

# Language-specific developmental changes in speech perception abilities and their neuropsychological reason: A hypothesis

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## 1.0. AIM OF THIS PAPER

One of the most debated issues in perceptual development is the relative roles that innate and experiential factors play in the process of acquiring speech perception abilities. Much of the previous research has provided ample evidence that infants under 6 months are able to discriminate a speech contrast, whether or not it exists in the native language, indicating that their perceptual abilities are not influenced by native language phonology (Werker et al., 1992). However, it has also been demonstrated that adults who have once acquired the phonological system often have substantial difficulty in discriminating some speech contrasts which do not exist in the native phonological system. This strongly indicates that perceptual abilities to distinguish some non-native speech contrasts decline in the process of acquiring a particular phonological system.

This paper has two aims, one is to identify the timing of the developmental decline, focusing on the perception of an American English contrast, /r-l/, by Japanese infants, and the other is to propose a hypothesis about the reason why such a developmental change is brought about.

## 2.0. EXPERIMENT ABOUT DISCRIMINATION OF ENGLISH /R-L/ AND /W-Y/ BY JAPANESE INFANTS

English /r-l/ is widely known as a speech contrast which does not exist in Japanese and therefore is very difficult for Japanese adults to distinguish. We investigated developmental changes in Japanese infants' ability to discriminate /r-l/ at 6-12 months, using /w-y/ as control stimuli. The contrast /w-y/ exists in the Japanese phonological system, as well as in English. We used a «conditioned eye fixation procedure», which is most similar to the experimental method employed in Best et al. (1988), and found that both /r-l/ and /w-y/ were discriminated at 6-8 months. At 10-12 months, however, /w-y/ was discriminated, whereas /r-l/ was not. The experiment required an expert knowledge and technique to carry it out. The procedures of the experiment were all reported in the *Proceedings of ICSLP 94*, Yokohama, Japan. In the ISAPL Conference 97, it was introduced using video .

### 3.0. NEUROPSYCHOLOGICAL REASON OF LANGUAGE-SPECIFIC DEVELOPMENTAL CHANGE

<Abstract > Human beings innately have two types of sound processing ?holistic and analytic (See Kohno's paper, 'A Psycholinguistic Study of Rhythm Processing' in these *Proceedings*(Kohno A, henceforth)), and they constitute a hierarchical structure: the holistic system constitutes the basic component, and the analytic system, a superimposed component. When the analytic processing is activated, the holistic processing is tentatively suppressed, although it is never destroyed. This mechanism will explain the language-specific developmental changes in sound perception.

### 3.1. HIERARCHICAL STRUCTURE OF SPEECH PROCESSING

#### 3.1.1. Rhythm processing by a patient with pure anarthria

##### *Experiment 1*

Three kinds of rhythm whose inter-beat intervals(IBIs) were 250, 500 and 1000ms were played to a patient with pure anarthria, by SEIKO Rhythm Trainer SQM-348. The patient was requested to tap the table simultaneously in time to those three rhythms with the knuckle of the third finger of his left hand which had no paresis. His tapping behavior was tape-recorded and then the IBIs were measured using of ILS. The result is shown in Table 1.

**Table 1 – Tapping behavior of a patient with pure anarthria (male, 45 years old, righthander)**

Target tempos	Inter-beat interval				
	n.	x	S.D.	r.v.	r
1000ms	54	1001	53	5.3	-0.42
500ms	67	503	28	5.6	-0.15
250ms	62	249	16	6.4	-0.38

n=number of IBIs, x=means of the length of IBIs (ms)

S.D.=standard deviation, r=autocorrelation among adjacentnt IBIs

r.v.=relative variance (S.D. $\div$ x /100)

The most remarkable phenomenon in Table 1 is about autocorrelation: the patient shows negative correlation even in the response beat to rapid 250ms stimulus. This suggests that, contrary to the normal (See Kohno A), he tries to make access analytically, one by one, even to the rapid rhythm. The patient's extremely analytic idiosyncrasy was also confirmed by other experiments, which were reported by Kohno et al.(1994).

Typical symptoms of pure anarthria often pointed out are extremely slow speed of utterance; too many breaks before syllables; putting a stress on every syllable; a lot of mispronunciation of the sounds which requires complex articulation; inconsistency of misarticulation, all of which are considered to be failure of harmonious and coordinated movements of several speech

organs such as tongue, lips and uvula. (Masaki et al. 1990, Higure et al. 1988 and others). All these phenomena can be finely explained by the patient's unusually analytic idiosyncrasy for processing sound sequences. He tries to analyze each movement of vocal and articulatory organs one by one rather than coordinate them. In this connection, his interesting words to the author (Kohno) were «Guessing the speed of a moving car was my special art, but since I suffered from the disease, I have completely lost that talent.» Does the patient have no holistic abilities in any sense then? To answer this question, we held the following experiments.

### 3.1.2. Relation between holistic and analytic processings

*Experiment 2:* The patient started his speech training, routine rehabilitation, on May 10, 1989 in the hospital. During the period of rehabilitation, we kept a record of his speech (reading texts aloud), and measured inter-syllable intervals (inter-voice-onset points) (ISI henceforth) and F0 by the use of ILS. At the same time, for the purpose of comparison, we analysed a normal adult's speech who read aloud one of the same texts (aged 27, male, right hander, same dialect speaker as the patient).

**Table 2 – Reading behavior of the patient and a normal adult**

Patient's reading behavior			
	n.	x (ms)	S.D.
6/22, 1989	75	777	325
7/24, 27, 1989	75	638	324
11/29, 1989	84	590	216
2/20, 27, 1990	103	495	222
4/4, 1990	91	510	190
5/30, 1990	46	429	156
7/25, 1990	98	430	180
8/2, 1990	53	410	154
8/30, 1990	145	423	146
Normal adult's reading behavior			
— 150	143	48	

n.= number of syllables which compose the stories

We can see from Table 2 that, contrary to the normal adult's reading behavior whose ISI was 143ms, the ISIs of the patient's speech were extremely long – all of which exceed the length of 330ms, the sphere of human's holistic processing.

The acoustical survey of F0s in the patient's utterance, on the other hand, revealed that he was apt to raise his pitch (F0) at the ends of some semantic and grammatical units. In order to find a more clear-cut figure, these units were reexamined from the viewpoint of the PSU (cf, 'Kohno's 'Rhythmic patterns in languages and psychology of speech perception' in these *Proceedings* (Kohno B)). Table 3 shows the result of the investigation.

Just as expected, the patient regularly raised F0 at the end of every unit corresponding to the PSU. The occurrence rate of pitch-rise at the end of the unit, interestingly to say, increased at the

date goes back. That is to say, when he was obliged to speak with very long ISIs, he used many pitch-rises.(See Column 2), but as his speech condition improved as a result of rehabilitation, this unusual habit of many pitch-rises gradually disappeared spontaneously. (Column 3).

Column 4 of Table 3, however, shows that there are some exceptions to our hypothesis – some pitch rises in the midst of the PSU, in addition to the rises at the end. This phenomenon was most remarkable at the beginning of rehabilitation but gradually disappeared as time went by. According to Higuchi *et al.*(1991), this patient committed a lot of word accent misplacements when his speech was nonfluent, with long pauses between syllables (for example *kàiko* (silk-worm) instead of *kàiko*), but as these pauses became shortened, these mispronunciations also began to disappear automatically. Column 4 of Table 3 shows these phenomena.

Table 4. Positions of pitch-rises and PSUs

conditions of pitch and PSU  Date	1	2		3	4
	total no. of PSU	Pitch-rise at the end of PSU		Pitch-fall at the end of PSU	Pitch-rise at the middle of PSU
		no. of occurrences	no. of syllables	no. of occurrences	no. of occurrences
6/22, 1989	19	19(100%)	3~7	0	4
7/24, 27, 1989	29	29(100)	2~6	0	2
11/29, 1989	19	18(95)	3~5	1	3
2/20, 27, 1990	24	21(88)	2~6	3	5
4/4, 1990	25	22(88)	2~5	3	0
5/30, 1990	15	15(100)	2~6	0	1
7/25, 1990	24	17(71)	3~6	7	2
8/2, 1990	16	14(88)	2~6	2	2
8/30, 1990	41	34(83)	2~6	7	1

The above phenomenon shows that, in spite of the extremely analytic idiosyncrasy, the patient still gives evidence of the concept of the PSU. The PSU, as already note in Kohno B, is a product of the holistic processing system. Judging from the fact that rising pitch at the end of the PSU is seldom heard in colloquial Japanese, except in a limited number of young children's speech, and that the patient had no such peculiarity of speech before the onset of the disease, that rising pitch is the specific device to delineate the PSU. The fact that the patient clearly keeps the PSU suggests that the analytic system never destroys the holistic system. In this connection, we should here recollect that the right hand of the split- brain patient can manipulate both rapid and slow tempos of rhythm, but the left hand only the rapid one. This suggests that the analytic system(which corresponds to the slow rhythms) may be built upon the holistic system(which corresponds to the rapid rhythms), but the holistic system is never premised on the analytic one(See Kohno A and Kashiwagi *et al.* ,1989).

How should we explain the two seemingly contradictory phenomena: the patient's overly analytic speech performance such as rhythm processing(Table 1) or the awkward way of speaking, and the fact that the holistic system's manifestation, PSU,is well kept in his speech? The answer is that the analytic processing (superstructure) tentatively suppresses the work of holistic processing(basic structure), and therefore, the holistic performance disappears from his speech.

If, however, the analytic idiosyncrasy were to be removed, holistic actions would automatically be resumed. In order to ascertain this, on August 30, 1990, we opened an experiment by tape-recording the patient's text reading. We then put an oblique line at the end of each PSU in the text, and asked the patient to do reading practice intensively, making efforts to read the PSU as fast as possible. A week later, we again tape-recorded his text reading. The ISIs and F0s of his utterance in the two recorded materials were measured with the result shown in Table 4. The occurrence rate of raising F0 was calculated according to the following formula: The total number of F0-rises at the end of PSU ÷ total number of PSU × 100.

**Table 4. Occurrence of F0-rises at the end of PSU and ISIs in the Patient's utterance**

	n.	x(ms)	S.D.	Occurrence Rate of F0 rises
Before practice	143	423	146	61%
After practice	145	375	140	48%
Normal adults	150	143	48	8%

n.= number of syllables; x = means of ISIs

Table 4 shows that, just as expected, as the ISIs became shorter as the result of rehabilitation, the occurrence rate of F0-rises decreased automatically.

As the conclusion, we might be able to say that holistic and analytic processing systems constitute two strata: the holistic is the basic structure and the analytic is a superstructure; and if the analytic system activates itself and builds up a linguistic constraints, it tentatively suppresses the more obvious holistic system's actions, without destroying it. When the analytic constraints are removed, the function of the holistic system is automatically resumed.

### 3.2. Mechanism of language- specific developmental change in sound perception

Speech perception abilities, as a matter of course, develop within the context of language acquisition as a whole. Judging from the fact that the timing of infants' acquisition of phonological perception coincides with the age at which infants begin to acquire words (Jusczyk, 1995), the phonological perception might be established by highly analytic processing, reorganizing phonetic perception. The analytic and holistic processing systems are both endowed innately in all infants, the former corresponding to slow rhythms, the latter to rapid rhythms (Kohno A). Hearing adults' speech, whose tempos are usually rapid with less than 330 ISI (intersyllable interval), infants would automatically activate their holistic processing system. (Kohno B). The holistic processing is characterized as 'as it is' 'all-at-a-time' and 'Gestaltic' perception (Kohno A). It might be able to discriminate speech patterns. In this connection, Kashiwagi et al. (1989) demonstrated that, although the left hand of the split brain patient cannot produce any rhythmic patterns without simply repetitive fast rhythm, his left ear can discriminate various kinds of rhythmic pattern, by the experiment in which the stimuli were given to him monaurally, masking the contralateral ear by 40dBHL white noise.

Once the analytic processing begins to work to encode Japanese phonemes, however, the activity of holistic processing is tentatively suppressed, and infants begin to discriminate the sounds according to the constraints produced by the analytic processing. The holistic processing, however, is not destroyed at all. When people begin to learn a foreign language in later years, therefore, and if they nullify out the analytic restraints particular to their mother tongue, it is still possible for them to resume the ability to discriminate the sound contrasts, such as /l/ and /r/.

As a pilot study, the author (Kohno) held the following experiment. The subjects were 10 left hemisphere-damaged patients (but undamaged in the right) in their 50's and 60's (=experimental group). They were all male and had some language disorders. The other group of subjects were 20 normal adults of the same ages without any language disabilities?=control group?. Both groups listened to /l-r/ and /w-y/ stimuli that were used for infants (see 2.0). These sounds were produced by Macintosh Computer Power Book 5300 in succession and the subjects were required to push the space key when the sound sequences were changed from one in the pair to the other (i.e. /r/ to /l/ or /l/ to /r/, /y/ to /w/ or /w/ to /y/). The result is shown in Table 5.

Table 5 /r-l/w-y/discrimination by patients with language disorders and normals

	r-l			w-y		
	n	x	S.D	n	x	S.D
patients with language disorders	10	35.0%	6.0	10	95.0%	0.6
normal adults	20	10.0%	4.3	20	98.3%	0.3

The table shows that the patients can discriminate /r-l/ far better than the normal adults. There is no scientific evidence that the holistic processing will be dealt with in the right hemisphere, and the analytic processing in the left hemisphere. Nevertheless, the data show that /r-l/ discrimination ability was automatically improved very much by the loss of Japanese specific constraints, which are perhaps brought about by the works of the analytic system.

The above-mentioned study, of course, needs further examination, and might need to be revised on the basis of other scholars' opinions and criticisms.

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