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Identification of Temporal Sequence in Synchronization Task

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Abstract: We investigated the mechanism of predictive timing control in synchronization tapping.This is the synchronization task between tap onset and periodic tone onset. As a result, we clasified that subjective sequence between tap onset and tone onset can be modified by controlling the time difference between the two onsets. This suggests that prediction in subjective time is essential.

Keywords: Time perception, Synchronization tap, Timing control

1 Introduction

When we play sports, coordination of timing is needed. For example, when we play catch, it is too late for the ball to start to grasp when the ball reaches a palm. In fact, grasping the ball starts about 33 to 50 ms earlier than the ball reaches the palm. In order to synchronize with an external event, it will be necessary to generate a predictive action towards it [1].

"Sensorimotor synchronization" is an experimental paradigm for the study on the perception and processing of the time information in predictive action. "Synchronization Tapping" is one of the task of "Sensorimotor synchronization". The task in which a subject synchronizes finger taps with a simultaneous sequence of auditory stimuli.

"Negative Asynchrony" can be commonly observed in "Synchronization Tapping". "Negative Asynchrony" means that taps precede stimuli by several tens of milliseconds (20ms~50ms)[2][3][4]. A steady "Negative Asynchrony" can be observed in the range less than 2000~3000ms of inter stimulation interval (ISI) [5]. ISI is the period of auditory stimulus.

This kind of action can be referred to as predictive action. Thus, "Synchronization Tapping" was used to investigate the characteristics of predictive action. Two predict mechanism divided by ISI 1800ms was proposed by our former study [6][7].

However, the traditional way in the study was performed by controlled ISI. It was not controlled the synchronization error (SE) which was a time lag between onset of tap and stimulus.SE is the time difference between the tap and the stimulus. SE is negative when a tap is earlier than a stimulus. Here the way to investigate the time perception by controlled SE was designed. Then it can be found how SE changes a subject's time perception.

In this study, SE was controlled and the change of subject's time perception and subject's behaviours (i.e. Inter Tap Interval: ITI) were measured. As a result SE had influence on the motion of subjects. A subject was able to shorten ITI, when subject recognized an auditory stimulus was earlier than his tap. So was the contrariwise.

2 Method

2.1 Task

The sequences of stimulus were presented to the subjects through headphone. The subject's task was to synchronize his tap onsets with stimulus onset as precisely as possible.The short domain of ISI (less than 1800ms) was used in which few fluctuation and steady precedence is able to be observed.

2.2 Stimuli

Each trials consists of 60 times of taps. The trials were divided into two parts, in the first part (1~20), ISI was fixed, shown as Fig.1-a. Five different duration of ISI were used in different trials: 450ms, 600ms, 900ms, 1200ms and 1800ms. In the second part (21~60), SE was fixed. In other words, The stimulus was presented after tap in a time lag (Fig.1-b). Also, five different duration of SE were used in difference trial: 0ms, -10ms,

-30ms, -50ms, -70ms. The combination of fixed ISI and fixed SE was 25. Thus, a total experiment was consists of 25 trials. The duration of each auditory stimulus was 100ms. The pitch of sound was 500Hz. The volume was adjusted suitable for the subjects.

2.3 Assessment index

The onset time of auditory stimulus and the onset time of taps were recorded. ITI (Inter Tap Interval) was analyzed as an assessment index of subject's time perception. 5 times of taps of the beginning were excluded from the data for analysis, in consideration of that the taps were not stabilized. The remaining 55 times of taps divided into 15 times of the beginning, and 40 times of the remaining.

2.4 Subjects

Six male, right-handed subjects took part in the experiment. Subjects' age was from 20's to 40's. It was normal to subjects' hearing.

2.5 System

The system used in this experiment was mounted on PC. The OS is single task OS. The subjects were presented auditory stimuli from the headphone linked to PC. The button to push by the subjects is connected to PC through a parallel port. The program for an experiment is described by C language. The real-time chip(RTC) with a built-in PC was used for measurement. Time accuracy was 1/2048 second.

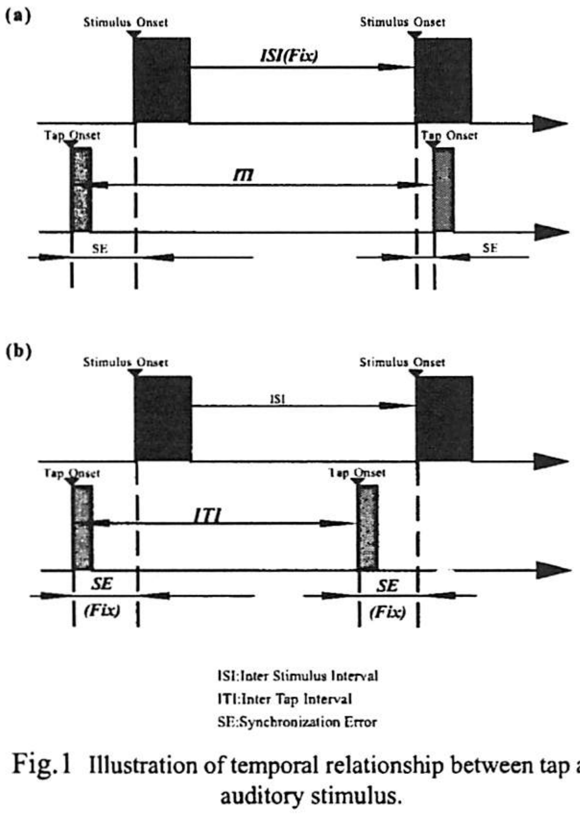

Fig.1 Illustration of temporal relationship between tap and auditory stimulus.

3 Result

3.1 Temporal development of ITI

Fig.2 shows three examples of temporal development of ITI. When SE was fixed, ITI shows decrease (Fig.2-a, SE 0ms), no change (Fig.2-b, SE -30ms), and increase (Fig.2-c, SE -70ms). It is suggested that change of ITI was caused by the subject's time perception. In Fig.2-a, the subject percepted onset of the auditory stimulus before onset of his tap. In Fig.2-b, the subject percepted onset of the auditory stimulus and onset of his tap simuletaneously. And, in Fig.2-c, the subject percepted onset of the auditory stimulus after onset of his tap. However onset of the stimuli were presented after onset of the tap. Thus the perceptive orders of Fig.2-a and 2-b were opposite from real orders.

3.2 The influence of SE and ISI

Fig.3 shows the rate of change of ITI, and Table1 shows the change of ITI by all subjects. It was observed that the rate of change of ITI has a tendency to be negative in short SE(i.e. SE 0ms,-10ms). And the rate of change of ITI has a tendency to be positive in long SE(i.e. SE -50ms,-70ms). Thus the direction of change of ITI was shown to be influenced by SE.

Concerning to the influenced of ISI, when ISI was short(i.e. 450ms to 900ms) the correlation between SE and change of ITI was observed. However when ISI is longer than 1200ms, the change of ITI did not show the strong influence from the change of SE. Thus the rate of change of ITI was also affected by ISI.

3.3 Statical Analysis

ITI was analyzed before SE fixed and after SE fixed by ANOVA ($a=0.05$, $p<0.1$). The result was analyzed that had the significant difference was classified into increase of ITI and decrease of ITI. Table2-a shows this classification. According to Table2-a, when SE was set up to 0ms and –10ms, the trials that decrease of ITI were made up to 65.5%. It can be suggested that short SE affect the proportion. And, when SE was set up to –50ms and –70ms, trials of increase of ITI were made up to 58.9%. It is suggested that long SE affect the proportion.

The trial of the decrease of ITI was partially caused by ISI. For example, when ISI was set up to 600ms, the trial in which the decrease of ITI was made up to 53.3%, and when ISI was set up to 900ms, the trial in which the decrease of ITI was made up to 46.7%(Table2-b). Furthermore the distribution of change of ITI turned flat and smooth with increase in ISI. For example, when ISI was set up to 1200ms, the increase of ITI was 30%, no significant was 30%, the decrease was 40%, and when ISI was set up to 1800ms, ITI's increase was 36.7%, no significant was 33.3%, decrease was 30%(Table2-b).

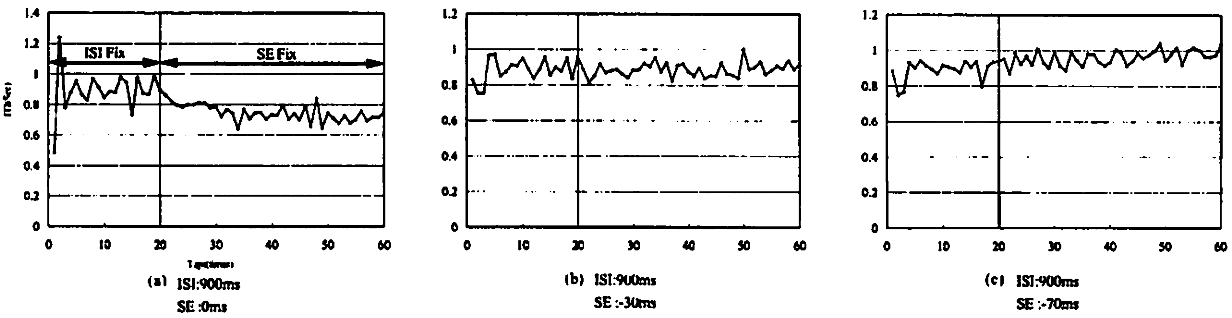

Fig.2 Example of time series of synchronization errors in a trial for 3 ISI duration. (a) ISI900ms. SE0ms, (b) ISI 900ms, SE-30ms, (c)ISI900ms, SE-70ms. Data from the trial of subject A are presented. The vertical line represents the change of task. In the first task, subjects are presented the periodically auditory stimuli. In second task, subjects are presented the auditory stimuli after fixed time from the tap.

4 Discussion

The factor of precedence tap can be explained by the Fraisse hypothesis[3]. From the Fraisse hypothesis, the cause of a precedence tap is considered as the difference in nerve transfer speed. For example, in this study, P_f stands for the transferring time in percepting the finger feedback, P_e stands for the transferring time in percepting the stimuli. T_f stands for the moment when finger taps. T_e stands for the moment when the buzzer sounds to create the stimulus. If the subject percepts simultaneity between his finger tap and the auditory stimulus, the equation of this time perception is "$T_f+P_f=T_e+P_e$". For the range of the ISI in which steady precedence taps are about 20ms-50ms earlier than stimuli was used. It was able to get "20ms<P_e-P_f<50ms". Therefore, the time lag of "-20ms>SE>-50ms" is needed for a subject to percept the simultaneity between the finger tap and the auditory stimulus. Thus, if SE>-20ms, a time order interchange from the real order to the percepted order can be proved by the Fraisse hypothesis. However, there are two problems that could not be explained by the Fraisse hypothesis through our result.

Firstly, the stability in the data of ITI could be observed, shown as Fig.2-a. From the Fraisse hypothesis, the time lag was caused by the nerve transference. And the physical condition of nerve transference is not able to be changed immediately. When SE was set up to 0ms and –10ms, subjects were always able to percept that auditory stimulus precedes by the tap. Therefore, ITI must decrease endlessly by the Fraissse hypothesis. However it is found ITI converged at last.

Secondly, the affection of ISI could be found. From the Fraisse hypothesis, ITI changes only with SE. However, in our study, ITI changed with ISI while fixes the SE (Fig.3). Therefore, the perception of the time lag in our mind can not be explained only as Fraisse

Table1 The change of ITI.

Subject	A	B	C	D	E	F
ISI_SE						(sec)
450_0	-0.109	-0.131	-0.005	-0.021	0.001	-0.026
-10	-0.047	-0.113	0.007	-0.022	0.009	-0.036
-30	-0.046	-0.006	0.010	-0.001	0.016	-0.003
-50	-0.032	0.001	0.003	-0.002	0.040	-0.002
-70	-0.007	-0.003	0.006	0.022	0.056	0.015
600_0	-0.185	-0.150	-0.157	-0.008	-0.110	-0.045
-10	-0.086	-0.007	-0.018	-0.023	-0.147	-0.089
-30	-0.064	-0.013	-0.006	-0.046	-0.043	0.003
-50	0.000	-0.026	-0.003	-0.029	-0.018	-0.009
-70	-0.024	-0.012	-0.012	0.019	0.082	0.021
900_0	-0.308	-0.159	-0.002	-0.193	-0.045	-0.213
-10	-0.152	-0.221	0.038	-0.162	0.056	-0.125
-30	0.030	-0.004	0.118	-0.007	0.142	-0.031
-50	0.036	-0.028	0.036	-0.095	0.229	0.043
-70	0.192	0.059	0.007	-0.069	0.129	-0.028
1200_0	-0.429	-0.022	0.107	-0.134	-0.480	-0.011
-10	-0.269	-0.151	0.074	-0.034	-0.132	-0.060
-30	0.085	0.014	0.140	0.134	-0.188	-0.061
-50	-0.041	0.022	0.203	0.102	-0.011	-0.014
-70	0.072	0.060	0.070	-0.038	0.009	-0.037
1800_0	0.044	-0.388	0.034	-0.106	-0.755	-0.050
-10	-0.063	-0.078	0.153	0.221	-0.382	0.011
-30	-0.099	-0.041	0.828	0.253	-0.312	-0.058
-50	0.491	0.099	0.105	0.406	-0.271	-0.039
-70	0.221	-0.008	0.149	0.290	0.018	0.133

Table1 shows the difference of the average of ITI of 15 taps in the first task and the average of ITI of 40 taps in the second task. Negative value corresponds to decrease of the ITI.

hypothesis.

Therefore, we could conclude:

1) The time order in perception and that order in real are not absolutely agreeable.

2) An other mechanism to percept the time lag may exist, besides that of nerve transference, and the mechanism may be useful for the study in prediction.

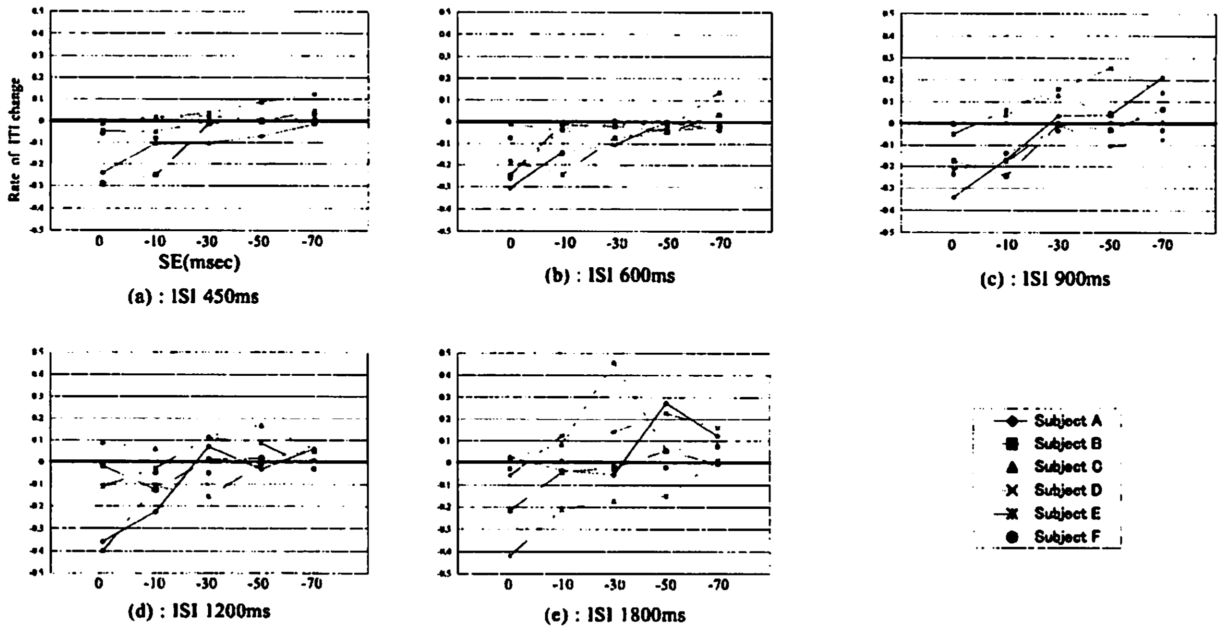

Fig.3 The Rate of change of ITI for each ISI. Data from lasthalf (40taps) in the all trial are presented. (a) ISI450ms; (b) ISI600ms; (c) ISI900ms; (d) ISI1200ms; (e) ISI1800ms. The horizontal thick line represents the no change of average of ITI.

Table2 The classified result of the change of ITI.

(a)

	Increase	Nosignificance	Decrease
SE_ISI			(%)
0_450	0.00	4.00	6.56
600	0.00	2.00	8.20
900	0.00	4.00	6.56
1200	2.56	4.00	4.92
1800	0.00	4.00	6.56
Subtotal	2.56	18.0	32.8
-10_450	2.56	2.00	6.56
600	0.00	2.00	8.20
900	5.13	0.00	6.56
1200	2.56	0.00	8.20
1800	5.13	4.00	3.28
Subtotal	15.4	8.00	32.8
-30_450	2.56	8.00	1.64
600	0.00	6.00	4.92
900	7.69	4.00	1.64
1200	7.69	2.00	3.28
1800	5.13	4.00	3.28
Subtotal	23.1	24.0	14.8
-50_450	2.56	8.00	1.64
600	0.00	8.00	3.28
900	7.69	2.00	3.28
1200	5.13	6.00	1.64
1800	7.69	4.00	1.64
Subtotal	23.1	28.0	11.5
-70_450	7.69	6.00	0.00
600	7.69	4.00	1.64
900	5.13	2.00	4.92
1200	5.13	6.00	1.64
1800	10.3	4.00	0.00
Subtotal	35.9	22.0	8.20
Total	26.0	33.3	40.7

(b)

	Increase	Nosignificance	Decrease
ISI_SE			(%)
450_0	0.00	6.67	13.3
-10	3.33	3.33	13.3
-30	3.33	13.3	3.33
-50	3.33	13.3	3.33
-70	10.0	10.0	0.00
Subtotal	20.0	46.7	33.3
600_0	0.00	3.33	16.7
-10	0.00	3.33	16.7
-30	0.00	10.0	10.0
-50	0.00	13.3	6.67
-70	10.0	6.67	3.33
Subtotal	10.0	36.7	53.3
900_0	0.00	6.67	13.3
-10	6.67	0.00	13.3
-30	10.0	6.67	3.33
-50	10.0	3.33	6.67
-70	6.67	3.33	10.0
Subtotal	33.3	20.0	46.7
1200_0	3.33	6.67	10.0
-10	3.33	0.00	16.7
-30	10.0	3.33	6.67
-50	6.67	10.0	3.33
-70	6.67	10.0	3.33
Subtotal	30.0	30.0	40.0
1800_0	0.00	6.67	13.3
-10	6.67	6.67	6.67
-30	6.67	6.67	6.67
-50	10.0	6.67	3.33
-70	13.3	6.67	0.00
Subtotal	36.7	33.3	30.0
Total	26.0	33.3	40.7

Table(a) and (b) show the percentages of the classified result of the change of ITI. Table(a) shows percentage of sorting by ISI. The subtotal show the percenteage of the same classified datas. Table(b) shows percentage of sorting by SE. The subtotals show the percentage of same ISI.

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