日本文入力方式　6－4
（1982. 7. 14）

タッチタイピングにかかわりのある 実験心理学的および大脳神経学的現象について*

山田尚勇
東京大学　理学部　情報科学科

VI.** Touch Typing Viewed as a Choice Versus Reaction Time Paradigm

It is often said in Japan that it is easy to type in English because there are only 26 letters in the alphabet, and that the typing of Japanese text is an altogether different matter because it requires a means to deal with at least 2,000 different characters or so. Yet, as we stated in the preceding section, it takes somewhere between 400 to 1,000 hours of experience at the keyboard to become a well accomplished English typist. This suggests that there is more to typing than such a simple comparison as above.

We may view the typing process as a psychological experiment of choice vs. reaction time paradigms, where the viewing of sentences of the manuscript is the stimulus set and the depression of appropriate keys is the response set. From the experiment of J. Merkel in 1885, it is known that the time required to depress a designated key increases linearly as the base-2 logarithm of the number of alternative stimulous-response combinations is varied from 0 to 3.32 (i.e., the number of combinations from 1 to 10). Posner [1966] summarizes later studies and classifies the stimulus-response combinations into three categories according to the compatibilites between the stimulus (S) and the response (R), as follows:

(a) Incompatible S-R, involving a transformation between a symbolic code and a spatial code. Examples are:
  (i) from an arabic number to pressing the corresponding key, and
  (ii) from a spatial array of lights to the spoken digit.
(b) Semicompatible S-R, involving a transformation from a spatial stimulus to the correponding spatial response in different planes. Examples are:
  (i) from light arrays in the vertical plane to key arrays in the horizontal plane.
(C) Compatible S-R, involving either symbolic stimuli and response codes, or spatial stimuli and response codes within the same plane. Examples are:
  (i) from arabic numerals to spoken digits,
  (ii) from lights to directly pointing them, and
  (iii) from key vibration to pressing that key.

Figure 10 is a schematic adaptation of the summary given by Posner on the reaction time in various stimulus-response categories, in terms of the number of possible S-R choices. One example cited by Posner shows that after extensive practice a subject's performance graph in a semicompatible S-R task coincided with that of the compatible catagory.

In terms of the above classification, the typing tasks of a novice are clearly of the incompatible S-R combination. Yet the performance of a very well practiced typist approaches that of compatible space-space combinations even for the number of choices of over 80 (see, for example, Figure 6 in Yamada [1980]). This may be accounted for by two possible reasons, namely, (a) after extensive practice, even the performance on incompatible S-R tasks would eventually be treated as if they are compatible S-R tasks, and (b) the sequence of S-R tasks in typing are not treated as separate tasks. Instead, they are chunked into the typing of a set of more complex patterns made up of groups of characters, as mentioned in the preceding section. Figure 10 shows that even if the reaction time of keying is brought down to the level of a compatible space to space task, it would be still on the order of 0.15 seconds for the number of choices of only 8. On the other hand, the key to key time of champion typists is less than 0.09 seconds on the average (and there are some who could bring that down to less than 0.06 seconds, using over 80 different key strokes to choose from). This clearly indicates the overlapping of the execution of the sequential motions of fingers. (see also Gentner, this volume).

These two factors in fast typing account for why English typists have to spend hundreds of hours for practice before they attain a professional status.

In recent years, there have been educational servies available for the initial training of touch typists based on some simple devices, such as the Sight and Sound which was originally developed by the British Navy, and claims are made to produce touch typists in 13 hours (or 17 hours for Kana typing). While their value as a teaching aid in the early stage of training is not deniable, we must also recognize the fact thet the trainees after 13 hours would have mastered the skill of only little beyond depressing keys one at a time without looking at the keyboard according to the text, and that is far short of forming some sort of symbol-space compatibility and pattern typing in reflexes in our cerebral cortex.

---

* This is a part of the chapter "Certain Problems Associated with the Design of Input Keyboards for Japanese Writitng," in the "Cognitive Aspects of Skilled Typewriting," edited by William E. Cooper, to be published in 1983 by Springer-Verlag, New York.

** Section numbers are left as in the above book.

X. Possibility of the Nonoptimality of Sound-Based Codes

In order to recall some basics of the theory of learning [Osgood 1953], take two learning tasks $T_1 : S_1 \rightarrow R_1$ and $T_2 : S_2 \rightarrow R_2$, where S_i is a set of stimuli and R_i is the set of corresponding responses. After an experience with task T_1, if a subject is given task T_2, then the performance of the subject on T_2 is expected to be influenced by T_1 in some manner. Depending on whether or not the experience on T_1 helps the performance on T_2, such an influence is called a positive transfer (PT) or a negative one (NT). Now the subject is again put back on T_1, and the experience on T_2 has some influence on the subject's performance on T_1 when compared with his initial performance on T_1. Again, depending on whether or not such an influence is favorable, it is called a retroactive facilitation (RF) or inhibition (RI).

Three well-known paradigms of such experiments together with experimental laws governing them are as follows, where "$\sim$" denotes a similarity, and "↑" denotes an increase and decrease, respectively:

(1) $T_1 : S_1 \rightarrow R_1$; $T_2 : S_2 \rightarrow R_1$ (i.e., $R_2 = R_1$)
(i) $(S_1 \sim S_2)\uparrow \Rightarrow$ PT↑ and RF↑ (e.g., Hamilton)

(2) $T_1 : S_1 \rightarrow R_1$; $T_2 : S_1 \rightarrow R_2$ (i.e., $S_2 = S_1$)
(ii) $(R_1 \sim R_2)\uparrow \Rightarrow$ NT↓ and RI↓ (e.g., Osgood)

(3) $T_1 : S_1 \rightarrow R_1$; $T_2 : S_2 \rightarrow R_2$ (general case)
(iii) $(S_1 \sim S_2)\uparrow \Rightarrow$ NT↑ and RI↑ (e.g., Gibson)
(iv) Skaggs-Robinson phenomenon, to be discussed.

Figure 13 is an extension of the schematic surface for transfer and retroaction by Osgood [1949]. Axes SS' and RR' are for the types of stimuli and responses, respectively, and the markings I, S, N, O, and A along these axes indicate "identical", "similar", "neutral", "opposite", and "antagonistic", respectively. The vertical axis indicates the degree of the transfer and the retroaction, where the upward direction corresponds to the positive transfer and the retroactive facilitation. Each of four laws (i) though (iv) mentioned above is indicated by a thick line curve on the surface. (The surface beyond RR' line toward S' is what we conjecture, and no validation for it is offered here.)

Take the case of 2-stroke Kanzi code typing. A straightforward reasoning goes as follows: we see Kanzis (S_1) and read them (R_1) day in day out. That constitutes task $T_1 : S_1 \rightarrow R_1$. Now we read kanzis ($S_1$) and type them in their coded forms (R_2). This is task $T_2 : S_1 \rightarrow R_2$. If the codes are different from the original sounds of Kanzis, then R_2 is different from R_1. As the codes deviate more and more from the natural sounds we will be traversing along curve (ii) by Osgood. From the shape of this curve, we see that the more the codes deviate from the natural sounds along the curve from (a) to (b), (c) and (d), the more negative the transfer effect becomes. A conclusion is that the codes are better if they are closer to the natural sounds of Kanzis. However, this is in conflict with what we think our experience with our own codes mentioned above tells us, that is, the codes for Kanzis which are aimilar to their natural sounds appear to give a more negative transfer effect than neutral codes. We must resolve such a seeming paradox.

The only possible locus on the transfer surface which would explain the paradoxical experience is the one which traverses along a line which is something like the one from point (a) to (g) via (e) and (f). If this is the case, then the process may be explained as follows [Yamada 1977]. The set of Kanzis having the same sound but different meanings corresponds to point (a), if the same sound is typed for all of them. As the codes gradually change from one Kanzi to another, the response performance tends to follow (a) to (c) as long as codes are kept as similar sounding ones. However, as codes deviate more and more from natural sounds, we begin to perceive the Kanzis of the set as more and more dissimilar stimuli because they now trigger distinct sound images in our mind. After all, they have different shapes and different meanings to begin with. In other words, the difference of the Kanzis is more emphasized than before, and the element of curve (iii) (i.e., Gibson) sets in. As a compound locus, the process traverses along curve (iv), which is known as the Skaags-Robinson phenomenon [Robinson 1927]. A further explanation for this phenomenon will be given in Section XIII.

It shold be noted that when we attempt to use codes which are variations of Kanzi sounds, they end up constituting somewhere between 30 to 60% of codes in various systems so far experimented with by various groups. Also, as we practice typing at point (g) while we continue to use daily the language in the natural manner, because of the neutral nature of point (g), the relative height of point (a) with respect to point (g) should become smaller as point (g) should rise with practice. As a consequence, the coding scheme which is based on the variations of natural sounds would fall somewhere between (e) and (f) and be inferior to the neutral coding at point (g). We must emphasize the fact here that the above explanation is only a hypothesis we are proposing based on some limited experience we have had, and it should be tested by a well controlled experiment.

For example, it is possible that the replacement errors among similarly sounding codes may be due to the fact that they receive less attention in practice than neutral codes because their sounds give a ready crutch for memory, hence they more easily fade with the lapse of time. How is such a possibility explainable on the surface in Figure 13?

The recall of well practiced codes is in conjunction with long term memory. However, as far as short term memory is concerned, it is known that, when alphabet letters are visually presented, the recall of "similarly sounding" letters is poorer than the dissimilarly sounding ones [Conrad 1964]. We do no know how such a property projects itself onto long term memory and contributes to the explanation of our observations on the Kanzi code memory.

Another fact which may or may not have some relevance to the phenomonon under discussion is that, when a computer programming language is designed to emulate natural language so that it could be used with minimal training, there have been some reports that programming errors are often due to confusion with natural language. However, since such reports are again not based on controlled experiments, their claims seem to lack objectivity.

XI. Association Codes and Interference to Pattern Typing

We have seen in Section IX some ways in which Kanzi codes are designed based on their reading, the mnemonics for, or associations with, the meaning of Kanzis, and the descriptions of the graphic structures of Kanzis. When we are faced with the task of learning 2,000 or more 2-stroke Kanzi codes, it is natural to feel that the task is a formidable one. Therefore, it is also quite natural to try to design the codes so that the difficulty of code learning will be alleviated as much as possible.

Kawakami's Rainputto code may be called a masterpiece of the art of such code design. In spite of the fact that it is designed to minimize the amount of hand motion and maximize the ease of hand movement, as we shall see later, his code is still highly mnemonic and associative. Kawakami's code is proprietary only to the system users and not made public. However, according to Tatuoka [1970], out of the codes of 1850 basic Kanzis, approximately 44.5% are based on the reading sound, 16.5% are on the association with common phrases, 13.2% are on the component structures, 5.5% are on the corresponding English words, and 20.3% are on others including fairly farfetched associations.

In order to be able to use such associative codes for such a high percentage of basic Kanzis, while maintaining good characteristics with respect to hand and finger motions, Kawakami uses a custom tailored letter arrangement on the keyboard so that both alphabet and Katakanas are strategically distributed for the purpose.

The Kantec system is an offshoot of Rainputto. However, unlike Rainputto, it uses the JIS standard Kana keyboard, but uses 2-stroke association coding as Rainputto, sacrificing altogether good hand and finger motions. Even with that, a good speed performance is still claimed by the users, but no details are found reported by this author. Similar association method called KIS is also used by Kudan Computer Service Co. [Sakamoto 1978], and others.

In order to make the association codes more uniform and easier to recall, some have advocated or used more than three strokes per character. A few examples are : (a) Kizawa [1969] proposed to code Kanzis by the combination of 3 or 4 Kana strokes representing the <u>On</u>-<u>Kun</u> sound pair of each Kanzi, for example, sa-n=ya-ma, go=i-tu, and syo=na-sa, for "mountain", "five", and "nasake", respectively, where "=" marks the boundaries between <u>On</u> and <u>Kun</u> sounds, and "-" marks the boundaries between Kanas, both of which are not the part of codes. The distinction among Kanzis, Hiraganas and Katakanas is made by appropriate mode shifts. (b) The KITEN system by Nippon Information Science Co. also uses the Kana typewriter and the combination codes of Japanese reading of Kanzis and the initial letter of their English equivalents, for example, ka-wa=ri, ka-wa=re, and ka-wa=su for "river", "leather", and "skin", respectively. (c) The majority of common nouns in Japanese are written in two Kanzis. Taking advantage of this fact, Hotaka [1969] proposed to use as the code of a Kanzi the reading of a common noun containing the Kanzi, and, in order to indicate which one of the two Kanzis in the common noun is being coded, he sandwiches the part for the coded Kanzi by periods, or simply prefix it by one period, if it were the tail part. For example, "relationship" is "ka-n=ke-i" in Japanese, consisting of Kanzis "kan" and "kei". In order to code the "kan", ".ka-n.ke-i" is used while "ka-n.ke-i" is used to code "kei".

Since 3 or more strokes per Kanzi requires more time to type than 2 strokes, and since 2-stroke codes turn out to be not more difficult to memorize than 3 or more stroke associations, to the best of the author's knowledge, Kizawa's and Hotaka's ideas have not been used for actual production work.

Also it appears as if it saves some strokes to type Kanzis in two stroke codes and Kanas in one stroke, by using boundary markers in between, rather than using two strokes even for Kanas. It turns out that the number of "strokes" per character, including non-Kanzis, is almost 2 (i.e., 1.99 in IBM's experimental Apollo system), by the time we count spaces, shifts and character mode changes [Clauer 1977]. Besides, in such a system, the typing error rate is extremely high (an incredible 0.17 per stroke measured in a controlled study [ditto]) due to the complex finger manipulations required. In addition, it appears more difficult to maintain and use two streams of queues simultaneously in our mind at a high speed, one for character codes, and another for the class designations of character codes. This is not only implied by the above data, but also alluded to in the in-depth interview by the experimental trainees who participated in the above study. This phenomenon appears to be an interesting problem to be settled by a well designed psychological experiment. Apparently similar phenomena were experienced by W.J. Koppits [1971], and by R. Seibel [1962], at the IBM Research Center when they experimented with the possibility of using abbreviations for frequent words in English text, using (multiple) shift keys to indicate abbreviations (besides capital letters). At any rate, there are no practical systems based on this mode-switch separation of character classes, that are used by well trained professional typists.

Because the majority of Kanzi code input methods which have been in use or have been proposed so far are association mnemonic, be they uniform length codes or variable length codes, such coding schemes are often called "association method". The association approach may be a good compromise to assuage the initial aversion to take up the seemingly impossible task of learning 2-stroke Kanzi code typing. (It may also be good for those who would not intend to become an expert typist, nor type that often.) However, from the standpoint of designing an expert's tool, it is a futility because the very association most likely will stand in the way of the acquisition of an expert skill.

This phenomenon may be closely analogous to a known fact about the acquisition technique of Morse code. In the 1930's, because of heightened military activities, Japanese armed forces were suddenly faced with a dire shortage of Morse code operators and devised a technique for their quick training, called the "word association" (<u>gôtyôgo</u>) method. Taking advantage of the fact that Japanese syllables are clearly separable into short and long ones, a Japanese word is associated with each of Morse codes for Kanas so that the pattern of short and long syllables of the word is the same as the pattern of dots and dashes of the Morse Kana code. Some examples are:

Kana	Morse code	associated word	meaning
"i"	- —	itô	(Mr.) Itô
"ro"	- — - —	rozyôhokô	stroll on a street
"ha"	— - - -	hâmonika	harmonica
"ni"	— - — -	nyûhizôka	increase in expenditure

Initial experience with this word association method showed that signal operators could learn Morse codes quickly, and the training method was adopted by the services. However, after a few years experience, it became clear that (a) although the initial pick up of codes is quick, the speed gain of signal reception thereafter is slower, and that (b) it is easier with this method to loose the continuity of reception in the middle of a sentence. Thus the Navy aboandoned the method after four years or so, and the Army followed suit a few years later. In the meantime, reasons for such phenomena were investigated [Kuroki 1943].

It is clear now why the word association method failed. In short, first of all, in order to decode Morse codes, the operator must associate words to letters, then isolate the initial letters of words to find the letters sent. This means that there is an extra level of association task involved in the process, which would most likely require extra mental processing time. Second, the pattern matching involved in the word association process brings the meaning of those words into consciousness which are unrelated to the meaning of sent messages. As a consequence, the meaning of the received message becomes clear only after a chaining of the isolated letters recovered from these association words is made. However, the operator's linguistic facility is mostly tied up with the recovery of the meaning of the association words, and it would not be able to keep track of the meaning of the sent message itself. Hence, once the decoding process goes out of phase on account of the decoding delay relative to the codes being received, the operator would easily loose the portion of the message because its semantic context is not available to assist to remove the uncertainty and to fill the gaps.

In sumarry, it is safe to state that, for the training of professional and highly skilled Morse code operators, semantic association will, in the long run, work as a hindrance rather than an assistance for a faster and effortless code reception. Therefore, for the training of such operators, in Japan as well as in the U.S., we now employ the method of the direct decoding from sound to letters, starting out the training with sentences in a basic subset of letters, transmitted at a reasonably fast speed so that trainees would not be able to resort to their own association crutches, and gradually increasing the speed, and after the speed is sufficiently high, continuing further training as a new subset of letters are added, and so on. We call this approach sound imagery (<u>onzô</u>) method, or "sound sensory" (<u>onkan</u>) method. This approach is known to enable the operators not only to attain the ultimately higher saturation speed faster, even if the initial start-up slope may be less steep, but also to take messages in terms of words, phrases, and sentences directly from sound, rather than in terms of letters. This latter ability allows operator to lay behind the transmission for a good part of a sentence, which is not possible with the word association method. This method also enables the increase of reception speed because it is sufficient to be able to follow the transmission at the average speed, even if instantaneous speed at times exceeds the average.

We should note here, however, that, although these two approaches make use of the brain functions in different ways, the language region of the left cortex of the cerebrum is still involved in both. In the case of copy typing work, even the regions of cortex used may be different in part, depending on the types of Kanzi coding, as we shall see later.

(We learned recently that at one time the communication operators of the U.S. Navy airplanes also learned Morse code by an association method using mnemonics such as, for example, "get a hair cut" for - - — - which is the code for "g". However, the voice communication has replaced the Morse code by now for such communications. Also in the Defence Force of Japan the communication is by voice or by teletypewriter by now and they now brought back the association method of training in Morse code for emergency use only.)

XIII. Possible Hemispheric Lateralization of Cerebral Functions in Typing

Starting with the research by Roger W. Sperry and his group on the split brain of animals at the California Institute of Technology in the early 1950's [Myers 1953], the lateralization of the functions between the left and the right hemisphere of the cerebrum has been extensively studied, and a fair amount of facts about it have been accumulated [Bogen 1969, Gazzaniga 1978, Bradshaw 1981]. (A good exposition is seen in Blakeslee [1980] with an extensive list of references, although certain of the material may be somewhat overly assertive.)

The most distinguished function of the left hemisphere is its linguistic facility, and that of the right the "manipulo-spatial mechanism" by which a spatial context is mapped onto the perceptual and motor activities of the hands [Le Doux 1977]. What we are aware of, and able to verbally express, are mostly the activities of the left hemisphere. The activity of the right hemisphere hardly surfaces to the level of consciousness, hence verbally not expressible. For that reason the right hemisphere activities are sometimes likened to the concept of id (However, it is likely that the left-right differences of hemispheres "may be more attributable to localized differences in cerebral origination than to the overall cognitive style of the hemispheres" [ditto].)

There are some indications which may be interpreted to show, although it is still a sqeculation on our part, that a well experienced (English language) copy typist may type more under the control of the right hemisphere than the left, while a novice typist may be much more dependent on the left hemisphere. If we were right in wuch a speculation, an experienced copy typist may be typing through a cortical reflex from the visual information of the manuscript to the execution of appropriate sequences of finger motions. This certainly involves the reflexive mapping from the letter sequence to the spatial information of the corresponding letter keys on the keyboard, and then to the perception of the locations of these keys in the space and then the desired sequential motions of fingers in such a space, which are all believed to be the function of the manipulo-spatial and subconscious right hemisphere. On the other hand, although a novice typist has to rely on the right hemisphere for the spatial sequencing of fingers over the keyboard, the execution is less reflexive, perhaps involving more of the left hemisphere activities. And the more logical and conscious the typing by the novice is, the more of the left hemisphere participation may be required. Hence, the difference in the degrees of the relative involvement of the left and the right hemispheres between an expert and a novice may be that the novice has to involove the left hemisphere more, while the expert is able to free it more by increasing the dependency on the right hemisphere cortical reflexes. The first observable fact which is congenial to the above conjecture is that an experienced typist is often capable of carrying out a matter of fact conversation while she is copy typing a text of normal complexity on a familiar subject, while it is our observation that a novice appears to have to stop typing in order to participate in such a conversation. This may be somewhat analogous to the fact that we can carry on a conversation of good contents while walking along a routine route, while a baby who can barely walk yet would often fall as soon as it is talked to.

Before we come to our second observation, we need to recall the phenomena of visual lateralization and lateral eye and head turning, both of which arise from the functional lateralization of the cerebral hemispheres. First of all, the anatomical structure of the eye is such that the nerves from the left half of the retina, where the image of the right visual field (RF) impinges upon, of both eyes are connected to the left cerebral hemisphere (LH), and the right half of the retina for the left visual field (LF) to the right cerebral hemisphere (RH). Hence, as Mishkin and Forgays [1952] found, when English words are tachistoscopically exposed either to RF or LF for a short time, more words are correctly recalled from the RF, which is congenial to the fact that the LH is the language hemisphere.

In order to understand this phenomenon, we need to know something about the information transmission in our nervous system. In 1912, A.T. Proffenberger studied the reaction time to a stimulus, which depends on the transmission speed of the nervous signal, by sending a stimulus to the right cerebral hemisphere, demanding a motor response from the left hemisphere, and measuring the required reaction time, and vice versa. He found out that the reaction time was about 6 ms longer for this type of case than it was for an ipsilateral response. He attributed this difference to the travel time of electrical impulses across the corpus callosum.

A study by H. Wallach, E.R. Neuman, and M.R. Rosnzweig in 1954 on the stereophonic localization of binaural clicks showed that the subjective mid-line localization is about 20 microseconds to the left, and a similar study by H.-L. Teuber and S.L. Diamond in 1956 gave that to be about 170 microseconds. Since each ear is known to have bilateral cortical representation, and yet the auditory cortex contralateral to the stimulated ear gives rise to larger and earlier evoked electroencephalographic (EEG) potentials than that of ipsilateral cortex, both the left shift of the mid-line and the smallness of the amount when compared with what Proffenberger gave are explicable.

About the same time, F. Bramer in 1958 also showed by a electrophysiological study the time of electrical excitation to cross from one hemisphere to the oposite hemisphere to be in the range of 10 ms.

The study reported by I.J. Hirsch and C.E. Sherrick, Jr. in 1961 on the ability to perceive the correct temporal order (sequence) of two light stimuli to the right and the left visual fields (RF and LF), may be interpreted to show that the subjective spontaneity occurs when the LF flash is 4 ms before the RF flash (or, the RH is stimulated 4 ms before the LH).

In 1962 A.M. Halliday and R. Mingay were interested in the time difference of transmission of electrical excitation to the brain between from toes and from the index fingers, found to be about 20 ms. (O. Klemm in 1925 carried out a similar experiment between forehead and foot and determined the signal transmission of nerves to be about 25 - 30 ms.) Their evoked EEG potential data were later interpreted also to have shown the left-right asymmetry.

R. Efron [1963] summarized most of these, repeated the experiments of Hirsch and Sherrick, and of Halliday and Mingay, showed 2 - 6 ms more delays to the RH stimuli, and also conjectured, perhaps for the first time, that the temporal order of sequenced stimuli is determined by the LH without compensation for the transmission delay of RH stimulus information across the corpus callosum, which is about 2 - 6 ms depending on the intensity of stimuli.

R.A. Filbey and M.S. Gazzaniga [1969] showed that the average "yes-no" verbal reaction time to tell a presence or absence of a dot in a tachistoscopically flashed image is shorter when the dot is in the RF (386 ms) than when the dot is in the LH (419 ms), or the dot is absent (420 ms), by about 35 ms. When the responses by the subjects are made by pushing a lever by the right hand toward the direction of the dot in the visual field, however, the average reaction time was about 420 ms for both LF and RF, against 380 ms for no dots. This shows that the signal arising from the visual information received by the RH reaches the LH motor cortex, which controls the motion of the right hand, much faster than the transmission of the visual information to the LH language area, which is required to go through the corpus callosum.

The next well-known phenomenon we note here is that, when the LH is more actively used (e.g., by a verval task), eyes (and even the head) generally tend to turn to the right, even when the active use of the eyes are not involved [Kinsbourne 1972 and 1973, and Gur 1977]. The turn to the oposite direction is generally less conspicuous when engaged in manipulo-spatial tasks. This phenomenon is reciprocal in that, when the eyes are turned to the right, the LH is more activated, and vice versa [Hines 1974, and Gross 1978].

Turning to our second observation, when experienced copy typists are at work, by far the large majority of them place their manuscripts on the left side of their typewriter. This has been so since almost immediately after typewriters became commercially available in the last century. We have asked for the reason a few people here in Japan as well as in the U.S. who are knowledgeable about typing, but have not received a really convincing answer so far.

Some possible reasons suggested by them are that (a) in the days of hunt and peck typing, some held the manuscript in their left hand and typed by their right hand, and the habit has been carried down, that (b) some early typewriters had the carriage return lever on the right end of the platen, (which is also unjustifiable a reason by now except by the power of intertia, considering that the most typewriters have it at the left end today which could block the left view, or none at all), that (c) four rows of keys are arranged with a slight skew toward the left at the top, which tends to cause the slight twist of the upper torso toward the left when both hands are placed over the keyboard in touch-typing posture, and finally that (d) it is a carry over of the habit of hand copying, which forces the dexterous (i.e., right handed) people to place the manuscript to be copied on the left. Each one of these does not appear to have the power of influencing professional typists for such a degree for so long a time. However, it is still possible that all of these combined could have produced such a habit.

At any rate, in recent years some schools of typing instructors appeared to preach the right side placement of manuscript. Indeed, if copy typing involves the fully committed activity of the LH, i.e., the language hemisphere, then it should be advantageous to place the manuscript on the right, i.e., in the RF, in order to send the visual image to the LH, as we have seen above. In fact, at the early stage of training, a large number of typists appear by feel more comfortable by placing text material on the right to type from.

Nevertheless, on the strength of the tradition of left side manuscript placement, it is our conjecture, based on the neuropsychological facts stated above, that an accomplished copy typists indeed relies less on the left language hemisphere (LH) than on the right manipulo-spatial hemisphere (RH) [Yamada 1982]. Considering the fact that the manuscripts are written in a language, it may appear paradoxical to prefer to handle it though the non-language right hemisphere. However, it is not the contents of the visual stimuli themselves but the type of the cognitive activities that determines to which side the eyes and the head be turned to [Kinsbourne 1973], and we think that the seeming paradox is not a real one. If we think of the fact that when we are proof-reading we hardly follow the semantic contents of the text, such right hemisphere dependency of typing also appears not so unreasonable. We will return to this subject again in the next Section.

In the light of the above discussion, we may reexamine the transfer and retroaction surface of Figure 13 in Section X. We mentioned an impirical observation that the association codes of Kanzis are sometimes more easily forgotten or cause more errors of replacement type than the neutral codes do. This means that their transfer effects should be expected to fall somewhere like points (f) and (g), respectively, on the Skaags-Robinson curve in the Figure and an explanation is needed which accounts for the effective shift of the stimuli as perceived from I to S to N, in spite of the fact that typists are dealing with the same Kanzis as the visual input stimuli as before. We speculate that this psychologically perceived change in stimuli may be due to the fact that the cerebral area for their processing shifts at least in part from the left hemisphere to the right, as we discussed in this Section. If this were the case, then we should expect that the neutral codes are more accomodating for the shift to the right hemisphere processing because they are not tied down with the linguistic processing as much as the association codes, which is consistent with our observation, although we expect that an experimental proof for such a hypothesis will be very difficult. Strictly speaking, the Skaags-Robinson curve on which points (f) and (g) sit may deviate side ways from the diagonal line from I-I corner (i.e., (a)'s projection) to N-N center (i.e., point (g)).

We note in passing that the transmission time difference of 20 ms of nervous excitation between the times for the toe and index finger to the cerebrum is about one fourth of the resolution time of consecutive actions of fingers in a good typist. In the research on typing equipment and devices, the use of feet was suggested time and again in history, and still is, without much success. For example, in the very first commercial typewriter of E. Remington and Sons in 1874, carriage return was effected by a foot pedal, which was changed to a push-down hand lever on the right side of the typewriter only several months after its introduction. This was yet the day of hunt-and-peck sight typing using only index fingers. In the present day of touch typing, the phase difference of one fourth cycle in hand-foot coordination (together with other factors) would make smooth operation difficult even with good training.

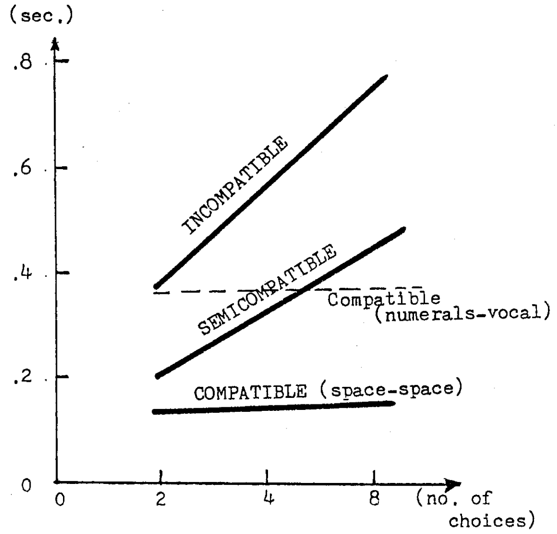

Fig. 10 Reaction Time for Various S-R Categories

(schematic adaptation from Posner 1966)

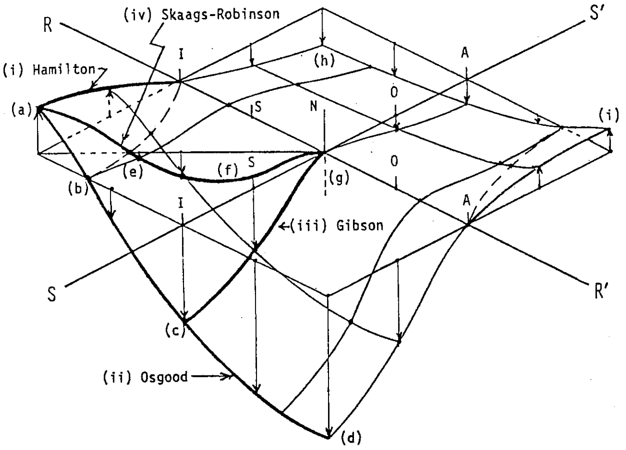

Fig. 13 Transfer and Retroaction Surface