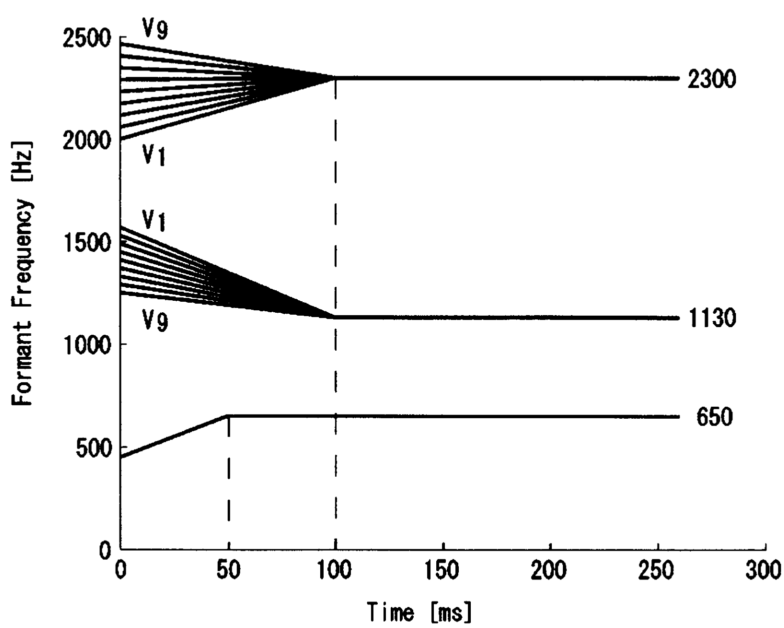

Figure 3 Formant transition of V_j(j = 1,2,...,9). The characteristics of formant frequencies are same as those used by Nittrouer (2002).

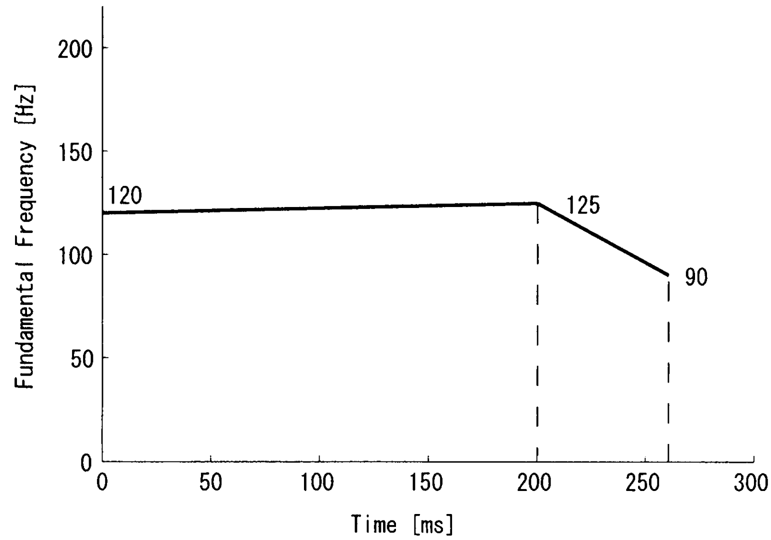

Figure 4 Characteristics of fundamental frequency of vowel portion. Fundamental frequency started from 120 Hz and fell throughout the portion to an offset frequency of 90 Hz same as in Nittrouer (2002).

2.4.3 Procedure

As in Hirai et al. (2005), AXB identification procedure was used. Participants were instructed to identify the stimulus X as A or B, where A was most like /ʃɑ/ (C_1V_1), B was most like /sɑ/ (C_9V_9), and X was 81 combinations of C_i and V_j ($i = 1,2,\cdots,9$; $j = 1,2,\cdots,9$). To counterbalance the order effect of A and B, 162 consequences of three stimuli composed of 81 AXB and 81 BXA consequences were created. One set comprised 162 consequences and these were presented randomly across participants.

Several exercises using a consequence where X was either C_1V_1 or C_9V_9 were conducted to confirm that the participants understood the procedure. After these exercises, five sets of the task were completed. Consequently, all participants made judgments 10 times for each C_iV_j presented twice in one set.

2.4.4 Analysis

2.4.4.1 Percent of /s/ responses and angle of the phoneme boundary line

Results of the identification of 81 stimuli C_iV_j is shown in a three-dimensional graph in Figure 5. The curved surface of percent of /s/ responses was approximated by the sigmoid function, as described previously in Hirai et al. (2005) (Figure 6). We termed the intersection of the approximated curved surface and the plane where percent of /s/ response was 50 as the phoneme boundary line, and defined the angle formed by the phoneme boundary line as θ (Figure 7). θ near 0° representing the phoneme boundary line tends to be parallel to the x axis and the listener responds based more on the formant transitions than on the spectrum of the fricative noise, while θ near 90° representing the phoneme boundary line tends to be parallel to y axis and the listener responds based more on the spectum of the fricative noise than on the formant transitions. That is, θ indicates which cue listener gives perceptual weight to: either to the spectrum of the fricative noise or formant transition. Thus, we computed θ to analyze the responses.

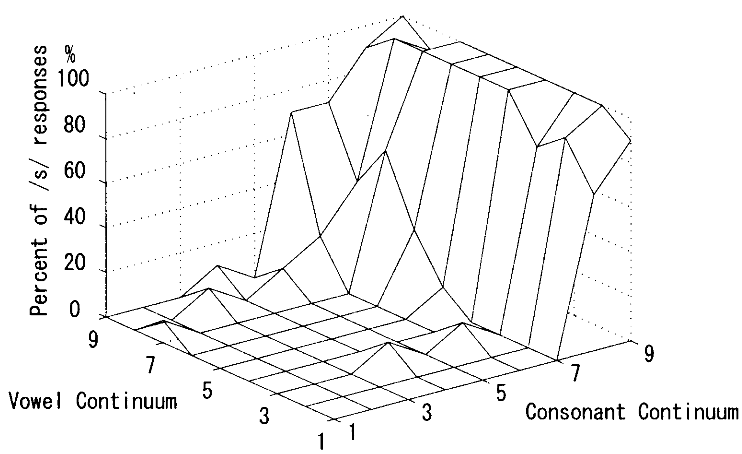

Figure 5 Percent of /s/ responses for C_i V_j. *X* axis represents *i*, *y* axis represents *j*, and *z* axis represents percent of /s/ responses.

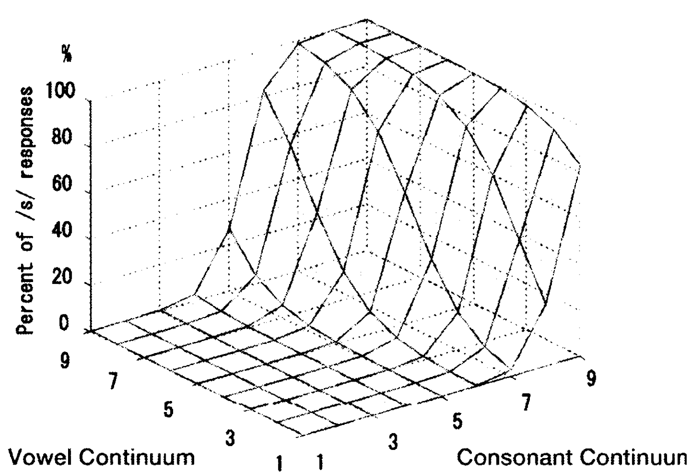

Figure 6 Of percent of /s/ responses curved surface approximated by the sigmoid function.

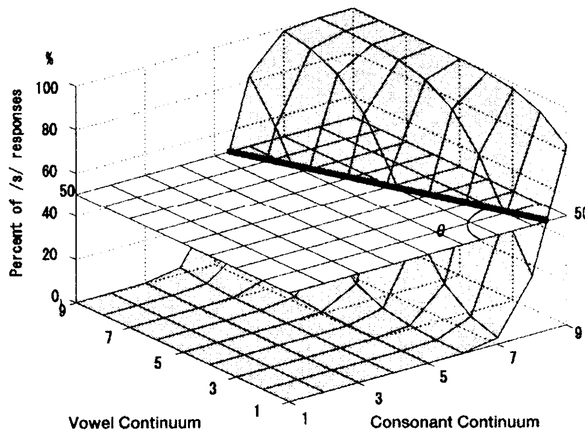

Figure 7 Angle of phoneme boundary line (θ).

2.4.4.2 Other parameters

To assess how categorically listeners responded, we calculated the largest slope of inclined plane of the approximated curved surface at the point where percent of /s/ responses was 50 (slope). The larger the slope, the more categorically the listeners responded.

In addition, we used mean square error (MSE) between the curved surfaces before and after approximation to evaluate how listeners responded reflecting the continuity of the change of the acoustic properties of the stimuli. The smaller the MSE, the more smooth the curved surface, which reflects more continuous listener's response.

3. Results

3.1 Children's articulation and language development

Child A consistently substituted /tʃi/ for /ki/, /tʃ/ for /kj/, /dʒi/ for /gi/, and /dʒ/ for /gj/ in syllable repetition, in word naming and in sentence repetition. She inconsistently produced distorted /d/ resembling /ɾ/ in conversation. She did not show stimulability. In confrontation naming of words in the articulation test, she often experienced naming difficulties for familiar words due to, for example, searching for target sounds. Child A's results of WISC-Ⅲ were 82 for full scale IQ, 89 for verbal IQ, and 80 for performance IQ, indicating she had a full scale IQ within average range, and verbal IQ and performance IQ did not differ significantly ($p > 0.05$). In verbal tasks, standard scores for Information and Digit span were low ($p < 0.05$). Picture Vocabulary Test score revealed that receptive vocabulary size was the same as that of a child of

7 years 4 months and that reading grade, shown by the Reading Ability Test, was about 2 grades below the level of reading ability for her chronological age.

Child B consistently substituted /tʃi/ for /ki/, /tʃe/ for /ke/, /tʃ/ for /kj/, /dʒi/ for /gi/, /dʒe/ for /ge/ and /dʒ/ for /gj/ in syllable repetition, in word naming and in sentence repetition and she inconsistently produced distorted /ɾ/ resembling /d/ in conversation. She also did not show stimulability. Child B's results of WISC-Ⅲ were 102 for full scale IQ, 99 for verbal IQ, and 106 for performance IQ, indicating she had a full scale IQ score around the mean score for age-matched children, and verbal IQ and performance IQ did not differ significantly ($p > 0.05$). In performance tasks, standard score for Coding was low ($p < 0.05$). The Picture Vocabulary Test and Reading Ability Test scores showed that receptive vocabulary size and level of reading ability were almost equal to those of her peers. During the test, however, because of difficulties in word retrieval, she could not easily express herself due to the frequent use of pronouns to replace target words, and misuse or deletion of Japanese postpositional particles.

3.2 Speech identification task

3.2.1 Percent of /s/ responses

Of the 42 adult participants, 36 tended to respond /ʃ/ for stimuli of consonants from around C_1 to C_6 and /s/ for stimuli of consonants from around C_7 to C_9 (Figure 8). This pattern suggested that many adults made judgments based mainly on consonants relative to vowels; in other words, they were weighting to consonants. In contrast, as shown in Figure 9, the remaining 6 adults tended to respond /s/ for stimuli of consonants from around C_4 to C_9 and vowels from around V_5 to V_9. The latter pattern indicated that these listeners did not give weight to consonants as strong as for the other 36 adults.

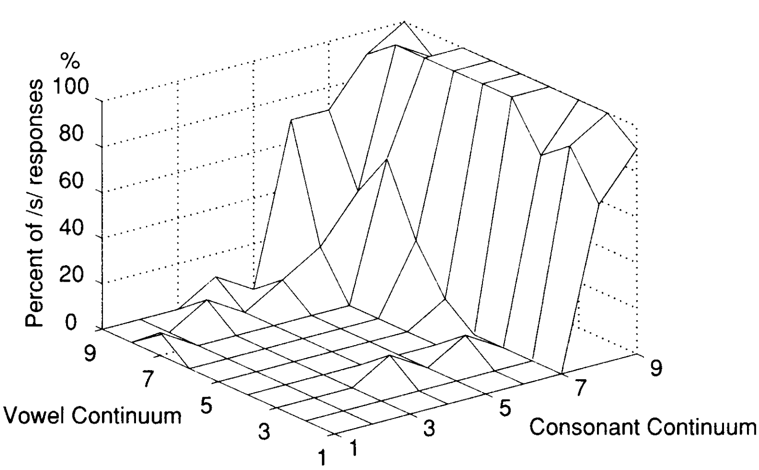

Figure 8 Percent of /s/ responses for one adult participant.

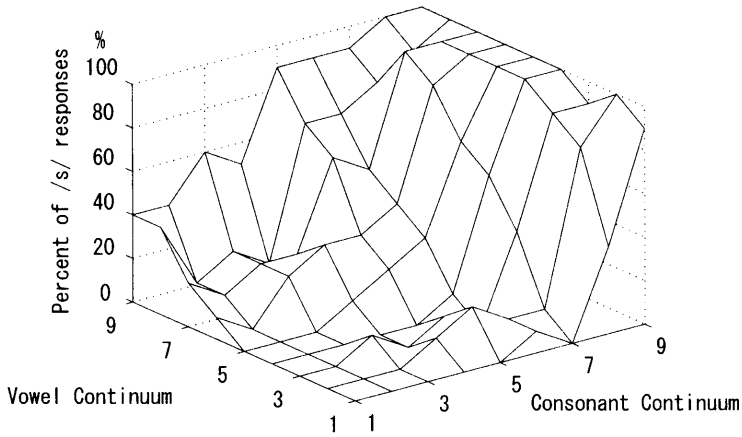

Figure 9 Percent of /s/ responses for the second adult participant.

The children's /s/ responses increased for stimuli consonants from around C_6 to C_9 and vowels from around V_7 to V_9 (Figure10 and 11). Thus, the children tended to respond similar to the smaller group of 6 adults, based on vowel portions of stimuli to a greater extent than did the larger group of 36 adults.

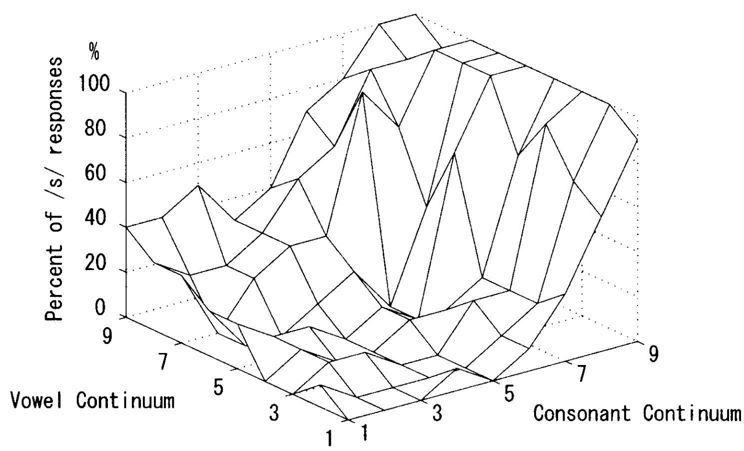

Figure 10 Percent of /s/ responses for the child A aged 9 years 11 months.

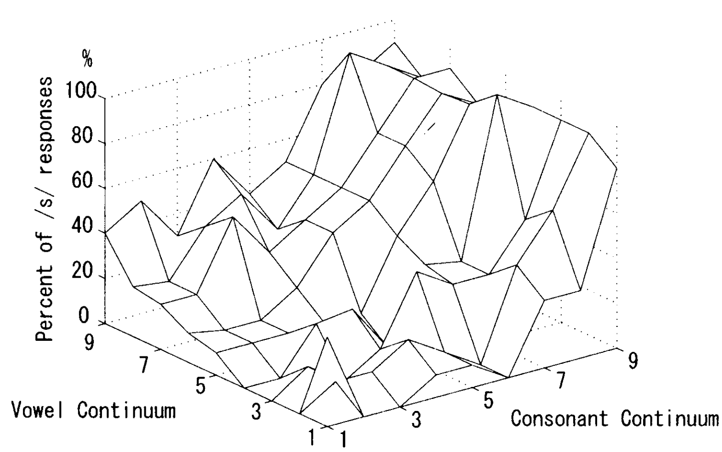

Figure 11 Percent of /s/ responses for the child B aged 10 years 4 months.

3.2.3 Angle of the phoneme boundary line

One adult participant was excluded because θ was almost 4 standard deviations below the average.

As seen in Figure 12, θ for many adults was generally parallel to the y axis, with the remainder generally parallel to the x axis. We fitted the histogram of θ to normal distribution to verify the prediction that θ distributed bimodal (Figure 13). The least square error of fitting to bimodal distribution was smaller (0.0175) than that to unimodal distribution (0.0899), we considered that adults responded in two ways differentiated by θ, where θ was either larger or smaller than 73.2°, which was the intersection of two normal distribution curves. That is to say, 36 adults with θ larger than 73.2° gave greater to perceptual weight to the spectrum of the fricative noise than did the remaining five adults with θ smaller than 73.2°. Moreover, because children's θ were smaller than 73.2°, they tended to respond like the five adults, responding more with respect to formant transition than with respect to the spectrum of the fricative noise.

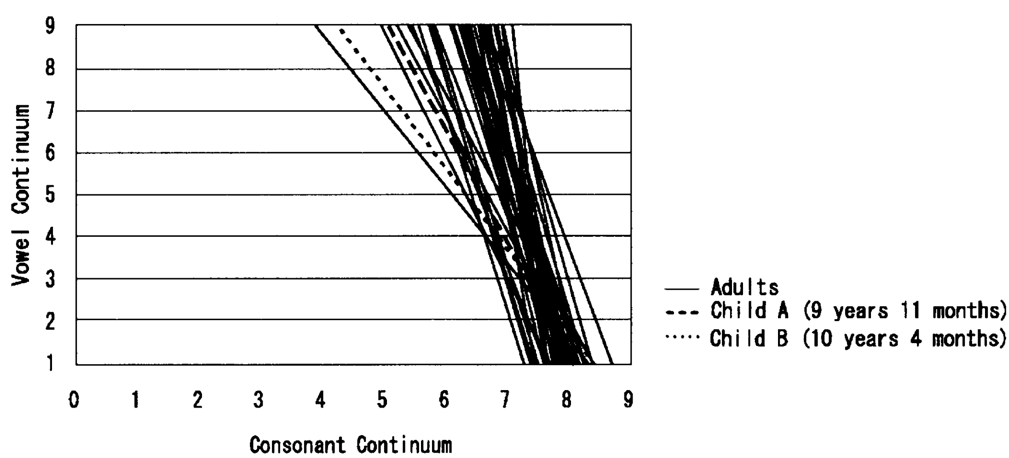

Figure 12 Phoneme boundary lines of 41 adults and two children with persistent developmental articulation disorder. Phoneme boundary lines depict the distribution of θ.

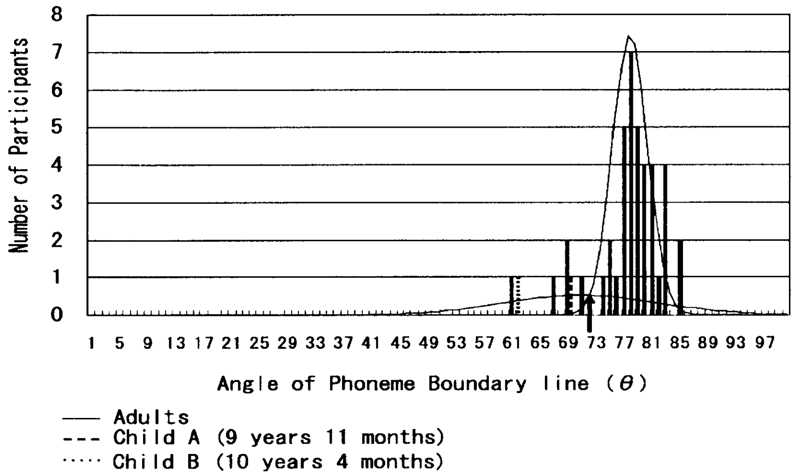

Figure 13 Histogram of the angle of phoneme boundary lines(θ). θ values were predicted to have bimodal distribution.

3.2.2 Other parameters

Slopes of the adult participants varied inconsistently, and those of almost all adults were larger than those of the children (Figure 14). Slopes of adults with larger θ did not significantly differ from those of adults with smaller θ, but θ and slope of adults with smaller θ correlated significantly (Spearman rank order correlation, $p < 0.05$).

As shown in Figure 15, many adults had a smaller MSE than the children. For adults with larger θ, MSE was significantly smaller than for adults with smaller θ (Mann-Whitney U test, $p < 0.01$). In addition, slope and MSE of adults with smaller θ showed a significantly negative correlation (Spearman rank order correlation, $p < 0.05$).

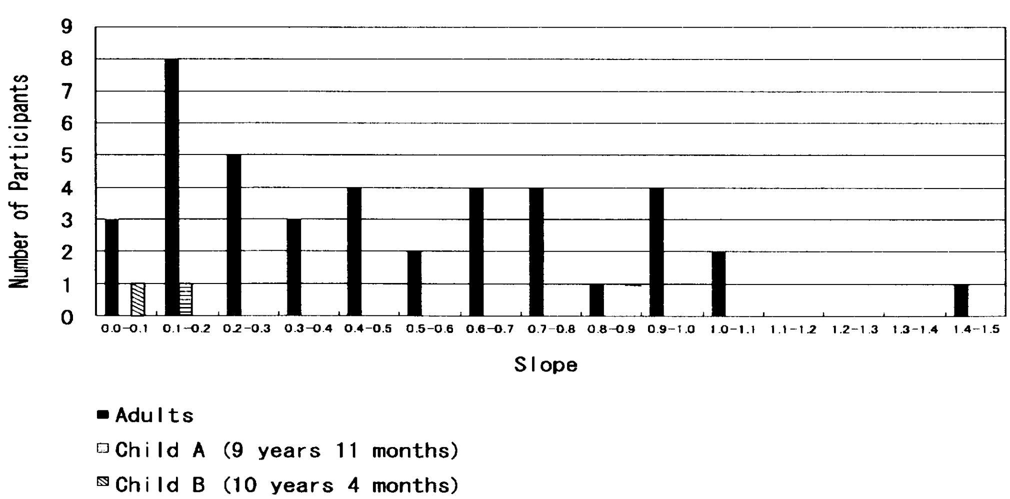

Figure 14 Histogram of slope.

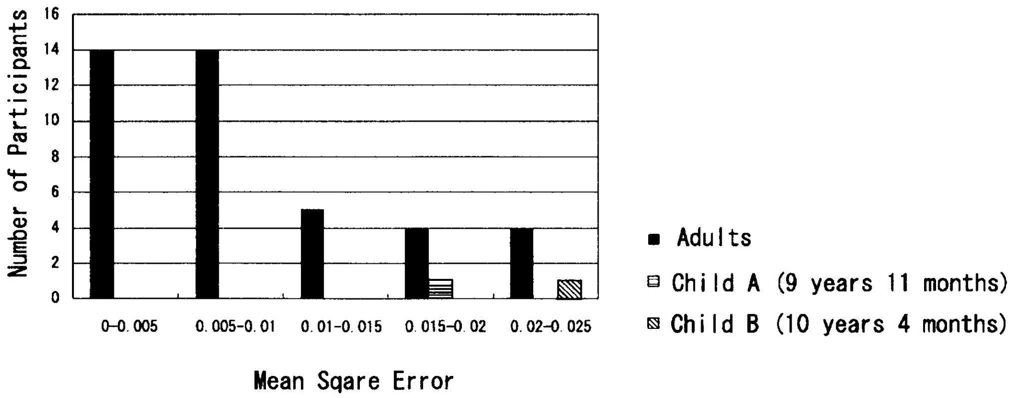

Figure 15 Histogram of MSE.

4. Discussion

Our study had three major findings. First, many Japanese native speakers appeared to base phonetic judgment of syllable-initial fricatives more on the spectrum of the fricative noise than on the formant transitions of the following vowel. Second, a small number of Japanese native speakers could make a judgment based more on the formant transitions than on the spectrum of the fricative noise. Third, children with persistent developmental articulation disorder appeared to give greater weight to formant transition and less to the spectrum of the fricative noise compared to the majority of adults.

4.1 Perceptual weight of adults

Most of our adult participants gave perceptual weight to the spectrum of the fricative noise, a finding that is in good agreement with the results of English native speakers, as reported by Nittrouer and Miller (Nittrouer, 1992, 1996, 2002; Nittrouer & Miller, 1997a, 1997b). Contrary to their results, however, a few adult participants did not seem to give perceptual weight to the spectrum of the fricative noise. This finding implies that adults' perceptual weight is not uniform. Nittrouer et al. hypothesized that children's perceptual weight changed to that of adults as a result of maturing speech perception, the strategy of developmental weighting shift (DWS) (Nittrouer et al., 1993; Nittrouer & Miller, 1997b). However, in the present study, perceptual weight of a small number of adults was actually based on formant transition to a grater extent than on the spectrum of the fricative noise, which indicates that the difference of the perceptual weight could not explained by only the notion of a maturation strategy of speech perception.

An alternative explanation for the differences in perceptual weight could be the type of information that listeners focus on at a given time. According to Best, Morrongiello, and Robson (1981), changes in identification function occurred dependent on whether the stimuli were heard as speech (phonetic, or categorical, mode) or nonspeech (auditory, or non-categorical, mode), not on actually whether the stimuli were speech or nonspeech. Repp (1981) assumed that phonetic and auditory modes were available for any speech-like stimulus and that they might be used simultaneously. Although the phonetic mode is the natural way to process speech, auditory properties of speech are often unfamiliar and require listeners to pay attention to fine detail, in other words, to listen using the auditory mode. Presumably, when it is difficult to decide the exact nature of a phoneme in the native language, listeners may analyze obscure speech stimuli using the auditory mode by reorganizing the phonetic mode in the process (e.g., "segregate the noise portion from the following vocalic portion"; Repp, 1981, p.225). Whalen (1981) argued that in the perception of /s/ or /ʃ/, if the fricative noise has typical frequency values of /s/ or /ʃ/, the fricative noise was the deciding cue, whereas if the fricative noise was too obscure to be judged immediately as /s/ or /ʃ/, the formant transition took on more weight as a cue. Whalen's proposition and our results here led us to conjecture that adults who made judgments largely based on the spectrum of the fricative noise were using the phonetic mode, while those who made judgments based more on formant transition were using the auditory mode. Grounded on this conjecture, the value of θ and slope may be larger for the phonetic (categorical) mode than the auditory (non-categorical) mode, because the greater the perceptual weight to the spectrum of the fricative noise, the larger the θ value, and the greater the categorical judgment, the larger the slope. Moreover, given that use of the auditory mode suggests that listeners perceive the stimulus to be too obscure to judge continuously as the acoustic properties of the stimuli change, the value of MSE may be larger for the auditory mode than for the phonetic mode, since the greater the discontinuity of judgment, the larger the MSE. Our findings in relation to θ, slope, and MSE may, at least in part, lend support to our conjecture that perceptual weight differs depending on perceptual mode. One such finding is the significant correlation between θ and slope, despite the fact that it was shown only in adults with smaller θ. Another such finding is the negative relation between θ and MSE and between slope and MSE.

The disparity between our results for adults and those of Nittrouer and Miller may be related to the difference in stimuli used (Nittrouer, 1992, 1996, 2002; Nittrouer & Miller, 1997a, 1997b). In the present study, stimuli changed for both the spectrum of the fricative noise and formant transition as it was varied along a nine-step continuum. Nittrouer and Miller, however, used stimuli that varied either the spectrum of the fricative noise or the formant transition along a nine-step continuum and other stimuli that were most like /ʃ/ and most like /s/. The obscurity of the stimuli used in our study might therefore differ from that of the stimuli used in their study. In addition, they compared adults to typically developing children, whereas we did not. To verify the perceptual weight of adults, further studies on typically developing native Japanese children are needed.

4.2 Perceptual weight of the children with persistent developmental articulation disorder

Basd on our findings, children with persistent developmental articulation disorder appear to place greater weight on formant transition than on the spectrum of the fricative noise, similar to 3- to 4-year-old children reported in the studies of Nittrouer and Miller (Nittrouer & Miller, 1997a, 1997b). This finding suggests that children with persistent developmental articulation disorder around age 10 years old have not yet experienced the developmental weighting shift, which leads us to surmise that their speech perception ability developed differently from those of typically developing children.

Articulation requires changing a consequence of phonemes to that of articulatory movements after encoding meanings and concepts to phonemic representation. Articulation disorder is attributable to problems of speech sound perception, because incorrect speech perception not only disturbs establishment of the phonemic representation system, but also gives rise to difficulty in phonologically decoding acoustically presented speech as well as matching phonemes to articulatory movements (Rapin & Allen, 1992). Inaccurate perception and an uncertain phonemic representation system might obstruct the development of self-correction via auditory feedback, making the articulation disorder persist. The children in the present study showed substitution (/tʃi/ for /ki/) until around age 10 years old. Some typically developing children also substitute /tʃi/ for /ki/, but many of them do not present with substitution at school age (Funayama, 1998). The origin of articulation disorder in the two children participating in the present study may well be different from that shown in typically developing children.

Findings related to perceptual weight and articulation disorder in children in the present study suggest that persistent articulation disorder results from problems of speech perception. However, since the results were for the small number of children with the disorder and those for native Japanese children without the disorder have not been obtained, to confirm this suggestion, studies for children with and without the disorder are needed to be accumulated.

4.3 Relation between speech perception ability and language development in children with articulation disorders

Both children that participated in this study demonstrated mixed receptive and expressive language problems, word finding difficulties, and reading and writing problems. They were diagnosed with language learning impairment, though their verbal IQ and performance IQ on WISC-Ⅲ did not differ siginificantly (Tanaka, 2005).

Since a speech perception deficit makes phonologically decoding speech difficult and may risk subsequent processing and programming operations (Rapin & Allen, 1992), it can cause a phonological processing deficit. Because a phonological processing deficit disturbs the development of phonological awareness and language ability, for example, the acquisition of receptive and/or expressive vocabulary, reading, and writing, it may too create successive language problems (Oishi & Tanaka, 2001). Though not all children with articulation disorders have phonological processing deficits (Rapin & Allen, 1992; Tanaka, 2005), the origin of language learning impairment of the children in the present study might be explained by speech perception deficits based on our hypothesis related to perceptual weight.

Similarly, Yuge (2001) and Miyairi, Oishi, and Sato (1992) reported that children whose IQ on the Tanaka Binet Intelligence test (Tanaka Institute for Educational Research, 1987) or performance IQ on the Wechsler Intelligence Scale for Children (in Japanese)(Kodama, Shinagawa, & Mogi, 1978) was within average limits had articulation disorders characterized by inconsistent errors and language learning impairment. Yuge (2001) tested ability in the perception of words modified by changing the pause between syllables and in phonological awareness. Based on comparison with a language learning age-matched control, Yuge assumed that child's speech and language difficulties might be related to problems in auditory perception. Miyairi et al. (1992) speculated that a deficit in speech sound perception could account for child's articulation disorders and reading and writing disabilities judging from the development of articulation, reading, and writing. Both studies suggest one possible origin of persistent developmental articulation disorder; however, these need to be verified as they were based on the findings of just one child in each study.

4.4 Early diagnosis of speech perception deficits

Language disorders suspected to derive from speech perception deficits tend not to be identifiable in young children. It is not until around school age that language learning impairments are considered to be potentially linked with persistent articulation disorder. Deficits in speech perception has affected also in early stages of language development, the effect of therapeutic intervention beginning around school age is limited. Children with these disorders start school without sufficient language skills and are often not able to keep up with their peers since almost all classroom instruction is given orally. Their inadequate language skills cause a cascade effect, further exacerbating the speech and language problems; not only do they have poor language skills, but also poor language skills prevent these children from acquiring new knowledge across the curriculum, which in turn limits improvement of a wide variety of skills. As the number of such children is growing, the need for early diagnosis and early intervention is becoming increasingly important.

However, a marker for diagnosis is not yet known, which is one of the reasons why the development of speech perception in typically developing native Japanese children is not well documented. If the developmental weighting shift (DWS) were to be verified in typically developing native Japanese children and if it were found to differ from that of children with articulation disorders suspected to derive from a speech perception deficit, the DWS would be a potential marker for the deficit. Such a marker could facilitate earlier diagnosis and intervention, thereby preventing persistent articulation disorder and language learning impairment. It is therefore a matter of urgency to establish whether DWS is in fact a marker of speech perception deficit, which requires elucidation of speech perception development in young children with and without articulation disorders.

4.5 Treatment for articulation disorder suspected to derive from a speech perception deficit

Problems with phonetic skills and phonological knowledge are implicated in developmental articulation disorders. Although phonetic and phonological approaches are usually combined in treatment for developmental articulation disorders (Bernthal & Bankson, 1998; Rvachew, Nowak, & Cloutier, 2004), these approaches tend not to be useful for children with articulation disorders suspected to derive from speech perception deficits.

Tallal and colleagues attempted to devise intervention approaches for language learning impairment based on the presumption that it is caused by specific deficits in auditory perception (Tallal & Percy, 1973; Tallal, Miller, & Fitch, 1993; Tallal et al., 1996). They demonstrated that many children with language learning impairment show impaired discrimination and sequencing of rapidly presented auditory stimuli. They interpreted these data as evidence that children with language learning impairment have basic constraints in the rate of processing and production of rapidly successive stimuli. This interpretation led them to the hypothesis that articulation and language disorders of children with language learning impairment resulted from specific deficits in auditory perception. Grounded on the hypothesis, they have developed training programs (Fast ForWord®) using synthetically modified stimuli, and have reported its effectiveness (Tallal & Benasich, 2002).

In a study involving a Japanese participant, Miyairi et al. (1992) noted that a child with persistent articulation disorder, receptive and expressive language disorder and reading and writing disability improved in a dictation task involving monosyllables when the duration of pauses between the monosyllables was extended.

Taken together, these findings indicate that acoustically modified speech stimuli might facilitate perception of speech sounds. However, Tallal et al.'s hypothesis is not supported by the findings of a study of children with dyslexia (Brady, 1997) showing that they had a specific deficit in phonological processing as supported by accumulating research. In addition, Miyairi et al.'s supposition came from experience of one child. Thus, the effectiveness of using modified speech stimuli remains controversial.

Taking another perspective—that of learning theory—a multimodal treatment approach developed from our knowledge of the neurological basis of language and of brain plasticity is also expected to work effectively for individuals with learning disabilities that include receptive and expressive language disorders and reading disabilities (Tallal & Benasich, 2002; Tuchman, 2000).

Probably no single approach adequately addresses all issues, and a combination of conventional approaches and use of acoustically modified speech stimuli may be effective for children in whom conventional therapy alone was unsuccessful. If the critical acoustic cues, namely those by which perceptual weight is assigned, are modified in such a way as to emphasize their distinctness, it will benefit speech and language development in children whose speech and language problems are suspected to result from a speech perception deficit. Further study is required to verify the effectivenss of treatment of these children using modified speech stimuli and an associated training program.

4.6 Speech stimuli

We used /sɑ/ and /ʃɑ/ to verify the DWS reported by Nittrouer and Miller (Nittrouer, 1992; Nittrouer & Miller, 1997a, 1997b) in native Japanese speakers. Nittrouer et al. also demonstrated the DWS in stimuli of /s/ and /ʃ/ followed /i/ and /u/ (Nittrouer, 1992, 1996, 2002; Nittrouer & Miller, 1997a, 1997b; Nittrouer & Studdert-Kennedy, 1987), but other researchers found conflicting results depending on the consonants and vowels used, and on the position of the target sounds (Mayo, Scobbie, Hewlett, & Waters, 2003; Mayo & Turk, 2004; Nittrouer, 2004). Thus, the DWS must be validated in various contexts.

Moreover, both children with articulation disorders who participated in the present study did not consistently misarticulated /sɑ/ and /ʃɑ/, but did /ki/, /ke/, /kj/, /gi/, /ge/ and /gj/. Because some individuals with articulation disorders inaccurately perceive speech sounds they can not produce correctly, but accurately perceive those they can produce correctly (Bernthal & Bankson, 1998; Winitz, 1984), further study is required to clarify how they perceive speech sounds other than /sɑ/ and /ʃɑ/, particularly those they substitute.

5. Conclusion

This study provides evidence for the potential usefulness of perceptual weighting as a marker for speech perception deficit. If perceptual weighting were verified as a marker, it could facilitate earlier diagnosis and intervention for speech and language problems and reduce the risk of developing persistent articulation disorder and concurrent language learning impairment. We are continuing in our attempts to further characterize the development of speech perception ability in children with and without developmental articulation disorder.

Footnote

In the early 1980's, many researchers focused on the importance of phonological development as the cause of developmental articulation disorder, and some proposed the term *phonological disorder* to replace *developmental articulation disorder* (Shriberg & Kwiatkowski, 1982). Despite considerable discussion among American and European speech language pathologists, a consensus on terminology has yet to be reached (Winitz, 1984). Accompanying this debate, the definition used by the American Psychiatric Association changed from *developmental articulation disorder* in the Diagnostic and statistical manual third edition revised (American Psychiatric Association, 1987) to *phonological disorder* in the Diagnostic and statistical manual forth edition text revision (American Psychiatric Association, 2000). Phonological disorder is defined in *DSM-IV-TR* (2000) as inclusive of both the problems of speech motor control for articulatory movement and of phonological development (Kato, 2003). We use the term developmental articulation disorder instead of phonological disorder in the present study because we consider that it is necessary to differentiate the articulation disorder as a symptom from the phonological disorder as the cause, for the purpose of the present study was to elucidate the mechanism behind developmental articulation disorder, and a possible candidate is phonological disorder.

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