

Control Behavior of Tapping Strength and Tapping Speed for Young Children

幼児におけるタッピングの強さと速さの制御行動

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Abstract

Three-Point-grading ability of alternate hand tapping was examined as to speed and strength instructions for four, five, and six year old children. Subjects were asked to tap a box on the knee with fast-moderate-slow and hard-moderate-soft instructions. Arm movement and tapping pressure were measured with tapping tempo. To test general three-Point-grading ability, other skillful movements (hand gripping, teacher's name calling, and bean scooping tasks) were also given to the subjects. The results indicated that the children have an ability to express the grading in the familiar tasks. For the tapping tasks it was found that the children understood the strength and speed instructions separately. However, some confusion of "fast" and "hard" on expressing the instructions was observed, because they showed a larger arm movement when asked to tap fast, though adults of the previous study showed a smaller arm movement. It is speculated that children do not have a mature grading strategy and there would be at least three developmental stages in tapping control strategy.

keyword : Tapping, Speed and strength, Motor development, Grading control

The learning of human movement skills has been studied in the field of psychology of sport and physical activities, while the nature of the movement skill itself has been studied in the field of biomechanics. However, how humans control the strength of the skill to behave appropriately in situations where the skill is needed has never drawn researcher's attention. Though it is very important for humans to decide movement speed or strength of muscular exertion to react adequately with the environment in an already mastered skill, appropriate attention has not been paid for the grading of the mastered skill.

The most important concern for general psychologists was how and when children develop each habitual movement.^{*1} On the other hand, psychologists and biomechanists in the field of movement research who have mainly deal with sport activities have not paid appropriate attention to the grade control, because the higher in speed or the harder in muscular exertion, the better the performance for almost all sports. Therefore, the development of grading behavior in movement has gathered little attention among researchers, though we

usually control muscle strength when we move in action. For example, a student may daily increase (control) of his/her walking speed not to be late for school.

Nonetheless, a few grading behaviors in sport and movement has been studied. Fumoto (1989) and Ohmichi, Miyashita and Mizuno (1979) reported the experiments of grading behavior using qualitative instructions (hard, moderate and so on) for badminton and tennis. The results indicated that the more skillful subjects were, the better they could separate the instruction of each grade except smashing in badminton in which a smash technique requires the hardest hit every time. On the other hand, Sadamoto and Ohtsuki (1977) studied using quantitative instructions (% of best effort) for a standing long jump and a vertical jump and reported that subjective performance always exceeded the objective norm except standing broad jump with eyes-open. They suggested from EMG and joint movement recordings that the distance jumped would be controlled by changing degree of knee bending not by changing maximum force applied during the kick movement.

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Ohmichi, Yagi and Morishita (1983) have reported useful observations on tapping behavior (Figure 1). They reported that a four year old's movement of the forearm became larger when the child was asked to tap "fast" compared to being asked to tap "moderate." On the other hand, an adult subject showed smaller forearm movements in the "fast" condition. They concluded that the younger children confused hard tapping and fast tapping. However, they only imposed the tapping task to their subjects in fast-slow condition but not in the hard-soft condition. Therefore, it is not clear whether the children confused instructions of "fast" and "hard" or the children could conceptually separate these instructions but could not execute the task well. In other words, subjects tried to tap fast but as a result tapped fast and hard (larger movement).

To check these two possibilities, Fumoto (1990) studied tapping behavior with first and second grade students and found that they could separate the two instructions, "fast" and "hard." However, though the fast tapping of the

adult was performed with a small forearm motion without exception, 5% (second grade male) to 41% (first grade female) of the students took the larger forearm movement strategy for the fast tapping. Theoretically speaking, the smaller movement is better for the fast tapping because movement distance and, as a result, movement time is short. This means that the students of this age show an immature movement pattern.

It could be expected, therefore, that the younger children (preschool age) will move their arms obviously larger when they are asked to tap "fast." Moreover, the possibility of the confusion of "fast" and "hard" instructions could not be eliminated for the younger children. The main purpose of this study is to identify whether four, five and six year old children can understand the two kinds of instructions separately or not. If the young children could not understand the difference between the two instructions, the two conditions would show the same result.

Another focus is to know the extent to which the younger children confuse their preparation in movement and performance level. For this purpose, grading of other skillful tasks was given to the children and whether the children could understand the instruction of three-point-grading or not was checked.

Method

Subject

Subjects were four (15 males and 9 females), five (16 males and 13 females) and six (14 males and 14 females) year old children of kinder garden or nursery school. Mean ages of these groups were 4.6, 5.7 and 6.6 years. The range of each year group is from minus four months to plus eight months.

Tasks

The tapping apparatus was a box (20 cm x 30 cm x 7 cm). Rubber sheets (10 cm x 15 cm) with a picture of a hand are drawn on it. A microphone is fixed inside of the box to gather sound of tapping. The sound was recorded by a data recorder and used as an index of tapping pressure. A subject was asked to tap the hand shapes with both hands alternately until the experimenter said "stop." The tapping was stopped when a subject completed twenty beats of the hands without interruption. A movement of the forearm was recorded by a video camera (30 fps) placed on the right side of the subject 3-5m away in open shutter speed. The shutter speed was used because it was better to identify the frames

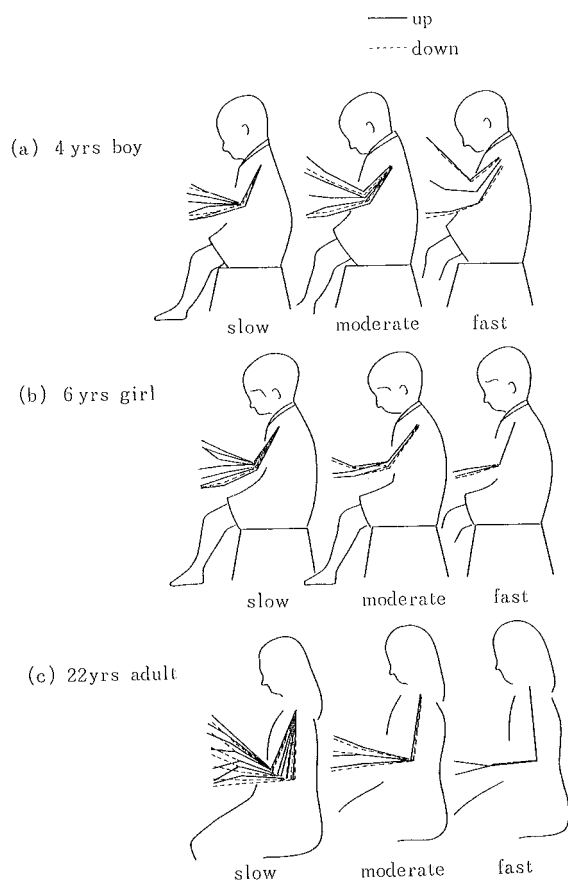


Figure 1 Development of an upper arm movement in a tapping task (Ohmichi et al, 1983)

Note 1. Stick pictures obtained from VTR pictures at the same interval.

where the arm changed direction.

The other three tasks are hand gripping (HG), calling teacher's name (CN), and bean scooping (BS). A grip meter for children was used for the HG task. A pin-up type microphone was used for the CN task to keep the same distance between the subject's mouth and the microphone. The BS task was to move beans from a large bowl to a small bowl by a hand or both hands. The large bowl was large enough to insert child's both hands and beans were much enough to scoop even though for adult.

Instructions

The instructions of the tapping task in the speed (SP) condition were "fast," "moderate" and "slow." The instructions of the tapping task in the strength (ST) condition and that of the HG task were "hard," "moderate" and "soft." For the CN tasks, "loud," "usual" and "soft" were used as instructions, and for the BS task, "many," "usually" and "a few."

In all experiments, the instructions of medium exertion were given first and a higher grade instruction or a lower grade instruction followed. A set of three trials of the different levels was repeated three times except the tapping tasks, where three repetitive tapping trials with twenty times were given in different instructions. Subjects performed the tapping task once in each instruction.

Procedure

The four experiments were done simultaneously in one or two rooms of each facility over two days. Therefore, the order and the span between the four tasks were not controlled except that the tapping tasks of SP condition and ST condition were given on different days.

Before the tapping experiment, an experimenter said "From now, I ask you to tap this box fast (hard) or slow (soft). Can you do it?" and tap the box several times with both hands in moderate speed. After that, a subject was allowed to tap a few times changing tempo or strength and the experimenter checked if he/she could understand the task. The other tasks were started by direct instructions; "Please grip as usual" or "please say 'sensei' (Japanese way to call a teacher) in a usual way" or "Please scoop a moderate amount of beans and move."

All instructions were done orally. If a subject seemed to understand the meaning vaguely, the experimenter added an extra explanation sometimes in different words but the experimenter did not provide a demonstration.

Except for the tapping tasks, two sessions of nine trials were given continuously in a different order. For the tapping tasks, the order was counterbalanced among subjects though the number of the subjects of both order were not equal in all groups, because a complete data set was not available for all subjects.

Measurement and data quantification

For tapping, ten stable consecutive beats in the twenty beats recording were taken and performance (pressure and tempo) were measured. For a pressure index, integration of voltage was measured as was done for EMG recording ($TC=0.01$) and relative values after rectification against a mean integration value of the moderate instruction were calculated. This index was sufficient to use as a relative value within subjects though it has no linearity against pressure.

To measure a tapping angle of the forearm, the angle between a box surface line and the forearm at the upper end of each beat were directly measured on a stopped picture of CRT display. This angle was not the exact angle between the forearm and the tapping surface because the forearm is not parallel to the box surface line. However, this value becomes larger when the same subject taps with a larger motion. This index is sufficient to compare within-Subject values.

Performance measure of the HG task was the exerted strength in Kg and performance of BS was a weight of the beans a subject scooped. Performance measure of CN was the integrated value as was performed for the tapping pressure.

Results

The mean performance change in HG, BS, and NC tasks against three instructions are shown in Figure 1. The number and percentage of the subjects who could correctly adjust their movements against middle grade performance corresponding to the instructions are shown in Table 1 for all tasks. The mean performance change for the tapping task and the mean values of related indexes are shown in Figure 2. Table 2 shows similarly treated indexes of the tapping tasks as Table 1 which is used to analyze the confusion of the instructions below.

Order effects of the three tasks except the tracking tasks and sex differences of all tasks were tested for all indexes of Table 1 and 2 by chi-Square test using summing-up

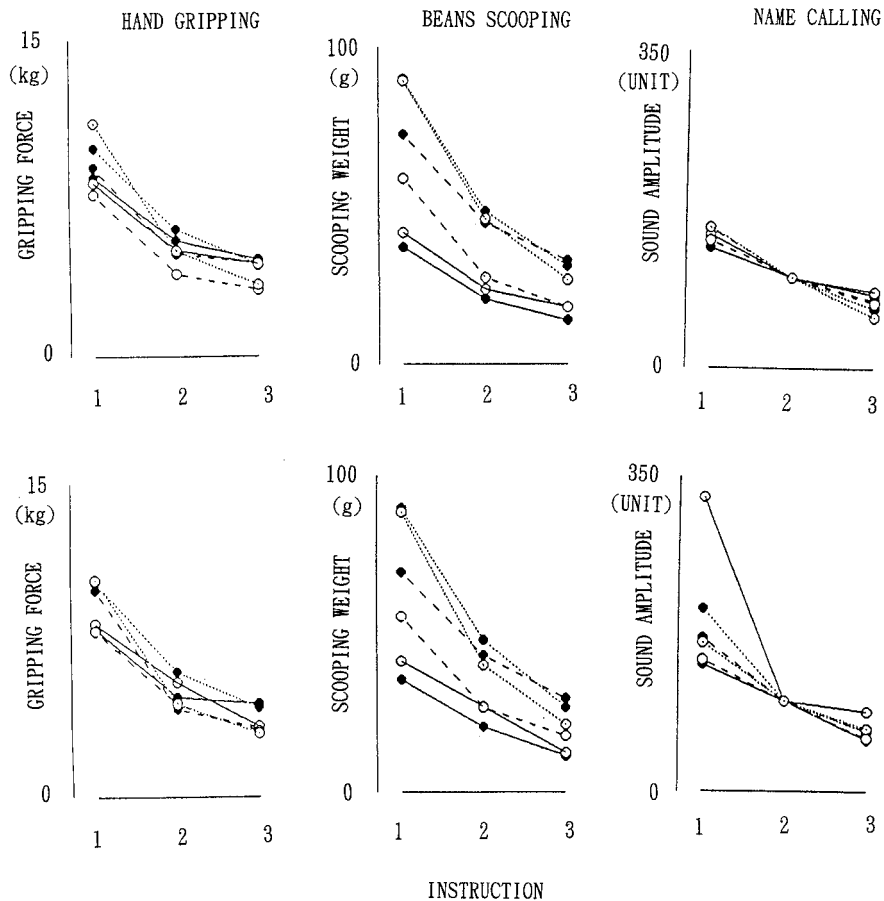


Figure 2 Changes of mean performance by different instructions for HG, BS and Cn tasks.

Note 1. Upper row is the results of middle-high-low grade order and bottom row is that of middle-low-high grade order.

Note 2. ● : male, — : Four years old (Same for Figure 3)
○ : female, - - - : Five years old
· · · : Six years old

Note 3. Instructions

1 : High grade 2 : Middle grade 3 : Low grade

data through age groups. Significant order effects were not observed. Significant sex differences were also not observed except in the pressures of ST condition (between hard and moderate $\chi^2=5.23$ [DF=1], $p < 0.05$; between moderate and soft $\chi^2=4.18$ [DF=1], $p < 0.05$) and right hand angle of ST condition (between hard and moderate, $\chi^2=8.22$ [DF=1], $p < 0.01$; between moderate and soft, $\chi^2=13.35$ [DF=1], $p < 0.01$).

For the HG, CN, and BS tasks, the data in Figure 2 seem to support the psychophysiological law proposed by Stevens and Galanter (1957) though the distribution was not necessarily normal. The difference between the moderate and low instructions was small. However, the percent of correct responses revealed that most subjects could succeed in separating three grades of instructions

and the smallest percent of correct performance was 74% (ascendant order of the CN task between the high and moderate grading).

To obtain the significant level of the values, a sign test was used based on the direction of the change in performance from the middle grade instruction because the distribution of some indexes was not normal and the number of each group was not high. The sign test revealed that even 74% is significant at 1% level (Table 1). This means that the subjects could produce a correct performance in these tasks.

For the tapping asks, Figure 3 indicates that in general the difference between indexes of higher grade trials and moderate grade trials were clearer than the difference between the moderate and lower grade trials. Table 2 also

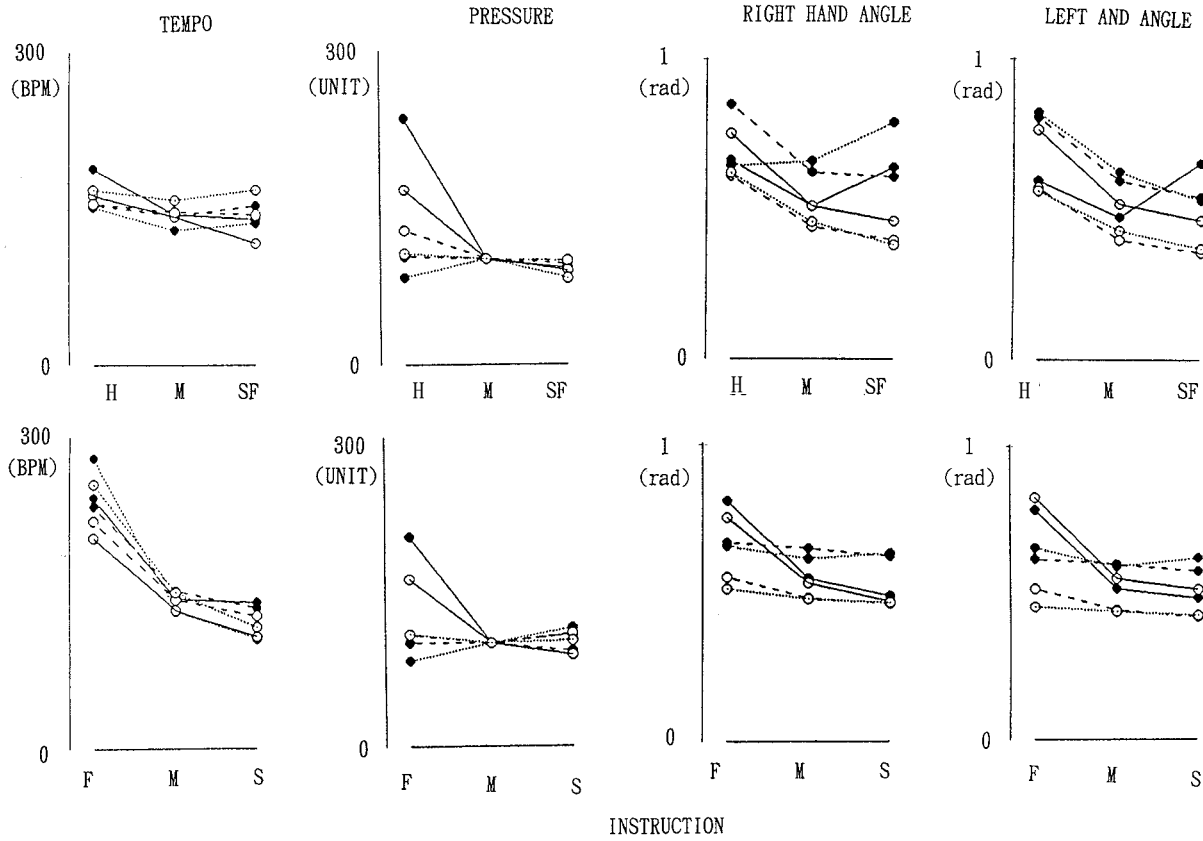


Figure 3 Changes of mean performance and changes of mean values of related indexes by different instructions in tapping tasks (upper : ST condition, lower :SP condition)
 Note H:Hard, M:Moderart, SF:soft, F:Fast, S:Slow

Table 1. Number and Percent of Correctly Responding Subjects for Each Task

Difference	Sex	Group (Age)	Tapping		Hand Gripping		Beans Scooping		Name Calling	
			SP	ST	A	B	A	B	A	B
Between High and Middle Grades	Male	4	12(80)*	9(60)	14(93)**	11(73)	14(93)**	13(87)**	10(67)	13(87)**
		5	13(81)*	6(38)	14(88)**	13(81)*	16(100)**	14(88)**	13(81)*	13(81)*
		6	14(100)**	1(7)##	14(100)**	14(100)**	14(100)**	14(100)**	10(71)	12(86)*
	Female	4	9(100)**	8(89)*	8(89)*	9(100)**	7(78)	9(100)**	7(78)	7(78)
		5	12(92)**	7(54)	13(100)**	12(92)**	12(92)**	11(85)**	10(77)	13(100)**
		6	13(93)**	7(50)	14(100)**	13(33)**	14(100)**	14(100)**	10(71)	14(100)**
	Total	73(90)**	37(46)	77(95)**	72(93)**	77(95)**	75(93)**	60(74)**	72(89)**	
Between Low and Middle Grades	Male	4	8(53)	8(53)	10(67)	13(87)**	12(80)*	13(87)**	11(73)	13(87)**
		5	10(63)	8(50)	11(69)	16(100)**	12(75)	13(88)**	11(69)	15(94)**
		6	10(71)	7(50)	13(93)**	14(100)**	13(93)**	14(100)**	13(93)**	10(71)
	Female	4	7(78)	7(78)	6(67)	9(100)**	7(78)	8(89)*	8(89)*	7(78)
		5	9(69)	8(62)	9(69)	12(92)**	10(77)	13(100)**	11(85)*	11(85)*
		6	11(79)	12(86)*	13(93)**	14(100)**	13(93)**	14(100)**	13(93)**	12(86)*
	Total	55(68)**	50(62)	62(77)**	78(96)**	67(83)**	76(94)**	67(83)**	68(84)**	

Note 1. Letters in parenthesis mean percent.
 Note 2. *p<0.05, **p<0.01, ##p<0.01(significantly incorrect) by sine test
 Note 3. SP: Speed condition. ST: Strength condition
 Note 4. A: Moderate-high-low order, B: Moderate-low-high order

Table 2. Number and Percent of Subjects Who Showed Larger Value in Higher Grade Instruction for Tapping Tasks

Difference	Sex	Group (Age)	Strength Condition			Speed Condition			
			Tempo	RH Angle	LH Angle	Pressure	RH Angle	LH Angle	
Between High and Middle Grades	Male	4	9(60)	9(60)	9(60)	9(80)	11(73)	11(73)	
		5	10(63)	16(100)**	15(94)	3(19)#	11(69)	11(69)	
		6	10(71)	5(36)	13(93)	0(0)##	9(64)	10(71)	
	Female	4	5(56)	8(89)**	8(89)*	6(67)	8(89)*	9(100)**	
		5	8(62)	13(100)**	13(100)**	4(31)	10(77)	8(62)	
		6	8(57)	14(100)**	14(100)**	6(43)	12(86)	10(71)	
	Total			50(62)*	65(80)**	72(89)**	28(35)##	61(75)**	59(73)**
	Between Low and Middle Grades	Male	4	7(47)	3(20)	3(20)	9(60)	11(73)	9(60)
			5	5(31)	11(69)	11(69)	11(69)	9(56)	8(50)
6			2(14)#	5(36)	11(79)	4(29)	7(50)	7(50)	
Female		4	7(78)	8(89)*	9(100)**	7(78)	7(78)	7(78)	
		5	5(38)	10(77)	10(77)	5(38)	8(62)	9(69)	
		6	1(7)##	11(79)	9(84)	5(36)	9(64)	9(64)	
Total			27(33)##	48(59)	53(65)**	41(51)	51(63)*	49(60)	

Note 1. Letters in parenthesis mean percent.

Note 2. *: $p < 0.05$, **: $p < 0.01$, #: $p < 0.05$, (Lower), ##: $p < 0.01$ (Lower) by sine test

Note 3. RH: Right hand, LH: Left hand

reveals that the indexes, except performance, were also confused between the moderate and the lower instructions compared with the difference between the higher and the moderate instructions.

Table 1 shows that, in SP condition, 90% of the subjects could correctly react to the "fast" instruction in total, but only 68% could react to the "slowly" instruction, although this value was still significant. On the other hand, the rates of correct responses were not significantly higher than chance in ST condition even between the high and moderate instructions.

As a measure of confusion of instructions, the tapping tempo (for ST condition), the tapping pressure (for SP condition) and the movement of forearms were examined. When the subjects were asked to tap "hard," 62% increased their tempo ($p < 0.05$), and, moreover, when asked "soft," only 33% of the subjects increased their tempo. The latter means that 67% decreased their tempo (Table 2). This tendency was also significant ($p < 0.01$). This means that the subjects were apt to increase their tapping tempo when they made the effort to change the tapping pressure. On the other hand, when the subjects were asked to tap fast, only 35% increased the tapping pressure ($p < 0.01$).

For the forearm movement, Table 2 indicates that, in SP condition, about three quarters of the total subjects moved

their forearm with greater amplitude when asked to tap "fast." This rate was a little less than in the ST condition when asked "strong." Nevertheless, the number of subjects who showed higher pressure in the "fast" instruction were significantly less in total ($p < 0.01$). However, reverse (high pressure) tendency in the "fast" instruction was observed for the four year old groups (These groups only showed the values of more than fifty percent). The similar tendency was also observed between "moderate" and "slow" conditions, where younger groups (four year old groups and five year old male group) only showed the values of more than fifty percent, although the significant value was only obtained for the right hand movement in total ($p < 0.05$).

In ST condition, only 62% of subjects could produce higher pressure when they were asked to tap "hard," though more than 80% moved the forearms larger.

Discussion

There are many studies using finger tapping. However, the main concerns of these studies were hemispheric problems and laterality (see item "finger-tapping" of subject index in Psychological Abstract). Here, the tapping task was used as a tool to measure the hemispheric strength or the laterality, or to prove the existence of them. For that purpose, Halstead Finger-Tapping Test which was included in the

Halstead-Reitan Neuropsychological Test Battery (Golden, Osmon, Moses, & Berg, 1981) or similar tasks which require subjects to tap with an index finger has been used. Usually, this experiment was done leaving the palm of the hand firmly on a base plate (e.g. Gabbart, Hart, & Kanipe, 1993). On the other hand, it was clear that this situation is not natural and too difficult for subjects and Golden et al. (1981) had warned that some subjects tend to use the hand or arm in tapping (p.14). This indicates that the tapping with a finger without a movement of the forearm is not a natural movement. Nevertheless, research of tapping itself has never been reported. This means that the nature of tapping movement itself had been studied little in a natural setting especially from the viewpoint of development. For example, Sasaki studied tapping movement of three-to-eleven year old children (Sasaki, 1997, 2002). However, she studied the ability to adjust the tapping movement to metronome tempo, not the ability of grading. Tapping along with outer artificial tempo is not a natural situation.

Moreover, these tasks are one hand tapping tasks and there are almost no studies about the alternate tapping. So, comparable data are not available. As to the finger tapping task, Gabbart et al. (1993) reported rates of 130 bpm (four year old) to 172 bpm (six year old) and Knights and Moule (1967) reported 128 bpm (five year old) and 155 bpm (six year old) under the restricted condition mentioned above. Gabbart also reported with Hart (1993) foot-tapping rates of 91 bpm (four year old) to 138 bpm (six year old). These are maximum values and a little different from the "fast" condition of this study.

The values of the fast tapping in this experiment are higher than these values. Considering that these values were obtained by the restricted movement, however, the mean values of each group obtained in this study (about 200 bpm to a little less than 300 bpm) would be reasonable values because alternate tapping is faster than one hand tapping (Fumoto, 1990). These values are a little smaller than the values of first and second grade students in the same condition (Fumoto, 1990) and also a little smaller than the values of the same age groups by Ohmichi et al. (1983) where the instruction was "as fast as possible."

The relation between the instructions and the performances of the four tasks seemed to be the power function similar to the relation between ratio scales and

category scale proposed by Stevens and Galanter (1957). This power function was similar to the reports for muscular exertion by Stevens and Mack (1959) and by Itoh and Sanjou (1985). From the data except tapping tasks, whether preschool children could understand grading instructions and express those into movement exactly was examined. The results indicate that they could understand the three-point-grade instructions and express each grade without confusion. That is, they could adjust their performance intensity along with the experimenter's instructions. On this assumption, we now return to the tapping behavior of young children.

Discrimination of two instructions, "fast" and "hard"

The changing patterns of the tapping tempo and pressure along with the instructions were different between the two conditions. The subjects could correctly react to the speed instructions but not to the strength instruction. Moreover, when the subjects were asked to tap hard, more than a half of the subjects increased the tempo. On the other hand, when they were asked to tap fast, more than a half decreased the pressure. This indicates that the subjects made the effort to react in each condition, respectively. That is, the subjects tried the fast tapping and the hard tapping as different tasks.

However, some confusion in movement and performance were observed. For example, significantly more subjects tapped "fast" when they were asked to tap "hard." Moreover, in both conditions, significantly more subjects move the forearm with greater amplitude. Though, in Fumoto's (1990) previous experiment all adults moved the hand a smaller distance, and as the result, all adults showed less pressure in "fast" tapping, in this experiment, 35% tapped harder (high pressure) when they were asked to tap faster. This rate is larger than the value of first and second grade students reported by Fumoto (1990); from 12% of second grade males to 43% of first grade females and the average was 17.5%.

When the subjects were asked to tap "fast," the four year old groups only showed the increase in mean pressure. This corresponds to the fact that the hard beaters were more than a half only for four years old groups in spite of the fact that general tendency is the reverse of it. This means that the degree of the confusion is higher for the four year old groups.

These differences between the adult and the children indicate that the children's skill of tapping is not mature. Ohmichi et al. (1983) indicated that 4 to 6 years old children could not use the wrist joint well. In this experiment, the forearm and the hand were almost straight in line at the upper end of each beat. It is, however, not clear how the hand and the forearm were coordinated in the other phases. If children could not use forearm joint effectively, Gesell's proximal-distal development theory reevaluated by Newell, Kugler, Van Emmerik, and McDonald (1989) might be able to be applied. This experiment focused mainly on whether the children could understand the difference in instructions. Then, how immature the children's tapping skill was will be speculated later.

Confusion in ST condition

Performance of the ST condition was very confused. This is not due to the indirect measurement method taken by this experiment, because CN experiment using the same method showed reasonable data. For the "hard" instruction, the four year old groups showed the most correct responses, though the rates of subjects who moved the forearm larger in the "hard" instruction were higher in older groups except right arm movement of the six year old male group. If the subjects move the hands with the same muscle force, the movement from higher position must make higher pressure. The results of four years old group correspond to this speculation. The adults of Fumoto's (1990) study took the same method. However, the other groups of this study cannot be explained by this proposal. One speculation is that the older subjects had learned a final phase of the moderate tapping and had unknowingly adjusted the speed at the contact point. This speculation fits our sense of performing for the moderate tapping, and it also fits the result of the adults of Fumoto's experiment who showed almost the same pressure regardless of tapping speed. The adults who had overlearned the normal contact speed may be able to change the speed when they were asked to tap hard.

The failure to separate the moderate tapping and the soft tapping for many groups are similar to Fumoto's (1990) results where it was reported that the adults even failed to separate them. Reducing the speed in the contact phase more than moderate level may be more difficult than increasing it. One reason would be that it is seldom in daily life to reduce pressure below the pressure level of the

normal tapping.

The significant sex differences were only observed in this condition. These differences were caused mainly by the difference between six year old boys and girls. Only 36% of the six year old boys moved their right hand with greater amplitude in the "hard" instruction against the whole tendency (Table 2). This means that the six year old boys took a different strategy; perhaps a hard hit from the nearer position. However, I could not identify whether this result is due to distortion of sampling or this stage is one step of development.

Large motion in "fast" tapping

In this experiment, the four year old groups only show high pressure tendency in the "fast" instruction. Theoretically, hard is fast if the tapping is one time. However, if the subjects must keep the fast tapping for a while, another strategy must be needed. It is supposed that four year old subjects were not old enough to use this skill. As Gesell (1977) noted that there is greater ease and control of general bodily activity and economy of movement in five years old, from four to five may be an epoch for development of movement.

However, the older children's strategy is still different from the adult. The older subjects were also apt to move the forearm with greater amplitude in the "fast" instruction. As was mentioned above, some (5% to 41%) of the first and second grade students also showed a similar tendency. This large arm movement may be explained as the result of fast hand lifting phase in total movement cycle. To tap faster, they may speed up the cycle of the movement, although the adult makes the cycle smaller. There seem to be three stages in development of hand tapping. Therefore, the two critical periods in developmental phases (between four and five year old and between the second grade and the adult) should be studied precisely.

There remains one question why children show large arm movements when they are asked to tap fast. Observing this experiment, I suspected that the subjects seemed to start their hand movement from the lowest position; with the hands on the tapping box. From the position, the first movement of the hands is to the upper direction. Therefore, if a subject moves the hands fast, the hands must reach a higher position compared with the moderately starting movement. On the other hand, for adults tapping is the up-down movement with a fixed point in the middle of

movement range.*² If a subject start tapping from this position down, the fast movement does not necessarily produce the large arm movement. This difference in the starting point of the hands may affect the difference of the arm angle movement between the older children and the adults. If the subjects were asked to start tapping with the hands at the position 10 cm or 20 cm high from the tapping box surface, the older subjects could have shown similar movement to the adults.

It may be useful for the research of the learning and development of many kinds of cyclic movements to consider the starting point of one cycle. Those cyclic tasks are often used in dynamic approach of motor control. However, the starting point of movements was never considered in discussion. More precise observation of the movements and theoretical consideration is needed based on the observation for such cyclic movement as tapping.

Relationship between grading behavior in this experiment and variability of practice hypothesis

In the field of motor learning, Schmidt (1988) insisted that what was learned was not some particular movement, but rather the (generalizable) capacity to produce any of a variety of movements of this type (p395). This capacity was first called schema by Schmidt (1975). According to this theory, this experiment seems to show that schema of the strong tapping and schema of fast tapping are not perfectly separated for young children.

As to the schema of young children, Shapiro and Schmidt (1982) reported that the schema is not well developed in children. This comment was, however, used to explain that a practice variability effect is more often observed in children than in adults, but not to explain the differentiation of the schema. If a target is shown to a person with a developed schema, he/she should show better performance than a person with a poor schema. In this type of experiment, the target is shown by an experimenter. However, the ability to make a target (a grade of speed or strength) by oneself and to perform the task well has seldom been studied, although such motor control is often demanded in daily life. This problem has never been discussed in the field of schema development. So, I did this research without a clear hypothesis. This research attitude is supported by Gorge (1970), in which he stated that psychology should have imitated the historical development

of the natural sciences, and should not have chosen to imitate the particular phase of growth the natural sciences coincidentally happened to be in when psychology came on the scene (p92). Therefore, I performed this study without a strict hypothesis concerning schema development. Because Shapiro and Schmidt (1982) stated "almost nothing is known about how a complex series of muscle contractions come to be associated so effectively and efficiently into a single unit. schema theory cleverly sidesteps these issues by assuming that the programs are already there and are selectable by the subject (p145)".

Note

*1 Most textbooks of developmental psychology have indexes concerning motor development. However, some textbooks of learning psychology lack indexes concerning motor learning (e.g. Howard; 1995 and Schwartz; 1989) or only have indexes concerning motor memory (e.g. Hintzman; 1978).

*2 From my observation of a mole bashing game or alike in a game center, when young children start beating movement, they often lift their hand from its home position though they had stood ready and their hand had already been on the moles. They did not seem to be able to move their hand down fast without the reactive movement; upper swing of the hand.

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This paper is based on a manuscript completed with the assistance of Dr. K. M. Newell, while I was at Pennsylvania State University as a Research Fellow Abroad. After returning to Japan, the manuscript was submitted to the Journal of Experimental Child Psychology, but it was returned with comments. It is difficult to handle motor behavior in general psychology, therefore some of the comments which seemed to be irrelevant. After some time, I started to rewrite the paper with the comments in mind. However, the process was slow and interrupted. Several years ago, I thought to submit it to an interdisciplinary journal concerning motor behavior because there is still very little research dealing with this research subject, but I could not. Indeed, I could find several papers using keyword 'tapping speed control' in CiNii but no papers using 'tapping speed grading'. This year, however, I noticed that my university bulletin now has an open advanced repository system, so I tried to complete this article before my retirement.

I have revised the paper from the original. A major change is that the paragraph outlining relations with schema theory was added at the end of the Consideration section because it was pointed out that the theoretical background was weak. Minor changes included adding new research in the Discussion and modifying some descriptions where problems were pointed out by the journal judges. Some of their indications were caused by bad translation of the 'baby talks' used in the experiment. However, I am still not confident whether I solved the problem.

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