A longitudinal study on a duration estimation: Effects of frequency of intermittent stimuli¹

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A longitudinal study was carried out to confirm the effects of frequency of intermittent stimuli on duration estimation in young children which had previously been found in a cross-sectional experiment. The findings of the present study were in full accord with those previously found, that is, (a) the duration accompanied by intermittent sounds, of which the frequency was 2.5, 5.0 or 10.0 s⁻¹, was estimated longer when the frequency of the sound was higher, and (b) the effect stated in (a) was optimal at the age of six while below that age the effect was less conspicuous and weaker.

Key words: duration estimation, time estimation, young children, intermittent stimuli, longitudinal study.

Recently, Matsuda (1989b) found that the more intermittent sounds the subject perceived, the longer the duration including them was estimated and, that the younger the subject, the stronger the effect at least from 6-year-old children to adults. She insisted from these findings that the developmental tendency is due mainly to "centration" (Piaget, 1961) to the intermittent stimuli in young children and "décentration" in older children which begins generally at seven years of age. She also found that the effect was optimal at the age of six and that below age six it was less conspicuous and weaker to a certain extent as the age decreased. To explain the findings she suggested two reasons based on Matsuda's model (Matsuda, 1985, 1989a); (a) a large variability of response duration itself because of large variance in a (due to fluctuation of attention paid to the elapsing of time) made the effect ambiguous, and (b) uncertain values of b under identical stimulus condition (due to fluctuation of attention

paid to the stimulus' attribute) resulted in an ambiguous and weak effect on the average, where a is a coefficient showing the degree of consciousness paid to the elapsing of time and b is another one showing the direction and the degree of the illusion. However, as the experiment in Matsuda (1989b) was cross-sectional, there remains a degree of suspicion that the peak of the effect of the intermittent stimuli at six years of age might be a kind of sample error. A longitudinal study should be carried out, before a definite conclusion can be safely drawn.

Method

Apparatus. The apparatus in the present experiment was exactly the same as that used in Matsuda (1989b).

Procedure. The procedure in the present experiment was also the same as that in Matsuda (1989b), except the experimental session was repeated five or six times about every six months.

In each experimental session, subjects first carried out learning at a duration estimation of 10 s. The criterion of acquisition was set as two appearances of response durations between 9 and 11 s, not necessarily successive. After reaching the criterion, the subject began the

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² The experiment was carried out at Hiroshima Women's University. Calculations were mainly done at Data Processing Center, Kyoto University.

Table 1
Mean ages in year and month of subjects of Groups 1 and 2
(in parentheses, ranges)

Session	1	2	3	4	5	6
Group 1	4:3 (4:0-4:6)	4:8	5:3	5:8	6:3	6:7
Group 2		4:7 (4:1-5:0)	5:1	5:6	6:1	6:5

experiment examining the effects of intermittent sounds without any rest or instructions. Intermittent sounds were given during response durations. Three kinds of intermittent sound frequencies, 2.5, 5.0, and 10.0 s^{-1} , were used in random order and three response durations were obtained for each of the three kinds of frequencies for each subject in each session. Besides, four to six response durations under the vacant condition were obtained. (A more detailed procedure could be seen in Matsuda, 1989b).

Subjects. Twenty-seven young children served as subjects. Seven of them (Group 1), which consisted of four males and three females, repeated the experimental session six times and the others (Group

2), which consisted of 12 males and eight females, did it five times (see Table 1). All these subjects were included in the ones who had succeeded in the learning in the experiment of Matsuda and Matsuda (1983). Mean number of trials to reach the criterion of learning had been 17.3, 12.6, 13.9, 7.1, 9.1, 3.9 for the six sessions in Group 1, and 14.5, 11.6, 10.6, 8.6, 7.0 for the five sessions in Group 2.

Results

Mean response durations were calculated for the three frequency conditions and the vacant condition for each subject in each session. Means for the four conditions in each session are shown in Figs. 1 and 2 respectively for Groups 1 and 2. Analysis of variance with two-way classification (Sounds $\times$ Sessions) was

Fig. 1. Mean response durations under the four conditions of sounds for each session in Group 1.

Fig. 2. Mean response durations under the four conditions of sounds for each session in Group 2.

Table 2
Number of children who belong to each pattern in each session

Session	1 <i>n</i> =7	2 <i>n</i> =27	3 <i>n</i> =27	4 <i>n</i> =27	5 <i>n</i> =27	6 <i>n</i> =27
Pattern 1	3	9	6	12	19	12
Pattern 2	2	12	17	11	6	10
Pattern 3	2	5	3	3	0	2
Pattern 4	0	1	1	1	2	3

applied to data for six sessions in Group 1 and combined data of the two groups for five sessions of two to six. From the figures, the analyses of variance and results of the individual comparison tests, the following findings were obtained. (a) The main effect of Sounds was statistically significant beyond .05 level in the latter analysis of variance ($F=36.64$, $df=3/78$), though it was significant only beyond .10 level in the former analysis of variance ($F=3.06$, $df=3/18$). That is, the mean response duration with 2.5 s^{-1} sounds and that under the vacant condition were longer than that with 5.0 s^{-1} sounds, which was also longer than that with 10.0 s^{-1} sounds. (b) The main effects of Session were not statistically significant for either of the analyses. (c) The effects of interaction between Session and Sounds were also not significant in both analyses, though one can see the strongest effects of intermittent sounds in Session 5 for both groups.

Effects of intermittent sounds were classified into four patterns; in Pattern 1 mean response duration with 2.5 s^{-1} is longer than that with 5.0 s^{-1} , which is also longer than that with 10.0 s^{-1} ; in Pattern 2 mean response duration with 2.5 s^{-1} is longer than that with 10.0 s^{-1} , though that with 5.0 s^{-1} is not between them; in Pattern 3 mean response duration with 2.5 s^{-1} is shorter than that with 10.0 s^{-1} , though that with 5.0 s^{-1} is not between them; in Pattern 4 mean response duration with 2.5 s^{-1} is shorter than that with 5.0 s^{-1} which is also shorter than that with 10.0 s^{-1} . Pattern 1 is in full ac-

cord with the prediction by Matsuda's model, Pattern 2 is in fair accord with it, Pattern 3 is considerably inverse to it, and Pattern 4 is in complete opposition to it. Numbers of children who belong to these patterns are shown in Table 2. Ratios of children belonging to Pattern 1 were significantly different beyond .05 level among five sessions of two to six by Cochran's Q -test ($\chi^2=13.71$, $df=4$). A sign test at .05 level revealed that from Session 2 to Session 5 and from Session 3 to Session 5 there were significant changes of patterns, that is, to the direction in ac-

Fig. 3. Mean difference between the longest response duration and shortest one under each of the four conditions of sounds and the difference between the mean response duration with 2.5 s^{-1} sounds and that with 10.0 s^{-1} sounds, for each session.

cordance with the prediction.

For each subject, the session was chosen where the difference of the response duration with 10.0 s^{-1} from that with 2.5 s^{-1} had been largest. Mean of ages in these session was five years and 10 months (SD is 7.5 months and range is four years six months to six years seven months).

Among the sessions, coefficients of association in the patterns (combining numbers of Patterns 3 and 4), were values of .22 to .37 none of which were significantly larger than zero, except between Sessions 4 and 5, where the coefficient of association was .51 which was significantly larger than zero at .05 level ($\chi^2=14.14$, $df=4$).

As stated in the procedure, in each condition of frequency three response durations were obtained for every subject in each session. The difference in response duration between the shortest one and the longest one was calculated for each condition in each subject. The mean difference of 27 children is shown in Fig. 3 for each condition, 2.5, 5.0, or 10.0 s^{-1} , in each session. An analysis of variance with two-way classification (Session $\times$ Frequency) was applied to the data. Only the main effect of Session was significant beyond .05 level ($F=6.06$, $df=4/104$). In Fig. 3, there is also a mean of difference in response duration between the shortest one and the longest one under the vacant condition for each session. An F -test was applied to the data. The effect of Session under the vacant condition was not significant. In Fig. 3, another line is added for a comparison with these four lines of difference: It consists of the difference between mean response duration under the condition of 10.0 s^{-1} and that under the condition of 2.5 s^{-1} in each session.

Discussion

Effects of three kinds of frequency of intermittent sounds on length of response duration were in full accord with the

prediction from Matsuda's model as well as findings in Matsuda (1989b). That is, the more intermittent sounds the subject perceived, the shorter the response duration was, namely, the longer the duration including them was estimated. In addition, the developmental tendency of the effects found in the present experiment, which was longitudinal, was in accordance with that in Matsuda (1989b), which was cross-sectional; the effects of intermittent sounds were optimal at about six years of age and below this age, the effects were less conspicuous and weaker to a certain extent as the subject was younger. "Décentration" from inserted stimuli seems generally to begin once a child is past six years of age. The uncertain values of b , which was under identical stimulus condition (due to fluctuation of attention paid to the stimulus' attribute) rather than a large variability of response duration itself (because of large variance in a due to fluctuation of attention paid to the elapsing of time) seem to make the effects less conspicuous and weaker. This was evidenced by the fact that the variability of response duration under the vacant condition did not decrease at all in children from four to six years of age though the variability of response duration under intermittent sounds decreased rapidly. In children from age five and a half to six, the effects of intermittent sounds seemed to be fairly stable.

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