TWO PROCESSING MECHANISMS IN RHYTHM PERCEPTION

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ABSTRACT

In Experiment I, it was found that the left hand of a patient with infarction involving the forebrain commissural fibers (S-1) could not follow the slow rhythms of 500 and 1000ms IBIs, but it could follow the rapid stimuli of 250ms IBI. The right hand of S-1, however, could synchronize his tapping with all rhythms as well as normal adults (S-2). Negative autocorrelations were detected among the adjacent IBIs in slow response beats by S-2 and by the right hand of S-1, but these correlations were never found in the rapid response movements (250ms) of any subjects. This means that normal adults use ongoing, analytic processing for slow rhythm but holistic processing for rapid rhythm. Evidence was found that the left hand of S-1 can use only the holistic approach, not only for the rapid rhythm but also for the slow rhythm, and that this is the very reason why it cannot follow the slow tempos. Experiment II was performed to show that the above two processings are qualitatively different from each other, and Experiment III & IV show that the holistic approach is more tenable to memorize a nonsense succession of approximately seven syllables than is the analytic processing.

1. PURPOSE OF THE PRESENT STUDY

There are no established ideas about the universal timing fundamentals among phoneticians.

This paper is to propose the universal timing measure on the basis of neuropsychological experiments on sound sequence processing using as subjects a patient with infarction in corpus callosum, children with age variety from 1 year and 4 months to 9 years of age as well as normal adults.

2. MECHANISM OF RHYTHM PROCESSING

2.1 Experiment 1

Subjects: Three kinds of subjects were prepared.

Subject 1 (S-1, henceforth) was a patient (male) with infarction involving the forebrain commissural fibers. He was a 56-year-old right-handed public official having education of 16 years. He developed a sudden paresis on the right limb in December 1983, and was admitted to a local hospital. Diagnosis was made as having cerebral thrombosis, but no pathological lesion was recognized by the CT scan. On July 14, 1985, he was found not awaken in bed by a family and brought to another local hospital. His CT and MRI scans at the time of this study shows lesions situated in the posterior half of the genu and the whole truncus of the corpus callosum as well as in a posterior superior portion of the left medial frontal lobe, and in the left medial temporo-occipital lobes. Small low density spots are also found in the bilateral basal ganglia. S-1 was normal in his words and consciousness, and although he was disoriented in time and space due to an amnesia, general intelligence was not grossly impaired. Pathological reflexes and ankle clonus were negative. Muscle tone was

normal. He was not ataxic. He had neither gross paresis nor definite sensory loss, but he demonstrated a small step arteriosclerotic gait[2].

Other subjects were a healthy 55-year-old woman (right-handed) (S-2, henceforth) and seven young children with ages ranging from 1 year and 4 months old(1:4) to 9 years old(9:0). These children were all righthanded and had no known abnormalities.

Method: Three kinds of rhythm whose inter-beat intervals (IBI, henceforth) were 250, 500, 1000ms were prepared by the use of a metronome, SEIKO Rhythm Trainer SQM-348. and then they were demonstrated to the above-mentioned three kinds of subjects. They were all requested to tap the table simultaneously in time with the above rhythms using the knuckles of third fingers, first of their right hands and then of their left hands. When the children's tapping was measured, their mothers accompanied them together with the experimenter and explained how to carry out their tasks giving some examples and let them practice beforehand. The 1:4 child's tapping, however, was recorded in her house by her mother letting the child use a toy which made sound. The mother understood the aim of this experiment very well.

All the tapping records were analyzed by the YOKOKAWA Electromagnetic Oscillograph 2901 connected with the Amplifier 3125.

Results: Table 1 shows the tapping behavior of the normal adult(S-2) and Table 2, of the patient(S-1). These two tables tell us that the right hand of S-1 moves very normally as well as the both hands of S-2, which show the standard movements of normal adults. In other words, the means of IBIs (x) and the values of S.D. of the both subjects do not differ so much. S-1's left hand, however, moves very differently from not only the both hands of the normal adult (S-2) but from his own right hand. S-1's left hand can manage to follow the rapid stimuli of 250ms IBIs, but it can never follow any slow rhythms with 500 and 1000ms IBIs. The values of the S.D. spread very widely. The right and the left hands of S-1 seem to move separately. S-1 often said to the authors, "It(=the left hand) moves out of my own will."

Table 1 Tapping by a normal adult(female, 55 years old, right hander)

used hand	target tempos (A)	inter-beat intervals				
		n.	$\bar{x}$	SD	SD/A	r
right	1000ms	63	1022.7	52.1	13.0	-0.29
	500ms	55	512.7	22.9	11.5	-0.21
	250ms	99	257.5	10.8	10.6	+0.45
left	1000ms	57	1017.7	54.9	13.7	-0.10
	500ms	71	515.3	22.2	11.1	-0.12
	250ms	94	257.0	11.0	11.1	+0.04

Table 2 Tapping by a patient with infarction in the corpus callosum (male, 57 years old, right hander)

used hand	target tempos (A)	inter-beat intervals				
		n.	$\bar{x}$	SD	SD/A	r
right	1000ms	27	1020.1	46.5	11.6	-0.52
	500ms	46	506.3	31.6	15.8	-0.25
	250ms	56	261.9	27.1	27.1	+0.19
left	1000ms	62	673.3	285.7	71.4	+0.36
	500ms	99	476.4	198.9	99.5	+0.07
	250ms	51	266.6	36.0	36.0	+0.13

Table 3, which gives us the whole view of the tapping behavior of children, shows that movements of the children older than 4 years old(S-3, henceforth) are remarkably different from the movements of children younger than four (S-4, henceforth), and we should notice that the former's behavior is very much like the behaviors of the normal adult (S-2) and of the patient's (S-1's) right hand and the latter's one is exactly the same as the movement of the patient's left hand. In other words, younger children (S-4), just like S-1's left hand, can synchronize their tapping with the fast rhythm of 250ms IBI, but they cannot follow the slow tempos of 500 and 1000ms IBIs. In this connection, we should notice that, according to Krashen, the lateralization of the brain must be established at about the age of five[6].

Table 3 Tapping by the right hand of children
(All are right handers)

age	target tempos (A)	inter-beat intervals				
		n.	x	SD	SD/A	r
9:0	1000ms	25	1003.8	76.0	19.0	-0.15
	500ms	60	508.7	25.7	12.9	-0.82
(female)	250ms	76	253.4	20.8	20.8	+0.13
5:10	1000ms	13	1058.5	122.2	30.6	-0.36
	500ms	45	499.2	52.0	26.0	-0.33
(male)	250ms	43	301.3	31.5	31.5	+0.01
4:2	1000ms	56	637.2	340.6	85.2	-0.02
	500ms	30	479.0	31.2	15.6	-0.29
(male)	250ms	18	319.8	24.0	24.0	+0.57
3:9	1000ms	84	581.4	333.2	83.3	+0.34
	500ms	76	446.9	112.6	56.3	+0.31
(female)	250ms	87	284.5	25.1	25.1	+0.41
3:4	1000ms	50	801.4	354.7	88.7	-0.03
	500ms	78	431.7	109.0	54.5	+0.32
(male)	250ms	53	276.3	31.2	31.2	+0.38
2:8	1000ms	22	471.7	301.9	75.5	+0.32
	500ms	50	476.6	81.0	40.5	+0.60
(male)	250ms	36	348.6	30.2	30.2	+0.04
1:4	1000ms	11	706.5	218.4	54.5	
(female)	500ms	16	406.1	158.7	79.4	

(The left hand movements are the same as the right hand movements.)

Autocorrelation among adjacent IBIs (r) was then calculated for all the response data of Tables 1, 2 and 3 (see the right column of each table) and negative correlations (r= 0.2～0.6) were found among the adjacent IBIs in the slow response beats (fitted to 500 and 1000 ms) by S-2 (Table 1), S-3 (Table 3) and by the right hand of S-1 (Table 2), but we could not find any negative autocorrelations in any of the responses of the children younger than 4 years old (S-4) and the patient's (S-1's) left hands who produce only rapid responses even to slow stimuli like 500 or 1000 ms. None of the subjects' response beats to the rapid 250ms stimulus, on the other hand, produced any negative correlations.

All these mean that, as suggested by Hibi who did his experiment by letting subjects say "pa-pa-pa--" instead of tapping[1], the normal adults including the children older than 4 years old usually use ongoing, analytic (prediction-testing) processing to the slow rhythm, but holistic processing to the rapid rhythm. The right hand of S-1 can properly process both the slow and rapid rhythms correctly using either the analytic or the holistic approach, while his left hand cannot, nor can both hands of S-4.

The above-mentioned facts suggest that following the rapid tempos and following the slow ones are neuropsychologically different from each other --- the former is holistic and the latter is analytic.

3. MECHANISM OF ECHOIC MEMORY

Experiment 2

In order to verify the above-mentioned hypothesis of two mechanisms in perception from another viewpoint, the author held the following experiment, which also made clear the mechanism of echoic memory.

Method: Nonsense words of seven CV (consonant and vowel) syllables such as 'ga ta ku da do pe ki' were prepared. When these words were recorded, the speaker(a Japanese female in her twenties) read these words fitting each syllable to each beat produced by the metronome with beat intervals of 250, 500, and 1000ms, and then these intervals were adjusted so as to be rigidly spaced in these intervals by the use of ILS (DEC Micro Computer PDP 11/73). By the use of this method 6 nonsense words were made per each of the rhythmic patterns of 250, 500, 1000ms IBIs.

The materials were then given, in a language laboratory, to Japanese students(25 in number) majoring English at a women's college and before they tried to write down the nonsense words on the answer sheet, they were requested to do simple multiplication of two digit numbers (e.g. 16×75) immediately after they had listened to each of the nonsense words, and then soon to write them as well as possible. Marking was done giving two points to each correct answer, that is, correct recall not only in reproduction of the syllable but in its position in the words. As the initially presented nonsense word was used for exercises, the full mark was 70 (7×5×2) for each category of syllable intervals.

Results: Table 4 shows the result of the experiment.

Table 4

IBIs among syllables	the state of reproduction		
	n	$\bar{x}$	S.D.
1000ms	25	38.4	13.2
500ms	25	38.7	12.0
250ms	25	45.4	11.4

n=number of subjects

250>500 $t=2.01$ $p<0.05$
250>1000 $t=1.99$ $p<0.05$

These tables show that the syllables connected closely with short IBIs, which are processed holistically, bring about significantly longer retention than the slow-tempo-syllable-sequences which are processed analytically. The analytic processing of the nonsense words and the work of multiplication may be both cognitive, and therefore the retention of the nonsense words was interfered by the calculation. The holistic processing of the closely connected syllable sequence, on the other hand, will be neuropsychologically different from the work of multiplication, and it was never disturbed by the calculation.

The memory span of holistically processed syllable sequences, however, is not so large. Miller suggests that it might be 7±2[7]. Kohno and Tsushima confirm this number by the fact that the babbling and the one word utterances (in total, 2448) by a child of age one and half never continue over 7 syllables in succession[5].

4. Conclusion

Holistic processing copes with fast rhythmic condition of less than about 300ms IBIs, analytic one with slow tempos of more than about 400ms, and the tempos between 300 and 400ms IBIs may be the threshold area which belongs neither to holistic nor analytic ones (cf. [1]). Whether or not the tempos in this area belong to holistic or analytic will depend on individuals (Kohno & Ishikawa, forthcoming paper). Holistic processing, which is neuropsychologically different from analytic one, will never be disturbed by the latter, which plays an important role of 'analysis by synthesis' to get the whole meaning of discourse.

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