Limit of Duration of a Generalized Motor Program for Handwriting

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LIMIT OF DURATION OF A GENERALIZED MOTOR PROGRAM FOR HANDWRITING[1]

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Relative timing of handwriting movements was analyzed to define the limit of duration of a generalized motor program for handwriting, and to see if the frequency of usage of a character affects the limit.

Two groups of *S*s, one who have a certain Kanji character in their first names and another who do not have, wrote the character at two different speeds. The two groups did not differ in consistency of relative timing of strokes at different speeds. The consistency of relative timing was negatively correlated with the ratio of the overall writing durations, indicating that the larger the difference in the overall durations between two writing movements is, the larger the difference in the relative timings of the two is.

If the ratio of the overall writing durations was smaller than 1.7, the relative timing was significantly consistent saving exceptional subjects.

Key words: handwriting, generalized motor program, Kanji

Introduction

An assumption has been proposed recently as to how such extremely practiced types of motor behavior as handwriting are controlled. This assumption is called the generalized motor program hypothesis. It hypothesizes that a class of highly practiced behavior is controlled by a single abstract memory structure that, when activated, causes movement to occur, a generalized motor program (Shapiro & Schmidt, 1982). This means that an abstract memory structure governs responses that display similar movement characteristics (Shapiro et al., 1981), or that we can have one motor program that can run in a variety of different ways (Schmidt, 1981b). In the case of handwriting, it implies that a common motor program is used to write a certain character faster or slower, larger or smaller.

This assumption is based on the experimental evidences that 'relative timing' is invariant across a class of movements. The control of timing in handwriting as well

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as in typing is not an explicit constraint of the task (Gentner, 1981). However, Viviani & Terzuolo (1980) demonstrated that relative timing of handwriting movements is strictly invariant even in the case of words. Their subjects wrote characters slower or faster, expanding or compressing the durations of strokes strictly proportionally. Investigations on the motor programs for handwriting evolved thereafter are well represented in a book edited by Thomassen et al. (1984).

The present investigation concerns the question of how the frequency of the usage of characters influences the limit of the duration of a generalized motor program for handwriting. Schmidt (1982a, b) suggested that motor programs can run for longer duration if they are well-learned. Japanese learn to write more than one thousand characters, Kana (Japanese phonograms) and Kanji (Chinese-originated characters). Thus the characters differ extremely in the frequency of usage both among subjects and among characters. We would expect that the more frequently some characters are used, the longer the the programs for the characters can run. In other words, the more frequently used a character is, the more slowly it can be written using a common generalized motor program.

To determine if two handwritings of a certain character are produced using the same generalized motor program or not, we must accept the follwing working assumption; if two movements have the same phasing (ralative timing), then they are governed by the same generalized motor program; if the phasing is different, then the programs govering them are different (Shapiro & Schmidt, 1982).

In the following experiment, relative timings of handwritings at different speeds were analyzed with subjects who have a certain character in their first name and Ss who do not have it.

Method

Subjects: The frequency of the usage of a character was the among-subjects factor in the present experiment. Thirteen females who have the character 子/ko/ in their first names (Ko group), and 13 females who do not have (Non-Ko group) served as *S*s. The Kanji/ko/ is the one that is most commonly used in female first names among Japanese, such as 曜子/Youko/. The subjects who have it in their names are assumed to write it far more frequently than those who do not. The mean age of the two groups were 29.5 (*SD* 9.2) for the Ko group, and 29.4 (*SD* 6.9) for the Non-Ko group. The *S*s were university staff and undergraduates at Tohoku University.

Apparatus: The writing movements were recorded using a digitizer connected with a microcomputer system (NEC, PC9801). *S*s wrote on a sheet of paper fixed on the digitizer using a special ball-point pen. The accuracy of the position of the tip of the pen was 0.1 mm, and the sampling rate was 75Hz.

Procedure: *S*s were asked to write the character /ko/ at two different speeds, first at their natural writing speed, then at subjectively half of the natural speed. To

control the effect of the movement size, they were instructed to write the character in two adjacent frames of 2 cm×2 cm.

Results

The velocity of the writing movements was defined as the tangential velocity after Viviani Terzuolo (1980). The character /ko/ is written in a sequence of movements as shown in Fig. 1. The time course of the velocity of movement is shown in Fig. 1. The movement sequence for /ko/ is composed of four acceleration-deceleration strokes (S1, S2, S3, and S5) and an implicit (in some cases explicit) stroke (S4).

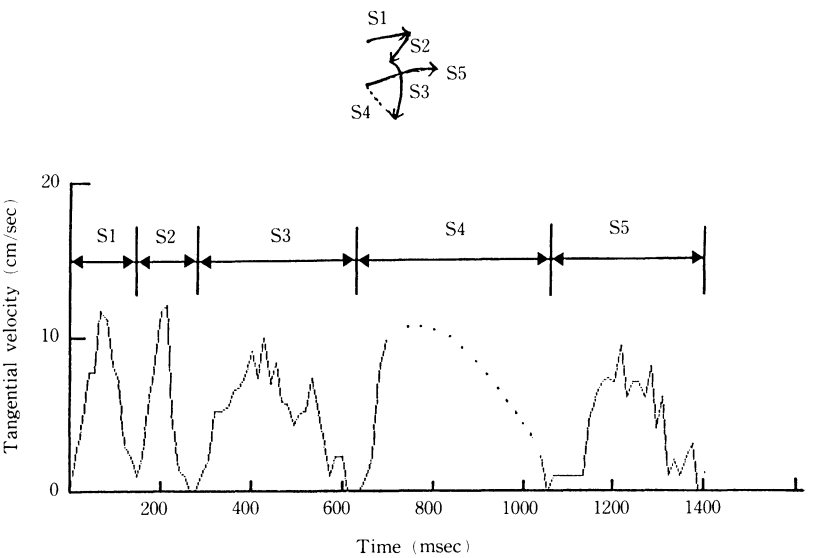

Fig. 1. An example of the velocity pattern in writing 子/ko/.

Table 1. Absolute time durations of the writing movement in writing 子/ko/. Two groups of Ss wrote /ko/ at two speed conditions.

Subjects		Speed conditions		Ratio (b/a)
		a. Ususal	b. 1/2 of usual	
Ko group	*Mean*	1513 msec	2955 msec	1.97
	(*SD*)	(301)	(424)	(0.31)
Non-Ko	*Mean*	1523 msec	2631 msec	1.73
group	(*SD*)	(297)	(678)	(0.37)
t		0.07	1.41	1.73*

*$p<0.10$

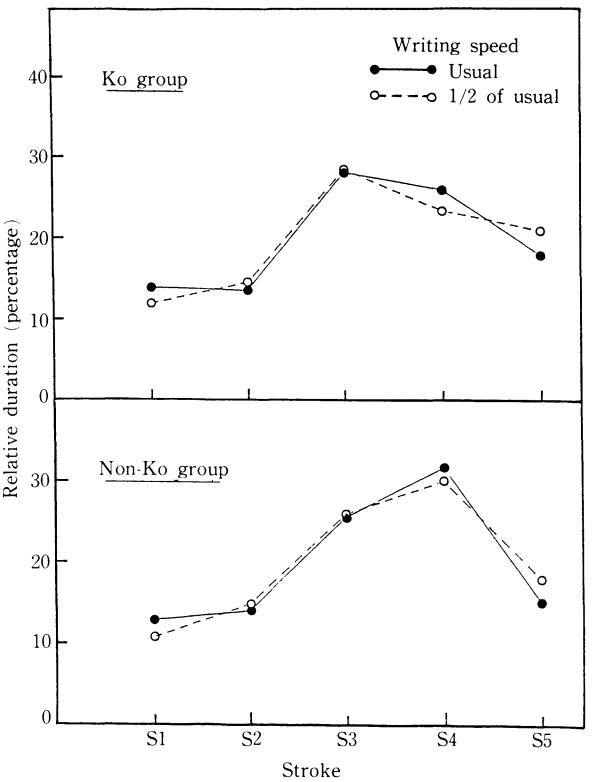

Fig. 2. Relative timing of the strokes in writing /ko/ for each group and at each speed condition.

The absolute time required to write /ko/ is shown in Table 1. In the "natural speed" condition, the mean writing durations did not differ significantly between the two groups. In the "half speed" condition, the mean writing duration of the Ko group tended to be longer than that of the Non-Ko group, though the difference was not statisticaly significant. The mean ratio of the writing durations at two speed conditions was larger, and closer to the designated ratio (2.0) for the Ko group ($p<0.10$).

In order to see if the relative timing of writing movements is consistent at two speed conditions, the proportions of the time duration of each component stroke within a character were calculated. Fig. 2 shows the results. No significant differences in the relative duration of each stroke were found for the two speed conditions. A between-groups difference was found in the relative duration of an implicit stroke (S4). The mean relative duration of the S4 of the Ko group (26.2%) was significantly smaller than that of Non-Ko group (31.9%) in the natural speed condition ($t(24)=2.36$, $p<0.05$), and also in the half speed condition (23.6% vs. 30.2%, $t(24)=3.86$, $p<0.01$). No significant between-groups differences were found in the relative durations of the four explicit strokes (S1, S2, S3, and S5).

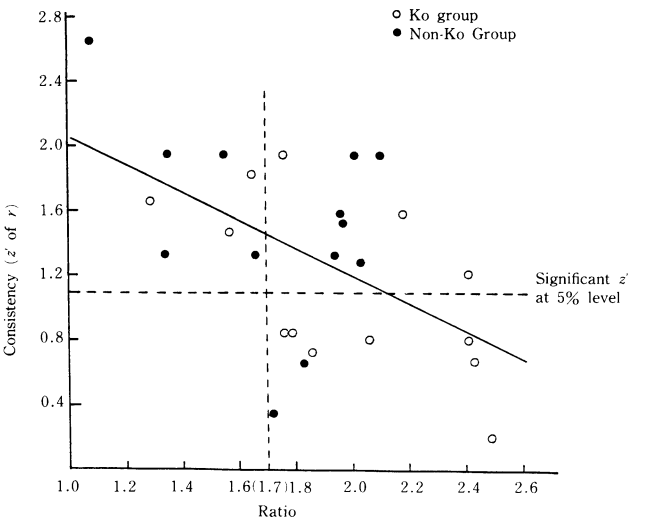

Fig. 3. Consistency of relative timing of strokes (normalized r of stroke durations) as a function of the ratio of overall writing durations for a character between two speed conditions. Consistency of relative timing was negatively correlated with the ratio of overall durations.

As another measure of consistency in relative timing of strokes, the correlation of the durations of strokes between the two speed conditions was calculated for each S. Though the correlations were based on only five pairs of strokes, it might be a rough index of consistency in ralative timing of strokes between the speed conditions. The mean correlation coefficient (r) was 0.74 for the Ko group, and 0.83 for the Non-Ko group. The difference was not significant with a t-test based on the normalized r (z'). As the consistency in relative timing of strokes was expected to depend on the ratio of the overall writing durations for a character between two speed conditions, and as the ratio was larger in the Ko group than in the Non-Ko group (see Table 1), the relation of the consistency (z') to the ratio was examined (Fig. 3). The consistency in relative timing was negatively correlated with the ratio, $r=-0.53$, $p<0.01$. That is, the larger ratio of the writing durations for a character between the two handwritings resulted in the lower consistency in relative timing of strokes between the two.

Fig. 3 shows that if the ratio is smaller than 1.7, the consistency in relative timing (z') is within the significant z' (1.11, one-tailed) saving exceptional subjects.

Discussion

The prediction of the present investigation was that *S*s who have a given character in their names should have established the generalized motor program for writing it more firmly than those who do not have it in their names, therefore the limit of the

duration of the motor program would be longer for the former group. That is, the relative timing of writing movements by the former *S*s was expected to be more invariant than that of the latter *S*s when they write the character at a speed for slower than the speed they usually write it.

Results indicated that the relative timing of the strokes in the subjectively half speed condition did not differ from that in the usual speed condition for both the two groups. There was no between-groups difference in the consistency.

Further analysis revealed that the consistency in relative timing negatively correlated with the ratio of the writing speeds. The larger the ratio of the speeds was, the less consistent the relative timing of writing movements was. The relative timings were significantly consistent if the duration of writing movement did not exceed 1.7 times of that in the usual writing speed. If we accept a working hypothesis that consistency in relative timing means the use of the same generalized motor program, this results might mean that the same generalized motor program for the character/ko/ is used within the range. However, the somewhat linear relation of the consistency in relative timing to the ratio of overall durations might leave a problem to the generalized program theory, which predicts a discontinuous relation between them.

There was no between-groups difference in the measure of the consistency (z' of r). However, the ratio of time duration between two speed conditions was larger for the Ko group, the group of *S*s who have the character /ko/ in their first names. It was easier for them to write the character at speeds other than the usual speed than the Non-Ko group.

An unexpected result was obtained. For the Ko group, the relative proportion of the inter-strokes pause (implictit stroke, S4) was significantly smaller than for the Non-Ko group (Fig. 2). Though we do not have any theory to explain this difference at hand, this result seems to suggest the necessity of investigation not only into the establishment of generalized motor programs, but also into the changes in the ingredients of them.

Analysed here was only a single character, one composed of a limited number of strokes and used very frequently. Analyses of other many Kanji and Kana characters will provide more informations about the generalized motor programs for writing characters other than alphabetical.

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