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Characteristics of human-generated random symbols—their dependence on symbol types and generation methods

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Abstract—We gathered and analyzed random number sequences generated by human subjects. We focused on the types of symbols (number or ten Japanese alphabet), and the types of generation methods (oral calling out or keyboard pressing). For the types of symbols, there is strong non-uniformity in Japanese alphabet sequences, that is, the strong positive correlation with the order of the alphabet used. We would like to note the Japanese alphabet's occurence frequencies are almost decreasing in the order of the position of the alphabet. And for the methods of generation, the subjects preferred central keys, whereas they reported no such preferences.

1. Introduction

Random number generation is among the frontal functional test of the human brain. That is, if a person's cognitive performance is lowered, the randomness of the generated numbers become lowered since the ability to generate high-variability number sequences is heavily dependent on manipulation of working memory. Also randomness is related to predictability of events, and prediction of events that are strongly related to intelligence [1].

There is a long history dating back to 1949 (according to Ref.[2]), and there are vast number of research in human-generated random numbers. In Ref.[2] fifteen research papers until 1971 are reviewed systematically with respect to the conditions (the number of alternatives in the choice set, types of alternatives, the length of generated sequences, paced or not, etc.), the measures of randomness (e.g. order of analysis), and main results obtained. The conclusion therein is that future research should work on the mathematical theories and experimental design. An example of deeper mathematical analysis on human-generated random numbers would be Ref.[3] in which the author proposes statistical model of random number generation. The research in this field continues to date, one of the most clear-cut examples being utilizing event-related potential (ERP) of the brain [4]. Ref.[4] is a good review of this field too.

We have gathered human-generated random numbers (not only numbers actually — since we also used Japanese Kana characters, kind of alphabet) and analyzed their occurrence and transition frequencies (in the following we say *frequency* and *frequency of difference of successive symbols*). We focused on types of symbols and methods of generation. Symbols used should interact with cognitive processes. So if we could find differences in sequences with respect to symbols used, it reflects difference in cognitive processes. And for the methods of generation we used oral calling out and keyboard pressing. In doing so, we wanted to see whether the generation methods affect the nature of generated sequences. If we could find differences with respect to the method, it reflects embodiment.

	/a/	/i/	/u/	/e/	/o/
/ /	あ	い	う	え	お
/k/	か	き	く	け	こ
/s/	さ	し	す	せ	そ
/t/	た	ち	つ	て	と
/n/	な	に	ぬ	ね	の
/h/	は	ひ	ふ	へ	ほ
/m/	ま	み	む	め	も
/y/	や		ゆ		よ
/r/	ら	り	る	れ	ろ
/w/	わ				を

Figure 1: Basic of Japanese Kana characters (alphabet). The characters with the same consonants are arranged in a row, and the same vowels in a column. The characters surrounded by a rectangle are representatives of each row, and are used in our experiments.

Now we would like to emphasize the novelty of using Japanese Kana characters (cf. Figure 1). For the Japanese-speaking people, there are ten fundamental (representative) Japanese Kana characters that are pronounced as /a/, /ka/, /sa/, /ta/, /na/, /ha/, /ma/, /ya/, /ra/, /wa/. To whom don't understand Japanese, it might sound there are no difference at all than the first ten English characters (A, B, C, D, E, F, G, H, I, J). But in fact there are big logical difference between them. In English alphabet, there exists no logical reason to end up in "J", the tenth character. Had we ever done so, we just arbitrarily stopped in the tenth character. Whereas in Japanese Kana characters, /a/ is the start and /wa/ is the end in the two-dimensional representation of the alphabet. Therefore the set of ten Japanese Kana characters has other meaning than the English alphabet, and also different from the ten digits in the sense of occurrence statistics in everyday language. This might lead to new direction of discussion on human-generated random numbers, for example, with respect to sound information processing as the most fundamental elements of the language.

2. Experiment

The subjects were twelve normal adults (Japanese, university students) who understand what "random" is. We instructed them to generate as much symbols as possible, and as randomly as possible for one minute. We have done a set of sessions for six subjects, and for the rest of the subjects (six subjects) we have done a set of sessions a day for five days. A set consisted of three sessions. To express in the form (symbols, method), three sessions are (digits, oral), (digits, keyboard), and (Japanese Kana, oral).

In the keyboard condition, we used a notebook computer where the ten digits are aligned in a row (1, 2, . . . , 9, 0).

3. Result

We analysed the number of symbols generated, randomness, histogram of symbols, histogram of difference in successive symbols (in the analyses, we mapped the ten Japanese Kana characters to ten digits), etc. We also traced change of these characteristics in time (in five days). The number of generated symbols in a minute in the first day and the fifth day is shown in Table 1.

Here we just show histograms of symbols and histograms of difference for three conditions of generation.

Table 1: Average number of generated symbols in a minute.

	digits, oral	digits, key	J Kana, oral
1st day	71.2	157.8	60.0
5th day	85.3	233.7	76.2

4. Discussion

Noticeable points are

1. Occurrence frequency histograms are totally different (Figure 2 (a) and (b)), whereas the difference histograms are almost the same for the "digits, oral" and "digits, keyboard" (see Figure 4 (a) and (b)), .
2. In digits, difference +1 is almost equal to or less than −1, whereas in Japanese Kana, difference +1 is larger than −1 (Figure 4 (a), (b) and (c)).
3. The frequencies of Japanese Kana characters tend to decrease in the order of the position of the characters in the alphabet (see Figure 1).
4. For "digits, oral" we could not see learning effect, for "digits, keyboard" there might be negative learning effect since the central keys became more preferred, and for "Japanese Kana, oral" we could see a little learning effect (Figure 3).

For the point (1), the act of choosing farther keys from the center might be suppressed perhaps by the unconscious optimization of consumed energy in hand movement. But it is unclear why the difference histogram is unchanged in spite of the totally different occurence frequency. For the point (2), the asymmetry would be due to the fact that, for the Japanese Kana, reversely ordered memory or speaking is rarely encountered whereas, for digits, those situation is prevalent. For (3), we would like to note that the frequency of those fundamental ten Japanese Kana characters in everyday Japanse language is nealy monotonically decreasing.

References

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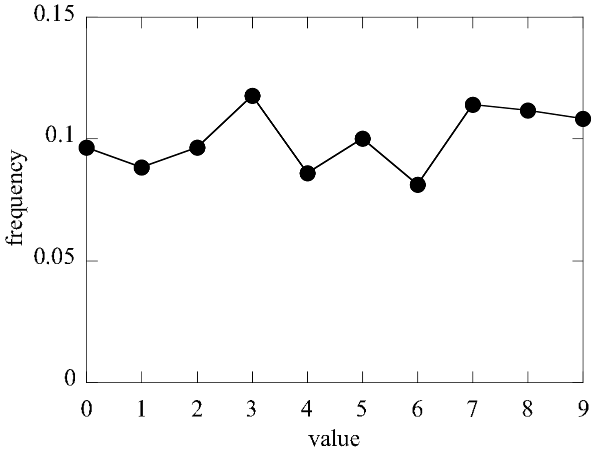
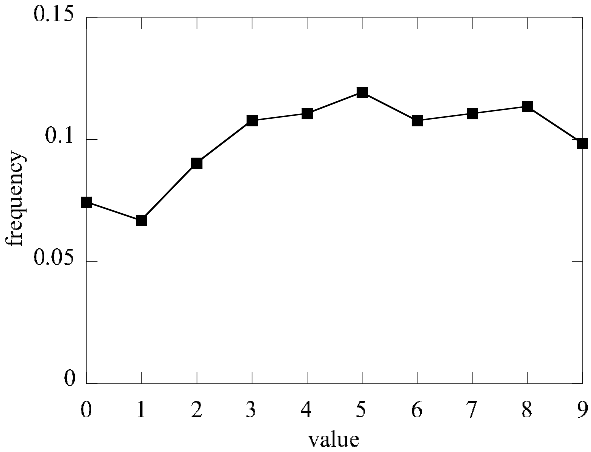
[3] Iba, Y. and Tanaka-Yamawaki, M.: "Statistical Analysis of Human Random Numbers Generators", *Methodologies for the Conception, Design, and Application of Intelligent Systems*, vol. 2, Eds. Yamakawa, T. and Matsumoto, G., World Scentific, pp.467–472, 1996.

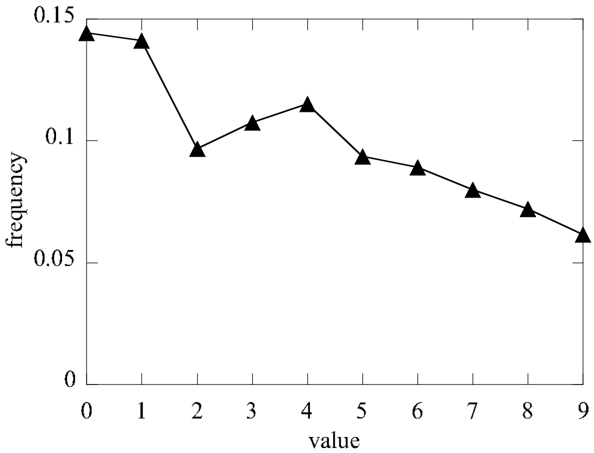
[4] Joppich G., Dauper J., Dengler R., Johannes S., Rodriguez-Fornells A., Munte T.F.: "Brain potentials index executive functions during random number generation", *Neuroscience Research*, vol. 49, no. 2, pp.157–64, 2004.



(a) digits, oral

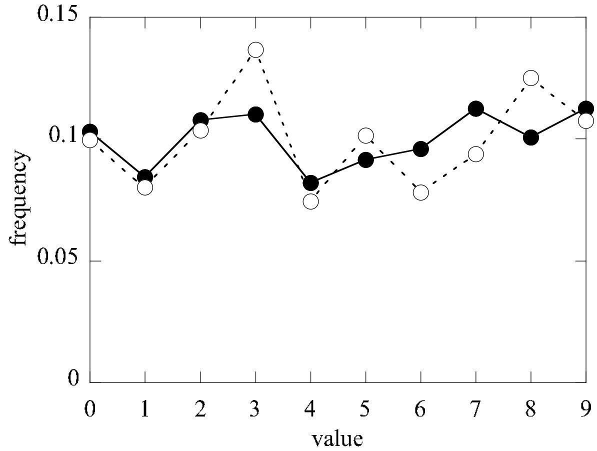


(b) digits, keyboard

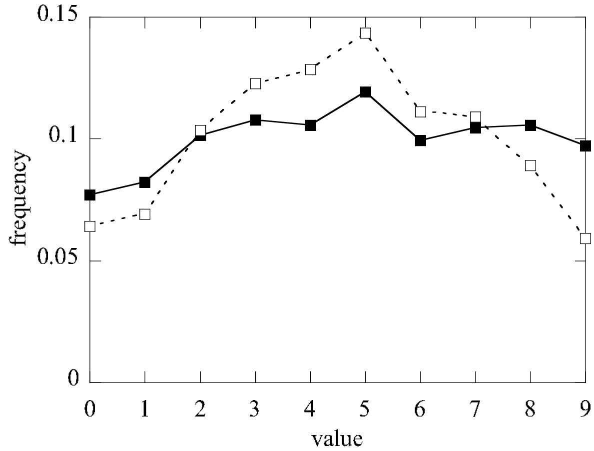


(c) Japanese Kana characters, oral

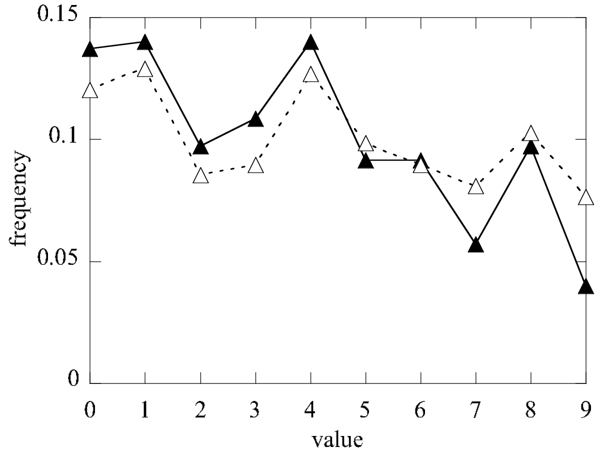
Figure 2: Frequency of generated symbols. Averaged over twelve subjects. Data obtained in the first session.



(a) digits, oral

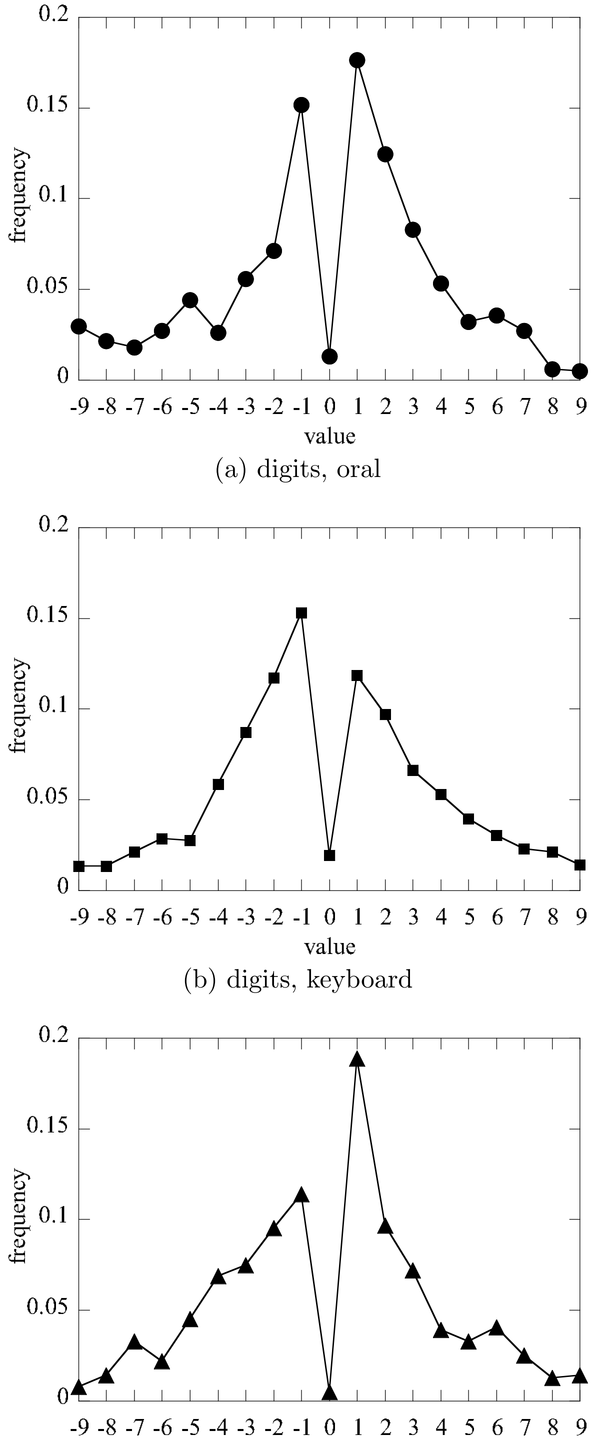


(b) digits, keyboard



(c) Japanese Kana characters, oral

Figure 3: Learning effect in the frequency of generated symbols. Averaged over six subjects. Filled marks represent the first day and open marks the fifth day.

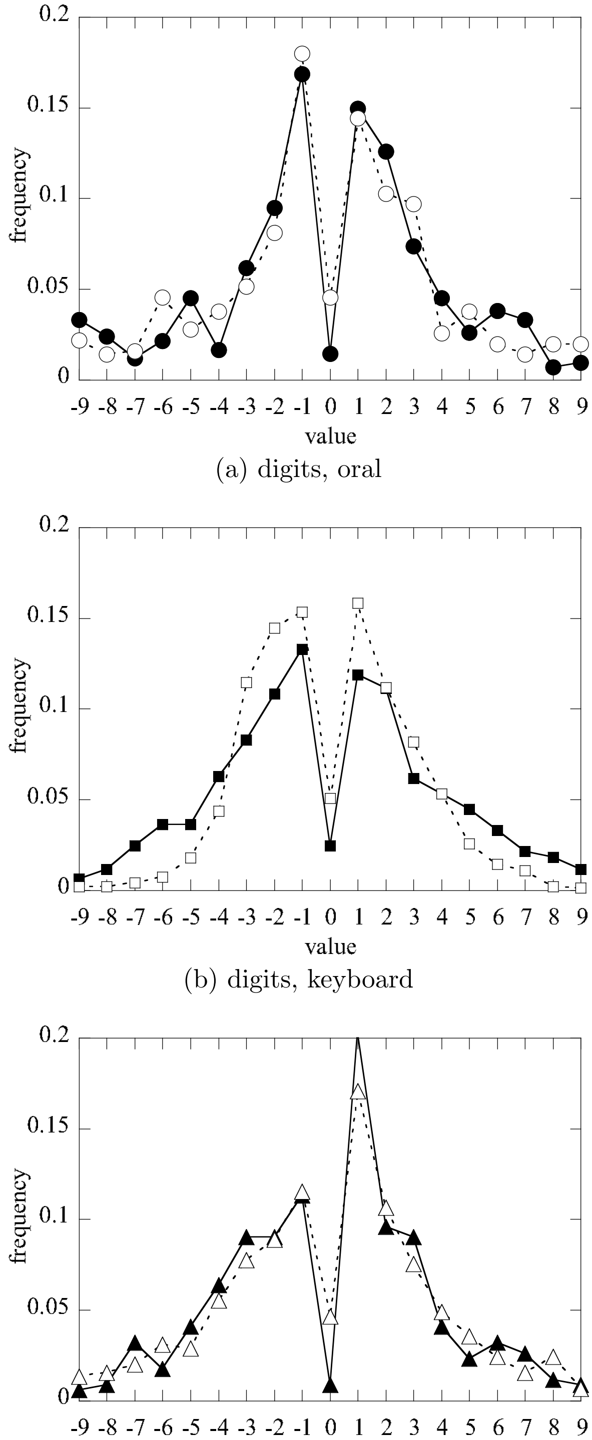


(a) digits, oral

(b) digits, keyboard

(c) Japanese Kana characters, oral

Figure 4: Frequency of difference of successive symbols. Averaged over twelve subjects. Data obtained in the first session.



(a) digits, oral

(b) digits, keyboard

(c) Japanese Kana characters, oral

Figure 5: Learning effect in the frequency of difference of successive symbols. Averaged over six subjects. Filled marks represent the first day and open marks the fifth day.