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Visual-Field Differences for a Number–Non-number Classification of Alphabetic and Ideographic Stimuli

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Subjects made a number–non-number classification for single numbers or non-numbers presented either in the left or right visual field. A right visual field advantage was observed both for numbers written ideographically (Arabic numerals) and alphabetically. The laterality effect was stronger for the alphabetic than for the ideographic script, but the interaction with visual field failed to reach statistical significance. The results are discussed in the framework of other studies contrasting the processing of logographic and phonographic scripts as a function of the visual field.

Introduction

During the last two decades or so, the study of cognitive processes involved in reading has developed into one of the leading topics in cognitive psychology (see Henderson, 1982 for an extended coverage of that field). It has also entailed a growing interest in the investigation of the characteristics of information processing in different writing systems (see Hung and Tzeng, 1981, for a review). It is a logical assumption to think that visual symbols that represent spoken language at different levels should be processed differently, at least as far as early processing stages are concerned. Therefore, comparing the processing involved in reading in phonographic writing systems, whose symbols map on to the spoken language at the sound level (the phoneme in alphabetic systems

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and the syllable in syllabic systems), and logographic writing systems, whose symbols (logograms, hereafter referred to as ideograms to follow the more common usage) represent morphemes (or words), should in principle shed some light on that question. It is the reason why many studies concerned with the reading of Chinese characters or with the mixed syllabic and logographic writing systems used in Japan and Korea have been published in the recent years (see Hung and Tzeng, 1981). However, even in languages that resort almost exclusively to an alphabetic principle for their visual representation, there are a few concepts—like for instance numbers or some mathematical signs—that can be represented either alphabetically (seven, percent, dollar . . .) or ideographically (7, %, $ . . .). It is therefore possible to get some insight into the processes involved in reading ideograms without necessarily studying Chinese or Japanese orthographies. However, this possibility has been relatively little explored so far (but see Besner and Coltheart, 1979, for a notable exception).

The purpose of the present paper is to document further possible differences in the processes leading to the meaning of numbers written alphabetically or ideographically. We used a number–non-number classification task with lateral presentations of the stimuli. In what follows, we will use the term "number" to refer to numerical stimuli independent of their method of being written; "digit" will be used interchangeably with "Arabic numeral". In our experiment, and in most of the experiments to be referred to below, only numbers smaller than 10 were involved. The choice of single hemifield presentations was intended to provide data that could be compared to the results of many experiments using Chinese ideograms or their Japanese form (Kanji characters) and Japanese syllabic symbols (Kana), which are based upon that procedure. A review of these studies should help to formulate some predictions about the pattern of results to be observed in the present experiment.

Initial work with normal Japanese subjects showed opposite field advantages in the processing of Kanji and Kana. Kana words (Hatta, 1978) or non-words (Endo, Shimizu and Hori, 1978; Sasanuma, Itoh, Mori and Kobayashi, 1977) were better identified in the right visual field (RVF), whereas Kanji words (Hatta, 1977a, b, 1978) gave rise to a left-visual-field (LVF) advantage. A non-significant LVF advantage was also observed with two-character Kanji non-words (Sasanuma et al., 1977). These data, as well as more recent findings, have often been taken as evidence of a difference in the respective competences of the two hemispheres in processing each kind of script (e.g. Coltheart, 1980, 1983). However, our reading of the literature leads us to believe that it is premature to conclude that the difference in lateralization between Kana and Kanji is necessarily determined by intrinsic properties of the two written representations. Although the RVF advantage for the processing of Kana has been confirmed (Endo, Shimizu and Nakamura, 1981a; Shimizu and Endo, 1981), except when a visual same–different judgement is performed (Sasanuma, Itoh, Kobayashi and Mori, 1980), subsequent work with Kanji or Chinese characters leads to a perplexing picture since every possible outcome (LVF or RVF advantages, or no field advantage at all) has been observed.

A detailed analysis of the results observed with Kanji and Chinese characters suggests that several factors should be taken into account in order to get a coherent, albeit tentative, picture of the observed laterality effects. Here follows a brief outline of the conclusions of this analysis.

A first useful distinction is between studies using stimuli consisting of one ideographic character vs. those using more than one. A clearcut RVF advantage has always been observed with combinations of two ideographic characters into a meaningful unit (Hatta, 1978; Kershner and Jeng, 1972; Tzeng, Hung, Cotton and Wang, 1979). It holds true also for the meaningful combination of one Kana and one Kanji character (Hatta, 1978), but no significant laterality effect is found when two Kanji characters are combined into a meaningless unit (Sasanuma et al., 1977).

To put some order into the results observed with single ideographic characters, at least three variables should be taken into account. The first variable is the duration of the display (long vs. short exposure duration); the second characterizes the dependent measure (reaction time vs. accuracy of report); and the third deals with the kind of task that is performed (semantic vs. nonsemantic). At present, there is a considerable confusion between the roles of these three variables since there are not enough data in the literature in order to disentangle their respective influences. Here follows a tentative classification of the available data.

With short exposure durations ranging from 20 to 60 msec, the percentage of correct identifications of single Kanji characters is always higher in the LVF than in the RVF (Hatta, 1977a, b, 1978). With similar exposure durations, a phonological comparison of two Kanji characters yielded a RVF advantage (Sasanuma et al., 1980). The situation is less clearcut with Chinese ideograms. The LVF superiority for identification is confirmed by Tzeng et al. (1979), but no field advantage was found by Huang and Jones (1980), and Nguy, Allard and Bryden (1980) reported a RVF advantage for two of the three different types of characters they used and no field advantage for the third one. However, the last two studies mentioned have been judged rather uninformative by Hung and Tzeng (1981, p. 392) because of lack of specification of the characters in the case of Huang and Jones (1980) or of misclassification of some characters in the case of Nguy et al. (1980). A strong RVF advantage in the accuracy of report of Chinese single characters has also been observed by Wu-Tian and Rui-Xiang (1983).[1]

With long exposure durations ranging from 120 to 160 msec and reaction time as the dependent measure, a RVF advantage for single Kanji characters is often found, provided the task is semantic (Hatta, 1979, 1981a, b, 1983; Hatta, Honjoh and Mito, 1983). There are, however, discrepant results, such as the absence of any field difference in a lexical decision task (Hatta, 1981a) or a LVF advantage in responding to concrete nouns in a manual speeded classification of nouns vs. verbs and adjectives (Elman, Takahashi and Tohsaku, 1981).

A tentative conclusion is that both syllabic and logographic scripts are better processed in the RVF, which probably implies a left-hemisphere superiority for performing most of the tasks that have been studied so far. When observed, a LVF advantage for ideographic symbols is often associated with a very short exposure duration, one of the visual characteristics that, according to Sergent (1983a, b), could generate LVF superiority effects quite independently of the nature of the visual stimulus (but see Besner, Daniels and Slade, 1982, for a notable exception).

Higher-level cognitive factors also play a role in the determination of the laterality effect. With moderate eccentricity (4°), moderate character size (0.95°), and a 100-msec exposure duration, Endo et al. (1981a, b; Shimizu and Endo, 1981) have shown a modification in the laterality effect as a function of the degree of familiarity with the script. They used a categorization task in which four Hangul characters had to be mapped into two responses. Hangul is the alphabetic syllabary used in Korea (see Taylor, 1980, 1981). The results showed that Japanese subjects who cannot read Hangul were faster in responding to characters presented in the LVF than to those presented in the RVF (Endo et al., 1981a, b; Shimizu and Endo, 1981). Subjects who had been learning Hangul for about six months showed the opposite field advantage (Endo et al., 1981a). A small non-significant RVF advantage was also found with Japanese subjects who were taught the meaning and the pronunciation of the Hangul characters but who ignored the principle of Hangul orthography (Endo et al., 1981b; Shimizu and Endo, 1981).

Arabic numerals form a small set of ideograms used in a very

[1] Most of the Chinese characters are composed of a semantic radical, the "signific", which gives a clue about a semantic category, and a "phonetic", which gives a clue about pronunciation (e.g. Wang, 1973). One factor that has been overlooked in studies using hemifield presentations is the location of the radical in the character. This factor might have determined part of the laterality effects that have been reported by favouring the RVF for characters having the semantic radical on the left side and the LVF for characters having the semantic radical on the right side.

specialized domain. They are also less complex physically than most of the oriental ideograms. Therefore, there is no a priori reason to believe that these non-alphabetic symbols should necessarily be processed in the same way as Chinese or Japanese ideograms. However, the picture that emerges from studies involving Arabic numerals is pretty much the same as the one resulting from the analysis of the data on oriental ideograms. A RVF advantage is found in studies involving numbers composed of more than one digit (Carmon, Nachshon and Starinsky, 1976; Hatta and Dimond, 1980; Hines and Satz, 1971, 1974). With reaction time as the dependent measure and with long exposure duration, the naming of a single digit leads either to a weak 10-msec RVF advantage (Geffen, Bradshaw and Wallace, 1971), or to no field advantage (Gordon and Carmon, 1976). Manual two-choice tasks involving only two digits also lead to a small RVF advantage of 13 msec (Geffen et al., 1971) or 14 msec (Cohen, 1975, Experiment 3, cued condition). Only one of these results (Geffen et al., 1971) was reported to be significant. Shorter response latencies for stimuli presented in the RVF were also observed in more complex tasks, as in judging whether the numerical size and the physical size of two digits are congruent or not (Hatta, 1983), or which of two digits is numerically the largest (Besner, Grimsell and Davis, 1979). However, in the last-mentioned task, no field advantage was found by Peereman and Holender (1984), and an opposite LVF advantage was observed with a short (50-msec) exposure duration (Katz, 1980). Finally, a huge RVF advantage in the accuracy of report of single digits has been observed by Besner et al. (1982).[2]

In the experiment reported below, subjects had to perform a binary classification according to whether or not a single stimulus presented in the LVF or in the RVF was a number. The present study departs from other related work in predicting no opposite field advantages for numbers represented alphabetically or ideographically. The rationale underlying this prediction is the following: (1) Our visual parameters (long exposure duration, small eccentricity, moderate stimulus size) are

[2]Besner et al. (1982) observed a very strong RVF advantage for the accuracy of report of Arabic numerals and for their Kanji counterparts. It has been obtained with large eccentricity, short exposure duration, and large stimuli; that is, in psychophysical conditions that, according to Sergent (1983a, b), are best suited for the observation of a LVF advantage. However, luminance of the stimuli, which was not reported, is also expected to interact with the other physical parameters. Moreover, the presentation of a pattern mask immediately after stimulus exposure might have played a considerable role in the determination of the RVF advantage that was observed. On the other hand, the opposite field advantages found by Besner et al. (1979) and Katz (1980) are consistent with Sergent's hypotheses; they can be explained by the difference in exposure durations in the two studies.

most appropriate for determining a RVF advantage (Sergent, 1983a, b). (2) In such conditions, most of the studies reviewed above dealing with Chinese or Japanese ideograms or with Arabic numerals yielded a RVF advantage. (3) The RVF advantage first reported by Mishkin and Forgays (1952) for alphabetic words has been confirmed in a variety of tasks ever since (see, e.g., Bradshaw, Nettleton and Taylor, 1981, for a review). It holds particularly true for lexical decisions using items written alphabetically (Babkoff and Ben-Uriah, 1983; Barry, 1981; Bradshaw and Gates, 1978; Bradshaw, Gates and Nettleton, 1977; Leiber, 1976; McKeever and Hoff, 1982).

An additional prediction is that numbers written alphabetically should yield a stronger RVF advantage than Arabic numerals. It is a tentative prediction that rests upon the currently held view that laterality effects depend on cognitive operations rather than on stimulus characteristics (see Bertelson, 1982, for a discussion, and remember the opposite field advantages observed by Endo et al., 1981a, b and Shimizu and Endo, 1981, as a function of the degree of familiarity with the same stimuli). Assume, as did Allen (1983), that performing any complex cognitive task depends on the integration of the activity of various subprocessors that differ in their distribution within hemispheres. Assume further that most of the subprocessors involved in a number–non-number classification task are the same whatever the input format, since subjects are basically engaged in the same mental activity. Then, examination of the literature, which often shows RVF advantages when digits are involved, suggests that some of these subprocessors are lateralized[3] in the left hemisphere. In this framework, the putative interaction would be achieved if more left-lateralized subprocessors are involved in processing alphabetical rather than ideographical symbols. Obvious candidate left-lateralized subprocessors are those related to the derivation of phonological representations from the printed symbols. There is a good deal of evidence showing that this could be achieved either postlexically or prelexically (see Coltheart, 1978). Postlexical phonology is generated from the lexical representation that is itself partly specified phonologically. Postlexical phonological representations are independent of the form taken by the sensory input (in the present case alphabetic or ideographic) used to access the lexicon. Prelexical phonology can be derived from the building blocks of phonographic writing systems (letters or syllables), but not from ideograms. It is

[3]Applied to a subprocessor, "lateralized" either means that the subprocessor exists only in one hemisphere, or that although duplicated in each hemisphere, it is nonetheless relatively more efficient in performing its function in one hemisphere than in the other (Allen, 1983, pp. 93–94).

widely held that both forms of phonological derivations[4] are the exclusive prerogatives of the left hemisphere (Coltheart, 1983; Gazzaniga, 1983; Patterson and Besner, 1984a; Zaidel, 1983). Hence, we have found one possible supplementary source of laterality in the processing of alphabetic compared with ideographic numbers. Unfortunately, we cannot assess whether or not prelexical phonology (and postlexical as well) is going to play a functional role in the task. This implies that although alphabetically written numbers *could* lead to a stronger RVF advantage than Arabic numerals, they *need* not necessarily do so.

Method

Subjects

Sixteen subjects, eight of each sex, aged 17 to 33, volunteered to participate in the experiment. All subjects were right-handed, as assessed by a French adaptation of the Edinburgh Inventory (Oldfield, 1971). All had normal or corrected-to-normal vision. Subjects were tested individually during one 40-min session. They were paid for their participation.

Stimulus Material and Apparatus

Stimuli for the alphabetic condition were the numbers 0 to 9, with the exception of 4, which is a six-letter word in French. Six of the number names are four letters long, and the remaining three are two, three and five letters long, respectively. Each number was associated with two non-numbers consisting of pronounceable non-words having the same number of letters as their paired number and sharing at least two letters (one letter in the case of 1) with it. Shared letters did not systematically occur in the same positions as in the original number name. Stimuli for the ideographic condition were the Arabic numerals 1 to 9, inclusive. Two paired non-numbers, constructed from pieces of digits, were associated with each digit.

Alphabetic stimuli were printed horizontally in upper-case black letters (press-on letters Alfac 59). They were centred 2.4° to the right or to the left of the fixation point and subtended visual angles ranging from 0.7° to 1.6° horizontally and 0.3° vertically. Ideographic stimuli were centred 1.8° on either side of the fixation point. They subtended 0.8° in height and 0.6° in width, except for 1 and its associated non-numbers which were 0.4° in width.

Four blocks of 36 trials were constructed. Blocks A and B contained each of

[4]The pre- and postlexical distinction was based on the assumption that the prelexical phonology is derived exclusively by application of grapheme–phoneme conversion rules (Coltheart, 1978). This conception has been challenged by Glushko (1981) who provided evidence for lexical involvement in this process, thereby rendering the terminology misleading. A better distinction has been proposed by Patterson and Besner (1984b) who replace pre- and postlexical phonology by assembled and addressed phonology, respectively.

the nine numbers twice, once in the LVF and once in the RVF. The 18 different non-numbers each appeared only once in a block, one set of nine each in the LVF and in the RVF. Blocks A′ and B′ were the same as blocks A and B, except that the sequences were run in the opposite order and the side of presentation of each stimulus was changed. Stimuli were pseudo-randomized according to the following constraints: no more than three successive presentations in the same visual field; no repetition of the same stimulus and no sequence involving one number and one of its associated non-numbers; an equal number of repetitions and alternations between responses in each visual field;[5] no more than two repetitions of the same response.

Stimuli were presented through a three-field tachistoscope (Electronic Development). A black fixation dot positioned at the centre of a white background field was continuously presented except during stimulus exposure. A switch to be held in the nonresponding hand was used to trigger the trials. A small lever, to be held between the thumb and the index fingers, was fixed to the table in front of the subject. Reaction times (RT) were measured by means of a timer (Electronic Development) and manually recorded by the experimenter.

Procedure

Subjects were asked to fixate the central dot and to trigger the trial when they felt ready. Pressing of the switch determined the immediate disappearance of the fixation point and the presentation of the stimulus for 120 msec either in the LVF or in the RVF. The fixation point came back immediately after stimulus offset. The onset of the stimulus triggered the timer, which was stopped by the response of the subject. Both speed and accuracy were emphasized in the instructions. Half the subjects were required to respond to a number by pushing the responding lever away from the body and to a non-number by pulling the lever towards the body; the other half of the subjects were given the opposite stimulus–response assignment. Subjects were given one practice and four experimental blocks of trials in each condition. The eight possible orders of presentation of the four blocks that could be generated by alternating blocks of type A and blocks of type B were used, each by two different subjects. Order of presentation was the same in the alphabetic and ideographic conditions. Responding hand was changed at each change of block. Order of presentation of the conditions and order of succession of responding hand were counterbalanced across subjects.

Results

Erroneous responses and responses with latencies longer than three standard deviations above the mean RT calculated from the data of the first and last blocks of trials in each condition were excluded from the

[5] It is well known from studies carried out in the 1960s and early 1970s that the overall speed of responding might be affected by the relative proportions of response repetitions and alternations involved in a sequence (e.g. Holender, 1980, Kornblum, 1973, for reviews). It is therefore advisable to keep the relative proportions of repetitions and alternations of responses roughly equal in the subsets of stimuli corresponding to each hemifield.

analysis. For the alphabetic and ideographic conditions, there were 2.0% and 1.9% of excessively long responses, and 6.9% and 5.0% of errors, respectively.

Table I shows the mean correct RTs and error rates averaged across subjects for each condition as a function of visual field and stimulus type (number vs. non-number). A preliminary analysis of variance indicated no main effect and no interaction related to the responding hand. It also indicated a highly significant effect of condition, overall mean RT being much faster in the ideographic than in the alphabetic condition (472 vs. 579 msec). Subsequent analyses were carried out separately for each condition, with the data collapsed across responding hands.

A repeated-measure two-way analysis of variance (Visual Field × Stimulus Type) was performed on RTs from the ideographic condition. The main effect of stimulus type was significant, $F(1, 15)=25.94$, $p<0.01$, indicating faster responses to numbers than to non-numbers (451 vs. 492 msec). There was no main effect of visual field, but its interaction with stimulus type was significant, $F(1, 15)=11.64$, $p<0.01$. Analysis of the interaction showed that the 13-msec RVF advantage for numbers and the 16-msec LVF advantage for non-numbers were both significant, $F(1, 15)=6.19$, $p<0.05$, and $F(1, 15)=6.33$, $p<0.05$, respectively.

A similar analysis of variance was performed on the RTs of the alphabetic condition. There was a significant effect of stimulus type, $F(1, 15)=43.94$, $p<0.01$, indicating faster responses to numbers than to non-numbers (551 vs. 608 msec). The visual field effect was marginally significant, but its interaction with stimulus type was significant, $F(1, 15)=7.05$, $p<0.05$. Analysis of the interaction showed the 26-msec RVF advantage for numbers to be significant, $F(1, 15)=7.87$, $p<0.05$, whereas the small 6-msec LVF advantage for non-numbers was not significant.

Table I

Mean Correct RTs[1] and Mean Percentage of Errors[2] as a Function of Visual Field, Stimulus Type and Type of Script

	Type of script			
	Ideographic		Alphabetic	
Stimulus type	LVF	RVF	LVF	RVF
Number	458 (4.5)	445 (4.0)	564 (8.3)	538 (6.2)
Non-number	484 (4.5)	500 (6.9)	605 (7.1)	611 (9.4)

Note: LVF: left visual field; RVF: right visual field

[1] In ms.

[2] In parentheses.

A planed comparison was used to test the prediction of a stronger RVF advantage for alphabetic than for ideographic numbers. It led to a nonsignificant result, $F(1, 15)=2.56$, $p>0.10$. An analysis of variance restricted to non-numbers also showed no significant interaction betweeen visual field and type of script.

Table II gives the number of subjects who showed either a RVF advantage, a LVF advantage, or no field advantage at all, as a function of stimulus type and type of script. Therefore, each column of Table II represents a different partition of the same group of 16 subjects. A difference of less than 11 msec between the mean RTs in each visual field led to inclusion into the no field advantage subgroup, the reason being to look at the results of the more lateralized subjects. The mean field advantage for each subgroup also appears in Table II.

Several points are worth mentioning. First, in each condition and for each stimulus type, about one third of the subjects failed to show any laterality effect. Second, in the three situations where an overall laterality effect was observed, only one or two subjects out of sixteen showed a laterality effect opposite to the one displayed by the entire group. Third, looking only to the partially overlapping subgroups of subjects showing a RVF advantage for ideographic and alphabetic numbers, the prediction of a stronger effect in the latter than in the former case was better fulfilled since the advantages amounted to 26 and 50 msec, respectively.

However, this latter observation cannot be tested statistically because these mean field advantages are only partially determined by the same subjects. This can be further qualified by calculating the correlation between the field advantages for numbers written alphabetically and those written ideographically. For the subgroup of subjects showing a RVF advantage for ideographic numbers, the correlation was 0.10. It

Table II

Number of Subjects Showing Each Field Advantage as a Function of Type of Script and Stimulus Type

	Stimulus type			
	Number		Non-number	
Field advantage	Ideographic	Alphabetic	Ideographic	Alphabetic
LVF	2 (−18)	1 (−19)	11 (−29)	5 (−39)
NONE	5 (2)	6 (−2)	4 (1)	6 (2)
RVF	9 (26)	9 (50)	1 (57)	5 (24)

Note: Mean field advantages (in msec) appear in the parentheses. A positive sign corresponds to a right field advantage.

was 0.02 for the subgroup of subjects showing a RVF advantage for numbers written alphabetically.

Discussion

The first prediction was confirmed, since both numbers written alphabetically and those written ideographically as Arabic numerals led to a RVF advantage. The second prediction was not fulfilled, since no significant interaction was found between the type of script and the side of presentation. No specific predictions were made about the results to be observed with non-numbers. There was no laterality effect for non-numbers in the alphabetic condition and a LVF advantage in the ideographic condition. The discussion will involve two points: First, the present data will be integrated within the relevant literature. Second, some further considerations about the approach will be presented.

The 26-msec RVF advantage for numbers written alphabetically is well within the range of results observed with other lexical decision tasks using words selected from larger semantic and grammatical categories (Babkoff and Ben-Uriah, 1983; Barry, 1981; Bradshaw and Gates, 1978; Bradshaw et al., 1977; Brand, van Bekkum, Stumpel and Kroeze, 1983; Cohen and Freeman, 1978; Day, 1977, 1979; Leiber, 1976; McKeever and Hoff, 1982; Pring, 1981; Shanon, 1979). The size of the laterality effect depends on many factors, some of which are subject variables such as sex or handedness, others being linguistics variables like grammatical category or word frequency or subjective variables such as imageability, concreteness. . . . Suffice it to say here that the picture that emerges from these studies is either an absence of laterality effect or a RVF advantage whose size rarely exceeds 40 msec (one notable exception is the above 80-msec RVF advantage reported by Leiber, 1976). As with other kinds of visual stimuli, extreme physical conditions such as large or small stimuli or very short exposure duration (Pring, 1981) could lead to a reversal of the laterality effect (see Sergent, 1983a), but such conditions are uncommon.

We failed to find any number–non-number classification task involving Arabic numerals in the literature. There are, however, related tasks that allow for a comparison. The small 13-msec RVF advantage showed by the Arabic numerals in the present study is of the same order of magnitude as those observed by Geffen et al. (1971) and Cohen (1975) in two-choice discrimination tasks in which two different digits were mapped into two manual responses. Moreover, Cohen (1975, Experiment 3) is also the only one to have contrasted ideographic and alphabetic scripts. In her cued condition, in which subjects were informed about the type of script before each trial, the 14-msec RVF advantage for Arabic numerals was not significant, whereas the 20-msec RVF advantage observed with numbers written alphabetically was significant. As in the present study, the interaction between type of script and visual field failed to reach significance.

The absence of laterality effect for alphabetic non-numbers is paralleled by frequent similar results for non-words in some of the studies showing a clear RVF advantage for words (Babkoff and Ben-Uriah, 1983; Bradshaw and Gates, 1978; Brand et al., 1983; Leiber, 1976). However, RVF advantages of the same size for words and non-words are also common (Barry, 1981; Bradshaw et al., 1977; Cohen and Freeman, 1978; McKeever and Hoff, 1982; Pring, 1981). For the time being, little is known about the conditions leading either to no field advantage or to a RVF advantage for non-words. The LVF advantage observed for ideographic non-numbers, which are in fact unfamiliar shapes, is paralleled by the LVF advantage shown by Japanese subjects dealing with unknown Korean Hangul characters (Endo et al., 1981a, b; Shimizu and Endo, 1981) and by the LVF advantage for unknown complex forms shown by Hannay, Dee, Burns and Masek (1981). Two points are worth considering. First, these results are not in agreement with the simplest mechanism we could conceive of for the determination of the negative response in a lexical decision task. Assuming that both the negative and the positive responses are simply determined by the consultation of the appropriate subpart of the lexicon and that the negative response is achieved by default, then equivalent laterality effects should be observed for numbers and non-numbers. However, the fact that this is not the case is not very surprising since we know that the determination of the negative response in a lexical decision task is more complex than assumed above (e.g. Coltheart, Davelaar, Jonasson and Besner, 1977). The second point is that the existence of verbal labels is often associated with the observation of a RVF advantage for complex visual stimuli. Shapes devoid of labels lead to a LVF advantage which either disappears (Endo et al., 1981b) or shifts to a RVF advantage (Hannay et al., 1981) when labels are acquired. As was pointed out by Sergent (1982), it might not be labelling per se which plays the determining role in the shift of laterality. Rather, the learning of the labels, which involves frequent exposures to the shapes, could be responsible for a change in the way visual information is processed, which, in turn, might underlie the shift in laterality.

The rest of the discussion concerns some after-thoughts about the use of laterality as a tool to study differences in processing between alphabetic and ideographic scripts. The most informative situation is the one in which opposite visual field advantages are observed. In such a case, laterality effects can be considered as providing evidence for the existence of distinct processing mechanisms. However, as was apparent from the review of the literature, there is little evidence to suggest that opposite field advantages would be observed with numbers written alphabetically and ideographically—quite the contrary. Of course, one would probably not even think of a laterality study without predicting at least some kind of interaction between field of presentation and type of script. Our specific prediction was that a larger RVF advantage would be observed with alphabetic numbers than with ideographic ones. The results were in the predicted direction but failed to reach statistical significance.

The prediction was justified on the basis of a descriptive examination of the literature and on the theoretical assumption that an extra source of laterality—prelexical phonological coding—could be involved in the processing of alphabetic compared to ideographic stimuli. Having no independent method of assessing whether this extra source of laterality would be functional in the task or not, we came up with a probabilistic prediction rather than a strictly deterministic one. The prediction relies simply on the idea that the more subprocessors lateralized on the same side could be involved, the higher the odds of observing a strong laterality effect. In the absence of a significant interaction between visual field and type of script, no information has been gained. More interesting is the question of whether, in the case of a significant interaction, the model proposed above would have been unequivocally substantiated or not. The answer is negative because the following considerations show that at least two other models are equally plausible.

The minimal formalization of the model underlying the prediction involves at least the existence of one left-lateralized subprocessor responsible for the overall right-side advantage, independent of the type of script. At least one second left-lateralized subprocessor is supposed to add its effect to the first to increase the laterality effect with alphabetic stimuli. Notice that the model not only predicts an interaction between visual field and type of script, but that it also implies a certain amount of correlation between the laterality effects, since one source of laterality effect is common to each type of script. Both aspects are worth considering.

We will assume that one or two left-lateralized subprocessors could be involved and that each of them contributes an additive independent amount to the overall laterality effect measured by the difference between the response latencies for left and right stimulus presentations. They also contribute independent components to the overall variance of the process. Two important unknown parameters must be mentioned: First, there is no way to predict the absolute magnitude of the laterality effect that would be generated by a lateralized subprocessor; second, the amount of laterality effect produced by a lateralized subprocessor common to both types of script may depend on the input format. Table III illustrates some of the interpretations that could be associated with each of the four possible outcomes resulting from the combination of a significant or nonsignificant interaction with a significant or nonsignificant correlation. The amount of laterality is symbolized by the length of a line of equal or plus signs, the former representing the effect of one subprocessor and the latter the effect of the second one. In each case, the top line represents the ideographic condition and the bottom line the alphabetic one.

Table III shows that when there is no correlation, each laterality effect is produced by a different subprocessor. It just happens that the effects have the same magnitude in one case (no interaction) and that alphabetic stimuli have a stronger RVF advantage than Arabic numerals in the other case (interaction). When there is a correlation, there is at least one subprocessor involved in both conditions. Two possibilities must be considered: The first is that the magnitude of the laterality effect engendered by a subprocessor common to both kinds of script is the same, whatever the input format. It is illustrated in cases (a). When there is no interaction, only one processor is involved with both types of numbers; when there is an interaction, the second lateralized subprocessor adds its effect to the first. The second possibility is that the

Table III

	No correlation		Correlation
No interaction	= = = = = = = = + + + + + + + +	a	= = = = = = = = = = = = = = = =
		b	= = = = = = + + = = = + + + + +
Interaction	= = = = = = = = + + + + + + + + + + + + +	a	= = = = = = = = = = = = = = = = + + + + +
		b	= =

Note: The table illustrates some of the interpretations that could be associated with each of the four possible outcomes generated by testing both the interaction between side of presentation and type of stimulus and the correlation between the laterality effects. The amount of laterality generated by one lateralized subprocessor is symbolized by the length of a segment of equal signs; the plus signs play the same role for a second subprocessor lateralized on the same side as the first. Each line represents one type of stimulus. Assigning ideographic numbers to the top line and alphabetic numbers to the bottom one, the model underlying the prediction formulated in the paper is illustrated by case a in the interaction-correlation cell of the table.

magnitude of the laterality effect produced by one common subprocessor depends on the input format. This extra degree of freedom allows for the interpretations illustrated in cases (b), which are compatible with the absence or the presence of an interaction.

Table III should generate some discomfort among the advocates of the use of laterality as a tool for analysing information processing. When only the test of the interaction between visual field and stimulus type is carried out, as is usually the case, a significant outcome is not more informative than a nonsignificant one. As regards the study of the correlation between laterality effects alone, a nonsignificant outcome is more informative than a significant one. It is better to study both the interaction and the correlation, but when the correlation is significant, cases (a) and (b) cannot be distinguished. Applied to the present study, it implies that the validity of the model underlying our prediction, which corresponds to case (a) in the interaction–correlation cell of Table III, cannot be assessed by the current, or by the improved, laterality methodology. A good way to test the prediction would have been to preselect a group of subjects showing a large laterality effect for Arabic numerals. Nine subjects satisfied this criterion in the present experiment (see Table II). They showed the same amounts of laterality effect with alphabetic and ideographic numbers, 25 and 26 msec, respectively, and no correlation between laterality effects ($r = 0.10$). This sample is too small, especially as regards the reliability of the correlation, to provide conclusive results, but it illustrates a pattern of results leading to an unambiguous conclusion (the no correlation–no interaction cell of Table III).

The main conclusion of these after-thoughts is, therefore, that neither the prediction nor the outcome is sufficiently constrained for the investigation of an interaction between type of script and visual field to increase our understanding of the processing involved with each kind of script. It also casts doubts on the utility of pursuing the cataloguing of laterality effects as if it were necessarily a useful tool for analysing processing of information into components. Were the methods of identification of processing operations better developed and the interactions between subprocessors better understood, it is not at all certain that laterality would still be an important issue. In any case, it seems that combining the usual approach based upon a test of the interaction between latencies of responses in each visual field and type of stimuli with an approach based upon the test of the correlation between the laterality effects associated with each kind of stimulus would at least be more informative than the use of either approach alone. This would probably require the use of larger samples of subjects than is usually the case.

The general conclusion is that ideographic symbols are as good as any other visual configurations for providing converging evidence about the role of most of the factors that determine visual laterality effects. Conversely, little has been learned so far about the properties of processing of logographic or phonographic scripts by resorting to lateral hemifield presentations. This conclusion, which is consonant with the one reached by Besner et al. (1982) and Henderson (1982, p. 202), holds true as regards processing of numbers written alphabetically and ideographically.

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