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MEASUREMENT ERRORS IN VOICE-KEY NAMING LATENCY FOR HIRAGANA [1]

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Summary.—This study makes explicit the limitations and possibilities of voice-key naming latency research on single hiragana symbols (a Japanese syllabic script) by examining three sets of voice-key naming data against Sakuma, Fushimi, and Tatsumi's 1997 speech-analyzer voice-waveform data. Analysis showed that voice-key measurement errors can be substantial in standard procedures as they may conceal the true effects of significant variables involved in hiragana-naming behavior. While one can avoid voice-key measurement errors to some extent by applying Sakuma, *et al.*'s deltas and by excluding initial phonemes which induce measurement errors, such errors may be ignored when test items are words and other higher-level linguistic materials.

A voice key is a useful device with which to measure naming latencies for various linguistic stimuli. The voice key, connected to a microphone which converts sound pressure into voltage, is triggered when the sound pressure reaches a predefined level, and the time that elapses between the stimulus onset and the voice onset is measured to the nearest millisecond.

Measurement errors, however, can be so substantial that obtained data may become utterly unreliable and meaningless (Kessler, Treiman, & Mullennix, 2002). A major reason for this problem is that it takes the voice key different amounts of time to detect different initial phonemes (see Kessler, *et al.* for more details and other causes of measurement errors). In this regard, Sakuma, Fushimi, and Tatsumi (1997) made an important contribution to psycholinguistic research on Japanese syllabaries (see Appendix, p. 1106), demonstrating that naming latencies for single syllabic symbols measured by a voice key and the same latencies measured more accurately by visual inspection of voice waveforms greatly differed; the mean difference between the two methods was as large as 110 to 120 msec. for syllables beginning with the unvoiced fricatives /s/ and /ʃ/ but only 18 to 20 msec. for those beginning with the nasal /n/. Sakuma, *et al.* concluded that the voice key is unreliable when measuring naming latencies of items whose initial phonemes differ.

The purpose of the present study was to make explicit the limitations

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and possibilities of voice-key measurement of naming-latency for syllabic symbols (cf. Sakuma, *et al.*, 1997; Kessler, *et al.*, 2002; Rastle & Davis, 2002). We examine three sets of voice-key data for basic hiragana symbols, i.e., (1) the voice-key latencies collected in this study, (2) those of Tamaoka and Hatsuzuka (1997), and (3) those of Sakuma, *et al.* (1997) against Sakuma, *et al.*'s speech analyzer latencies. Voice-key naming latencies may quantitatively vary from study to study because each voice key differently predefines the sound pressure which triggers the voice key. We thus asked whether the three sets of voice-key naming latencies and Sakuma, *et al.*'s speech analyzer data significantly correlated with one another. We also asked whether one can compensate for voice-key measurement errors (1) by applying Sakuma, *et al.*'s deltas and by (2) excluding word-initial phonemes which induce large measurement errors. Finally, we examined a word-naming study where voice-key measurement errors could possibly be ignored.

METHOD

Data Collection in Present Study

Participants.—Twenty-four undergraduate students (15 women and 9 men) at Hiroshima University, all native Japanese speakers, participated in the experiment. Their ages ranged from 19 years to 21 years.

Materials.—A hiragana syllabary consists of 71 symbols which are divided into two, 46 basic and 25 derived, symbols. The latter are derived from basic hiragana by adding a diacritic, e.g., /da/ derived from /ta/. In this study, 44 basic hiragana symbols were selected from the total of 71 symbols, and they were given to each participant in a randomized order.

Procedure.—This study followed a standard naming-task procedure whereby single hiragana symbols as stimulus items were individually presented to the participant in the center of a computer display at a comfortable distance (about 50 cm) in a dimly lit, quiet room. Stimulus items were randomly presented 600 msec. after the appearance of an eye-fixation point (an asterisk). The participant was required to pronounce each hiragana symbol as quickly and as accurately as possible. Each spoke into a table microphone connected to a computer via a voice-activated relay mechanism which turned off the timer used to measure naming latency. Each response was judged as correct or incorrect by the examiner and then entered into the computer. The next fixation-point stimulus was indicated 600 msec. after the examiner pressed the space key. Prior to the test trials, 24 practice trials were given to participants to familiarize them with the task.

Each hiragana symbol was used once in one session, and each participant was given three sessions. That is, each participant was presented a total of 132 hiragana symbols (44 × 3 sessions).

Tamaoka and Hatsuzuka's Data (1997)

The method of the Tamaoka and Hatsuzuka study was different from that of the present study in that all of the 71 hiragana and 71 katakana symbols were used as test items in one session, and only one session was given to participants. Participants were 24 undergraduate students, but it is unknown whether they were a sample drawn from a population qualitatively similar to ours (see Leong, Cheng, & Mulcahy, 1987, for the possible effect of literacy on naming latency for words).

Sakuma, et al.*'s Data (1997)*

In the Sakuma, *et al.* study, 10 staff members at the Tokyo Metropolitan Institute of Gerontology (mean age: 30.3 yr.) participated in a standard naming experiment. These researchers used 46 hiragana (36 basic and 10 derived) symbols in the first session, 46 katakana symbols in the second session, and 30 words in the third session. While naming latencies measured by a voice-key produced significant measurement errors, Sakuma, *et al.* remeasured them by visual inspection of voice waveforms, viewed on a speech analyzer, to yield a more accurate measure.

Variables and Analysis

Seven variables were examined: (1) voice-key naming latency obtained in the present study, (2) voice-key naming latency of Tamaoka and Hatsuzuka, (3) voice-key naming latency of Sakuma, *et al.*, (4) Sakuma, *et al.*'s naming latency measured by visual inspection of wave forms, (5) adjusted voice-key naming latency obtained by (1) minus (3) plus (4) (cf. Kessler, *et al.*, 2002), (6) adjusted voice-key naming latency obtained by (2) minus (3) plus (4), and (7) hiragana frequency (Amano & Kondo, 1999). Hiragana frequency was included as an independent variable because it may correlate with naming latency.

Because there were 36 basic hiragana symbols in the Sakuma, *et al.* study, those 36 symbols were the main targets for analysis (see Appendix, p. 1106). In addition, considering that problem items which lower the reliability of voice-key measurement are those whose naming latencies greatly differ between the voice-key and speech-analyzer methods, we excluded those hiragana items whose voice-key naming latencies differed more than 70 msec. from the Sakuma, *et al.* speech-analyzer latencies. Such excluded hiragana items were five initial /s-/ and five initial /h-/ symbols. We then examined the remaining 26 hiragana symbols to learn the extent to which voice-key data become more reliable.

For analysis of our own voice-key naming latencies, correct responses of hiragana naming latencies outside of 2.5 standard deviations from the mean of each participant were replaced by the boundaries indicated by those 2.5

standard deviations. The same procedure was employed in Tamaoka and Hatsuzuka. It is not known how Sakuma, *et al.* removed outliers in their analysis.

As for error responses, our study indicated that there were only 13 errors out of 3,168 responses (0.4%), and thus error rates were not analyzed.

Results

Correlations of our voice-key naming latency, Tamaoka and Hatsuzuka's voice-key latency, Sakuma, *et al.*'s voice-key latency, Sakuma, *et al.*'s speech-analyzer latency, our adjusted latency, Tamaoka and Hatsuzuka's adjusted latency, and hiragana frequency for the 36 hiragana symbols, are presented in the lower left of the diagonal in Table 1.

TABLE 1

Pearson Correlations Among Six Naming Latency Data and Hiragana Frequency: 36 Hiragana (Lower Left) and 26 Selected Hiragana Symbols (Upper Right)

	1	2	3	4	5	6	7
1. Voice Key 1		.70†	.77†	.59†	.49†	.63†	–.33
2. Voice Key 2	.70†		.78†	.05	.76†	.46†	–.31
3. Voice Key 3	.69†	.78†		.13	.41*	.80†	–.26
4. Adjust 1	.11	–.36*	–.40*		.40*	.50†	–.22
5. Adjust 2	.06	.12	–.19	.72†		.47†	–.31
6. S-A	.12	–.08	–.19	.66†	.63†		–.23
7. Frequency	–.44†	–.39*	–.25	–.06	–.14	.01	

Note.—Voice Key 1 is voice-key naming latency in this study; Voice Key 2 is voice-key naming latency in Tamaoka and Hatsuzuka; Voice Key 3 is voice-key naming latency in Sakuma, *et al.*; Adjust 1 is adjusted voice-key naming latency obtained by methods 1, 3, and 6; Adjust 2 is adjusted voice-key naming latency obtained by methods 2, 3, and 6; S-A is Sakuma, *et al.*'s speech-analyzer latency; Frequency is the frequency of hiragana. The upper right data consist of 26 items excluding 10 hiragana beginning with the /s/, /sh/, and /h/ initial syllables.
*$p < .05$. †$p < .01$.

For the 36 symbols, only our voice-key (VK1) and Tamaoka and Hatsuzuka's voice-key (VK2) latencies correlated significantly with hiragana frequency (–.44, $p < .01$, and –.39, $p < .05$, respectively), showing that the higher the frequency, the less time an adult requires to name the symbol. This result may appear to be consistent with the findings from a great many studies on word naming and word frequency (e.g., Seidenberg, 1985).

However, although both of the adjusted naming latencies correlate relatively highly with Sakuma, *et al.*'s speech-analyzer latency (.66 and .63, $p < .01$), they did not correlate with hiragana frequency (–.06 and –.14, ns). Sakuma, *et al.*'s speech-analyzer latency was not correlated either (.01, ns). On the other hand, the relatively high correlations of .69 to .78 observed among the three sets of voice-key naming latencies were not significantly different from one another.

Correlations of the same variables for the 26 selected hiragana symbols are presented in the upper right of the diagonal in Table 1. Now none of the variables correlated significantly with hiragana frequency. However, intercorrelations among latencies generally became higher; seven became significant, and two were not significant.

Discussion

This study verified that voice-key naming latencies can be unreliable when we use as test items single hiragana symbols whose initial phonemes are different from one another. If we had relied only on voice-key naming latencies, we would mistakenly have concluded that hiragana frequency accounted for naming latency for hiragana symbols such that the higher the frequency, the shorter the naming latency. We could avoid this pitfall by using two strategies: (1) to subtract bias deltas, i.e., voice-key latency minus Sakuma, *et al.*'s speech-analyzer latency, and (2) to discard inaccurate phonemes (/s-/ and /h-/). The first strategy works to some extent (see Table 1) although we have to be wary of Kessler, *et al.*'s statement (2002), "The numbers that obtain in one study do not necessarily apply to a different study; the differences range from the trivial to the alarming" (pp. 166-167).

With respect to the second strategy, Yamazaki, Ellis, Morrison, *et al.*'s study (1997) on kanji naming latency may be worth discussing (see Yamada, Takashima, & Yamazaki, 1998, for their naming latency data) because their voice-key study did not use such inaccurate phoneme-initial items and discovered a large effect of their intended variable, i.e., the effect of written age of acquisition on kanji naming latency. We computed the correlation between their original naming latencies and the adjusted latencies using Sakuma, *et al.*'s deltas. The correlation was .98 ($df = 112$). This extremely high correlation may be a surprise. But that surprise would tail off given the following comment. First, for the 113 items, initial phonemes or syllables were /a/, /i/, /u/, /o/, /k/, /t/, /ts/, /n/, and /w/, for which the mean of bias deltas was, according to Sakuma, *et al.*, 32 msec. ($SD = 16$). Second, voice-key naming latencies for words are variable enough. This variability inherent to linguistic materials may be indexed roughly by the proportion of the standard deviation of the mean; for example, the proportion of the *SD* for the mean of our own voice-key latencies for hiragana ($n = 36$) were 19 msec. to 446 msec. (0.04; less variable), whereas that of Yamazaki, *et al.*'s voice-key latencies for kanji words ($n = 114$) was 88 msec. to 635 msec. (0.14; more variable). If the effect size of this second factor is great, Yamazaki, *et al.* might have identified the target variable correctly even if they had included inaccurate phonemes. More data are needed to confirm this possibility, however.

Finally, we have to emphasize that, although we are probably correct

when we did not reject the null hypothesis concerning hiragana frequency, the very issue remains unresolved: What variables determine naming latency for hiragana symbols? Symbol frequency, learnability of hiragana in childhood, and ease of articulation may be candidates which well deserve study.

REFERENCES

Amano, S., & Kondo, T. (1999) *Nihongo goi tokusei [Lexical properties of Japanese]*. Tokyo: Sanseido.

Kessler, B., Treiman, R., & Mullennix, J. (2002) Phonetic biases in voice key response time measurements. *Journal of Memory and Language*, 47, 145-171.

Leong, C. K., Cheng, P. W., & Mulcahy, R. (1987) Automatic processing of morphemic orthography by mature readers. *Language and Speech*, 30, 181-197.

Rastle, K., & Davis, M. H. (2002) On the complexities of measuring naming. *Journal of Experimental Psychology: Human Perception and Performance*, 28, 307-314.

Sakuma, N., Fushimi, T., & Tatsumi, I. (1997) Onsei ha no shisatsu ni yoru kana no ondoku senji no sokutei [Naming latency measurement by visual inspection of sound wave forms]. *Shinkei Shinrigaku [Neuropsychology]*, 13, 126-136.

Seidenberg, M. S. (1985) The time course of phonological code activation in two language systems. *Cognition*, 19, 1-30.

Tamaoka, K., & Hatsuzuka, M. (1997) Hiragana to katakana no shori ni okeru kankaku benbetsu oyobi kankaku shikibetsu kinoo [Sense-discriminative and sense-determinative functions in processing of Japanese hiragana and katakana]. *Dokusho Kagaku [The Science of Reading]*, 41, 15-28.

Yamada, J., Takashima, H., & Yamazaki, M. (1998) Effect of ease-of-acquisition on naming latency for Japanese kanji: a reanalysis of Yamazaki, *et al.*'s (data). *Psychological Reports*, 83, 991-1002.

Yamazaki, M., Ellis, A. W., Morrison, C. M., & Lambon-Ralph, M. A. L. (1997) Two age of acquisition effects in the reading of Japanese kanji. *British Journal of Psychology*, 88, 407-421.

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APPENDIX

Naming Latencies For 36 Hiragana Symbols Measured in Three Studies

Symbol	Syllable	VK1	VK2	VK3	S-A	Delta
あ	/a/	449	426	403	387	16
い	/i/	440	422	367	343	24
う	/u/	424	423	377	361	16
え	/e/	448	436	398	385	13
お	/o/	441	421	403	386	17
か	/ka/	457	450	424	373	51
き	/ki/	479	489	446	379	67
く	/ku/	465	452	432	388	44
け	/ke/	467	465	422	365	57
こ	/ko/	482	465	425	394	31
さ	/sa/	484	508	485	367	118
し	/shi/	435	442	459	349	110
す	/su/	455	484	440	320	120
せ	/se/	466	489	442	365	102
そ	/so/	462	476	433	321	87
た	/ta/	462	463	409	384	36
ち	/chi/	454	496	445	385	91
つ	/tsu/	465	486	444	376	87
て	/te/	461	444	425	398	33
と	/to/	454	430	462	387	34
な	/na/	414	430	393	373	19
に	/ni/	422	407	363	345	14
ぬ	/nu/	450	418	361	342	20
ね	/ne/	450	422	373	353	24
の	/no/	433	415	363	343	20
は	/ha/	443	460	410	329	81
ひ	/hi/	501	460	425	335	90
ふ	/fu/	468	456	407	337	70
へ	/he/	449	464	397	335	62
ほ	/ho/	461	485	418	351	67
ら	/ra/	431	421	399	371	28
り	/ri/	432	430	409	377	32
る	/ru/	428	416	397	357	40
れ	/re/	443	427	396	365	21
ろ	/ro/	428	432	378	351	12
わ	/wa/	427	462	371	349	22

Note.—VK1: voice-key latency in the present study; VK2: voice-key latency in the Tamaoka & Hatuzuka study; VK3: voice-key latency in the Sakuma, *et al.* study; S-A: speech-analyzer latency in the Sakuma, *et al.* study; Delta: adjusted delta, i.e., VK3 minus S-A.