Asymmetries for the categorization of Kanji nouns, adjectives, and verbs presented to the left and right visual fields

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Abstract

Kanji is one form of written Japanese in which the symbolic/analytic characteristics of language are dissociated from systematic phonetic characteristics; as such, it makes possible a more careful test of which aspect of language is responsible for the frequently observed superior left hemisphere performance. In this study, subjects were asked to categorize tachistoscopically presented Kanji as nouns, adjectives, or verbs. The previously reported (Hatta, 1977) left visual field advantage for Kanji was found only in the case of nouns. Adjectives and verbs were processed more rapidly and correctly in the right visual field.

For a number of years there has been considerable debate over the precise nature of both functional and anatomical differences between the two cereberal hemispheres. There is no doubt that differences exist, but the correct formulation of those differences continues to elude investigators. Initial theories that the left hemisphere (LH) was specialized for language have been proven to be at least overly-simplistic; it is clear that the right hemisphere (RH) is capable of comprehending language and carrying out certain linguistic tasks (Zaidel, 1976). Current hypotheses regarding the functional specialization of the LH include the following:

(1) The LH is specialized for the temporal control of complex motor sequencing (Kimura & Archibald, 1974; Mateer & Kimura, 1977); this specialization is not peculiarly linguistic;

(2) The LH is preeminent in the resolution and processing of auditory sequences which involve rapid changes in frequency and/or amplitude (Tallal & Piercy, 1974);

(3) The LH is dominant in tasks which require detailed analysis of stimuli, especially when those stimuli are symbolic (Levy-Agresti & Sperry, 1968).

Attempts to confirm or disprove the above (or other) hypotheses using language stimuli are hampered by the fact that most language is at the same time analytic, involves rapid changes in the acoustic domain, and requires fine control over detailed motor gestures. This confounding of variables makes it difficult to interpret lateral differences in processing language stimuli.

Fortunately, there exist at least two linguistic forms in which some of the above factors are dissociated. American Sign Language (ASL) is an instance of language in which analytic processing is obviously essential, but which involves a medium which is not auditory or phonetic. If the LH is specialized either generally for analytic or specifically for linguistic operations, then we would expect LH superiority for the recognition of ASL. If, however, the LH is specialized for auditory or phonetic stimuli, and the RH for complex visual stimuli, then we might find RH dominance for ASL. Evidence currently available (Poizner, Battison, & Lane, 1979; Neville & Bellugi, 1978; Ross, Pergament, & Anisfield, 1979; McKeever, Hoemann, Florian, & Van Deventer, 1979) is inconclusive and somewhat contradictory.

Written Japanese is another language form in which linguistic/analytic and phonetic/auditory factors may be dissociated. Japanese may be written in any of three othographies. Kanji is ideographic: the grapheme-sound relationship is usually arbitrary. Hiragana and Katakana are syllabaries: the grapheme-sound relationship is systematic. The hypothesis of LH dominance for all linguistic material predicts a LH advantage for the recognition of both Kanji and Kana; the hypothesis that the LH processes phonetic stimuli predicts a LH superiority only for Kana, with possibly a RH superiority for Kanji.

Clinical evidence appears to bear out the latter prediction. Kimura (1934), Sasanuma and Fujimura (1972; Sasanuma, 1974) cite instances of differential impairment in reading Kanji and Kana among brain-damaged patients, depending upon the site of lesion. More recently, experimental data have been gathered which are consistent with the hypothesis that LH dominance is grounded in a specialization for phonetically related operations, while the RH is specialized for processing visual stimuli. Sasanuma, Itoh, Mori, and Kobayashi (1974) reported significant differences in the identification of tachistoscopically presented Kana and Kanji. Fewer errors were made identifying Kana in the right visual field than in the left; there was no significant field advantage for the recognition of Kanji, although a trend toward a left field advantage was noted. Hatta (1976) replicated Sasanuma et al.'s (1974) basic findings, and in addition obtained a significant left visual field advantage for the identification of Kanji.

Taken together, these results indicate a phonetic basis for superior LH performance, as well as striking RH abilities at processing linguistic material when presented in a form which takes advantage of RH visual capabilities. Although there is little doubt that the RH is capable of carrying out language functions (cf. Zaidel, 1976), Sasanuma et al.'s (1974) and Hatta's (1976) data are noteworthy inasmuch as they suggest that the RH can in fact excel at certain linguistic tasks. The data also imply that the LH's specialization is for phonetically coded stimuli, and not for a specifically linguistic or analytic mode of processing.

Given the significance of these issues, it seemed important to try to replicate and extend the findings regarding Kanji and Kana. One would like to know, for example, how task-dependent the RH superiority for Kanji recognition is. It is conceivable that naming is a sufficiently simple task that either a name or a perceptual pointer to a name can be quickly retrieved by the RH (in any event the name is probably passed to the LH in order to generate the verbal response), but that in more complex linguistic tasks this RH advantage decreases. Several investigators have found that hemispheric asymmetries may be made dependent on task demands (e.g., Kinsbourne, 1970). We were also curious as to possible differences in the processing of words from different grammatical categories (cf. Hines, 1976; Day, Reference Note 1; Orenstein & Meighan, 1976; Zaidel, 1976). To that end the following series of experiments was carried out.

EXPERIMENT I

Both Sasanuma et al. (1974) and Hatta (1976) asked subjects to identify Kana and Kanji, using a verbal report and number of errors as the response measure. In this experiment, we presented subjects with a set of Kanji which included nouns, adjectives, and verbs[1]. The subjects' task was to verbally report the grammatical category each word belonged to. Our intent was to see whether a task which is more linguistically demanding might decrease the expected RH advantage for Kanji, and whether all categories were lateralized in the same direction and degree.

Methods and Materials

Subjects. Ten Japanese male students (mean age 22.8) served as subjects. The subjects were participants in the Program in American Language and Culture, Univ. of Calif., San Diego; their level of English at the time of the experiment was basic. All subjects were paid for their participation.

Apparatus and Stimuli. A two-channel Scientific Prototype tachistoscope was used to present the stimuli. Forty-two Kanji were selected; there were equal numbers of nouns, adjectives, and verbs. Words were selected from the so called "educational Kanji" which are specified by the Ministry of Education of Japan as being taught in elementary and junior high school. We excluded words with a large number of strokes (the average number of strokes was: 9.35; maximum number was 15). Finally, we tried to discard words which were visually confusable with any other word, either in or out of the stimulus set. Each word appeared in random order once in both left and right visual fields; there were thus 84 items in total. Kanji were positioned such that their inside edge was at a distance of 3.18 degrees of visual angle from the point of fixation. Kanji subtended an area 1.91 x 1.91 degrees of visual angle. A digit between 1 and 9 was placed at the fixation point; digits were .96 x .96 degrees in size.

Procedure. After being informed as to the nature of the task, subjects practiced with extra stimulus cards (not used in the experiment proper) presented in free field vision. They were then told to focus on a circle which appeared in the center of the screen for 1000 msec at the start of every trial. This circle was followed by a test item. Stimulus exposure varied from subject to subject, and was adjusted at every session so as to guarantee an error rate of 60-70% for each subject; durations ranged from 25 to 120 msec; the experiment-wide average was 37.6 msec. Subjects were asked first to report the number at the point of fixation, and then the grammatical category of the *Kanji*. Items on which the number was misidentified were replaced and viewed later during the session. On trials in which the subject erred in grammatical category, the subject was immediately asked to identify the *Kanji*.

Results

A summary of the number of errors made by the 10 subjects is given in Table I; errors are tabulated separately by Grammatical Category (3 levels) and also by Visual Field (2 levels). In none of the errors was the *Kanji* correctly identified; that is, all errors were errors of perception, rather than categorization.

--- Insert Table I about here ---

A repeated measures analysis of variance revealed no significant main effect for Visual Field [$\underline{F}\ (1,9) = 0.128$]. A significant main effect for Grammatical Category was found [$\underline{F}\ (2,18) = 5.437$; $\underline{p} < .025$]; this consisted of significantly fewer errors for nouns than adjectives and verbs, and fewer errors for verbs than adjectives. There was a trend toward an interaction between Grammatical Category and Visual Field, but this missed significance [$\underline{F}\ (2,18) = 2.603$, $\underline{p} < .10$]. The trend was toward fewer errors for nouns in the Left Visual Field (LVF) than the Right, and fewer errors of adjectives in the Right Visual Field (RVF) than in the Left.

EXPERIMENT II

The pattern of results obtained in Experiment I differed somewhat from those reported by Hatta, although as will be seen later the findings are not mutually incompatible. In Experiment II we introduced three changes in order to refine the methods used in the first experiment. (1) We used a tachistoscope with three channels so that a mask could be presented immediately following the test item. (2) We were concerned that a verbal report (which is almost certainly mediated by the LH) might obscure cerebral asymmetries during initial processing, and so we obtained a non-verbal response. (3) We decided to use reaction times rather than number of errors as the response measure; response latencies are sometimes more sensitive indicators of lateral differences than number of errors.

Methods and Materials

Subjects. Ten Japanese students (7 males, 3 females; mean age 24.6 years) from the P.A.L.C., U.C.S.D., program served as subjects; none of these subjects had participated in Experiment I. All subjects were right-handed with normal vision. Subjects were paid for their participation.

Apparatus and Stimuli. A three-channel Gerbrands tachistoscope was used to present the stimuli. The tachistoscope was connected to a timer and response box with two buttons. The stimuli consisted of the same items used in Experiment I. Due to differences in the two tachistoscopes, the inside edge of each *Kanji* was at a distance of 2.14 degrees of visual angle from the fixation point, and subtended an area 1.28 by 1.28 degrees. The fixation numbers were .64 by .64 degrees square. Total screen area was 6.81 degrees by 8.49 degrees.

Procedure. At the beginning of each session subjects practiced categorizing extra *Kanji* as nouns, adjectives, or verbs. Subjects were instructed to press one button on a centrally positioned response box if they saw a noun, and the other if they saw a verb or adjective. Subjects used their right hands to respond, and positioned their hands on the response box equidistant from the two buttons. The sequence of events for a trial went as follows: the subject was told to focus on a circle which appeared at the fixation point on the screen for 1000 msec. Presentation of the circle automatically activated a timer. The circle was followed by a test item, and then a mask of 30 msec duration. *Kanji* exposures varied from 150 to 190 msec across subjects and were adjusted for each subject to guarantee approximately 95% correct responses. Subjects were instructed to categorize the *Kanji* as quickly as possible and to press the appropriate response button; the button press stopped the timer. Subjects then reported the number which appeared at the fixation point. The time and categorization were noted down and the next trial initiated a few seconds later.

Results

Reaction times (RTs) for individual subjects are presented in Table II. (RTs are given for correct responses only.) Again, results from a repeated measures analysis of variance showed no significant difference in RT between Visual Fields [$\underline{F}$ (1,9) = 0.953]. There was a significant main effect for Grammatical Categories [$\underline{F}$ (2,18) = 8.644, $\underline{p}$ < .005]: nouns were responded to significantly faster (943 msec) than adjectives and verbs (1028 msec and 1023 msec, respectively); there was no significant difference between adjectives and verbs [$\underline{F}$ (1,18) = 0.046].

--- Insert Table II about here ---

When the mean RTs for Grammatical Category are examined by Visual Field, an interesting and significant interaction is found [$\underline{F}$ (2,18) = 10.171, $\underline{p}$ < .005]. Nouns are responded to significantly faster in the LVF (RH) than in the RVF (LH), and faster than adjectives and verbs in the LVF (RH). Adjectives and verbs, on the other hand, are responded to more rapidly in the RVF (LH) than in the Left (but not as fast as nouns in the Left). This interaction is displayed in Figure 1.

---Insert Figure 1 about here ---

Post-hoc comparisons were carried out using the Scheffe procedure; there were no significant interactions between adjectives & verbs and Visual Field [$\underline{F}$ (1,18) = 0.670]. RTs for adjectives, verbs, and nouns were not significantly different in the RVF [$\underline{F}$ (1,18) = 1.790]; RTs for adjectives and verbs taken together were significantly different in the LVF [$\underline{F}$ (1,18) = 58.220, $\underline{p}$ < .0001].

(RTs were also converted into response speeds by taking the reciprocal of each time. An ANOVA was carried out using the transformed data; the results were identical to those obtained using the RTs.)

DISCUSSION

The results of the above exeriments suggest that the lateral differences for processing Kanji are perhaps more complex than earlier studies implied; at the same time, the present data may not necessarily be incompatible with previous work.

The current data do not clearly bear out the hypothesis that the grammatical categorization of Kanji is carried out in a way which results in a different pattern of lateralization than when Kanji are simply identified. Our results are superficially similar to those of Sasanuma et al. (1977) for Kanji.

More interestingly, we found that the pattern of a LVF advantage (presumably stemming from RH superiority) reported by Hatta (1976) was obtained only for nouns, but not for adjectives and verbs. The latter two classes exhibited RVF (LH) advantages. Neither Hatta nor Sasanuma and her co-workers specify the precise nature of the stimuli used in their studies. However, all the examples they give of their stimuli are nouns. We suspect, therefore, that their results and ours may not be contradictory.

It is not presently possible to do more than speculate as to the basis for the differential lateralization of the three grammatical categories of stimuli. One possibility is that different syntactic categories are represented in different areas of the brain. We see no a priori reason why this should be so. A more plausible syntactic explanation is that the stimuli we categorized as adjectives and verbs were more complex, since -- with the appropriate Kana suffix -- these words can belong to other grammatical categories as well. This difference between the "grammatical flexibility" of the stimuli might have been the cause for inferior RH performance at categorizing adjectives and verbs.

Examination of the stimuli from the viewpoint of phonological characteristics provides evidence for another explanation for our results. Tzeng, Hung, and Wang (1977) have reported that phonetic similarity of Chinese characters (which are basically identical to Kanji) interfered with subjects' performance on both a short-term memory task and a sentence judgment task, even though phonetic processing was theoretically not required to carry out the tasks. Anecdotally, we found that some subjects seemed to need to recall and pronounce the stimuli as they categorized them; others appeared to categorize without retrieving pronunciation (cf. Rozin et al., 1971). It happened that the three categories of stimuli differed (unintentionally) with regard to the number of mora each contained; nouns had an average of 2.1, adjectives had 3.4, and verbs had 2.5. Although it is unclear whether or not phonetic processing is a necessary prerequisite to carrying out further (syntactic) processing, or whether it even preceeds it, it could be that the greater number of mora of adjectives and verbs favored left hemisphere performance.

Another explanation for our results is that visual characteristics of the stimuli somehow affected hemispheric performance. It happened that there were small but consistent differences among the three categories in terms of the number of strokes of the Kanji. Nouns and verbs had fewer strokes (8.35 and 9.35, respectively) than adjectives (10.35). While one would certainly expect lateral differences in ability to process stimuli of differing degrees of visual complexity, the particular pattern of results obtained are not easily understood. First, nouns and verbs, although they contained fewer strokes, were treated differently by subjects. Second, if nouns were in fact less visually complex than the other stimuli, one would have thought this would facilitate LH processing, which it did not appear to do.

A final possibility relates to ways in which the stimuli differ along the dimensions of concreteness/abstractness and high/low imagery and interhemispheric differences in the ability to process stimuli along these dimensions. Upon reexaming our nouns, we found that the English equivalents of the Japanese words had a mean ranking of 6.52 for imagery and 6.80 for concreteness on Paivio, Yuille, and Madigan's (1968) scale; they were thus highly imagible and very concrete. The verbs and adjectives we used on the other hand, although relatively concrete, were inherently less so than the nouns. We are therefore inclined to interpret the LVF advantage for nouns as RH advantage for processing concrete and imagible stimuli, whereas the RVF advantage for adjectives and verbs probably reflects a LH advantage for abstract and low imagery material. This interpretation is consistent with results reported by Day (Reference Note 1), Hines (1976), and Ellis and Shepherd (1974) (but see also Orenstein & Meighan, 1976). These three studies revealed superior LVF performance for identification of concrete words compared with abstract words. RVF performance, as in the present study, was not significantly different for concrete vs. abstract words.

Our results do differ, however, in that RTs to (concrete) nouns were significantly shorter for LVF presentation than RVF presentation; that is, not only does the RH appear to do better at processing nouns than it does verbs and adjectives, it seems also to do better with nouns than the LH. This may be the result of the specific form in which the stimuli appeared: Kanji. A complete interpretation of our data would thus require the following two assumptions: (1) The RH possesses an advantage over the Left for processing Kanji, which are visually complex and have no systematic phonetic associations. This advantage is a perceptual one and probably occurs at an early stage of processing. (2) The RH (but not the LH) is selectively poor at processing abstract and low imagery stimuli. The LH does equally well with concrete and abstract words.

Thus, the RH's initial perceptual advantage over the LH for Kanji would be lost in the case of adjectives and verbs, as reflected by longer latencies for these two categories in the LVF. The RH's perceptual advantage would however be preserved for nouns, resulting in shorter RTs for LVF than RVF presentation of nouns.

This model is clearly speculative, although we believe it to be reasonable. A number of further experiments are indicated. First, if the RT differences for nouns, adjectives, and verbs derive from the relative concreteness/imagibility of these classes, we would expect to find similar lateral differences for stimuli which are all nouns but differ with regard to concreteness. On the other hand, if it is the syntactic category per se which is relevant, there should be no differences within the noun category regardless of concreteness. Second, if the RH advantage over the LH for nouns requires a stimulus form which is highly compatible with the RH, then this advantage should disappear with Kana; the results would then more closely resemble those obtained by Day (Reference Note 1) and Ellis and Shepherd (1974). Third, a phonological basis for the results obtained here could be tested by using stimuli which differ not only by grammatical category but in addition, number of moras. Similarly, the importance of visual complexity could be explored by orthogonally varying number of strokes with grammatical category. These experiments are presently underway in our laboratory.

In any event, the current findings are important insofar as they temper the conclusions implied by Hatta's (1976) results. Those results suggested that the frequent LH advantage for linguistic material was based purely on a superiority for phonetic decoding, and that given suitable "non-phonetic" linguistic stimuli, a RH advantage could result. In fact, there may be multiple factors leading to lateral differences in performance: the LH may be specialized for phonetic decoding and processing of abstract stimuli, while the RH is specialized for processing complex visuo-spatial stimuli.

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Footnote

[1]The question of determining grammatical categories of Kanji is not entirely straightforward. The stimuli we called nouns always function as nouns and only as nouns. The adjectives and verbs can frequently also belong to other categories, depending on context and the addition of a Kana suffix. We feel confident about our characterization of the stimuli for the following reasons: (1) We chose Kanji whose most typical usage is in the category we assigned them to; (2) Our stimuli did not contain Kana suffixes; we assigned stimuli to the unmarked category; and (3) We verified by means of informal testing prior to the experiment that, when presented with the stimuli in free vision, native speakers of Japanese would assign the Kanji to the appropriate categories.

Table I

Results from Experiment I.
Number of errors in grammatical categorization.

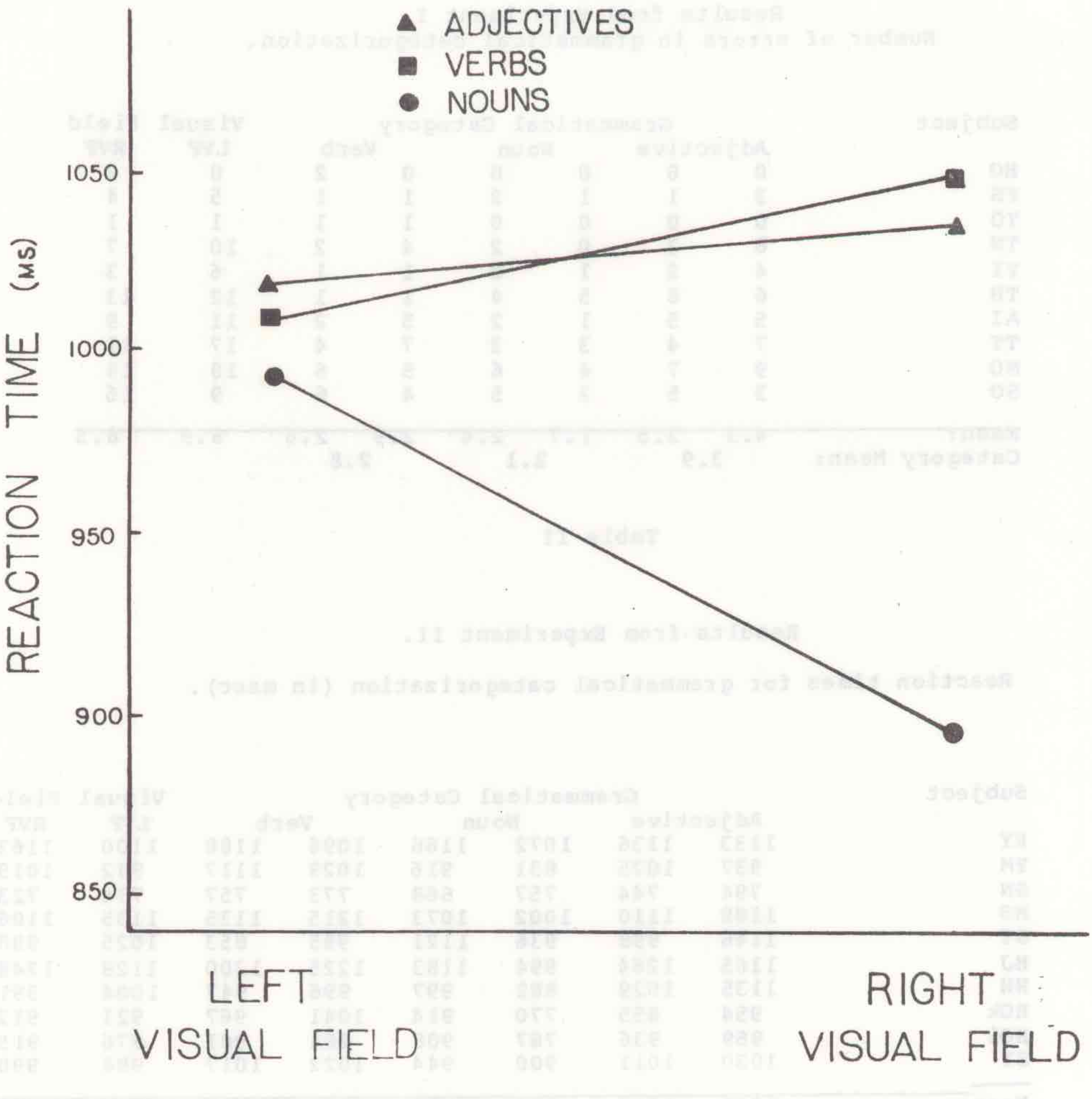
Subject	Grammatical Category						Visual Field	
	Adjective		Noun		Verb		LVF	RVF
HO	0	0	0	0	0	2	0	2
FS	3	1	1	2	1	1	5	4
YO	0	0	0	0	1	1	1	1
TN	6	3	0	2	4	2	10	7
YI	4	2	1	0	1	1	6	3
TH	6	8	5	4	1	1	12	13
AI	5	5	1	2	5	2	11	9
TT	7	4	3	3	7	4	17	11
MO	9	7	4	6	5	6	18	19
SO	3	5	2	5	4	6	9	16
Mean:	4.3	3.5	1.7	2.4	2.9	2.6	8.9	8.5
Category Mean:	3.9		2.1		2.8			

Table II

Results from Experiment II.

Reaction times for grammatical categorization (in msec).

Subject	Grammatical Category						Visual Field	
	Adjective		Noun		Verb		LVF	RVF
KY	1133	1136	1072	1166	1096	1188	1100	1163
YM	937	1025	831	916	1029	1117	932	1019
SN	794	744	757	668	773	757	774	723
MS	1189	1110	1002	1073	1215	1135	1135	1106
ST	1146	998	936	1121	995	853	1025	990
HJ	1165	1264	994	1183	1225	1300	1128	1248
HH	1135	1029	882	997	996	947	1004	991
HOk	954	855	770	914	1041	967	921	912
HOi	959	936	787	908	884	901	876	915
SI	1030	1011	900	944	1022	1017	984	990
Mean:	1044	1010	893	989	1027	1018	988	1006
Category Mean:	1027		941		1022			


ADJECTIVES
VERBS
NOUNS
REACTION TIME (MS)
1050
1000
950
900
850
LEFT VISUAL FIELD
RIGHT VISUAL FIELD

REFERENCE NOTE

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