Event-Related Potentials and *Kanji* Processing: The Interaction Between Configuration and Meaning

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INTRODUCTION

Investigations of linguistic vs. non-linguistic, verbal vs. nonverbal, concrete vs. abstract stimuli abound in the literature; however, such a simple dichotomy is open to serious question. In particular, Rosch and her colleagues (Rosch, 1975; Rosch & Mervis, 1975; Rosch, Mervis, Gray, Johnson & Boyes-Braem, 1976) have shown that for natural language categories, the classical notion of a digital "either or" membership is not the case. Rather, categories have a graded structure. That is, the members of a category are structured around a core ("best example") with other members at various semantic distances from the core. For example, the category *Furniture* would have "chair" at the center, while "lamp" would be a bit further away, and "piano" and "clock" even further from the center. While there is some controversy concerning whether or not all natural categories are structured in this way (see Wierzbica, 1984 or Lakoff, 1987, for example), there is substantial behavioral evidence that the relative strength of category membership (prototypicality) allows one to predict the time it takes to decide if an item is a category member or not, with the more prototypical members being identified faster than atypical members (e.g., McCloskey & Glucksberg, 1979). Prototypicality also is related to ease of category learning, with less typical exemplars being more difficult to learn than the more typical (Mervis & Pani, 1980; Rosch, Simpson, & Miller, 1976). Moreover, typicality has been useful in the analysis of the types of semantic deficits observed in brain damage (Grossman, 1981; Grossman & Wilson, 1987; & Dennis, 1987).

In 1984, Langman and Saito, using categories consisting of the same Japanese character (*kanji*) written in the five standard styles of calligraphy (see Fig.1 and Appendix I) so that each category consisted of five distinct yet related configurations having identical meanings, compared the ratings of prototypicality (p-ratings) by native Japanese (who, of course, knew

KAISHO (Block) | REISHO (Scribe) | GYOSHO (Semi-cursive) | SOSHO (Cursive) | TENSHO (Seal)

(REAL MEANING=CHILD)

FIGURE 1 (FROM LANGMAN & SAITO, 1984)

the meanings of the *kanji*) and four groups of naive Americans each given a different type of information related to the categories: No meaning, the Real (Japanese) meaning, and Iconic and Non-iconic meanings with reference to the pictographic *Tensho (seal)*[1] style. The authors hypothesized that category membership (indicated by a style's p-rating) for the American subjects would depend on the degree of overlap between the graphemic (configurational) and semantic (meaning) aspects for each *kanji* style. In the No Meaning condition, overall visual similarity would account for the p-ratings, while for the three meaning conditions, the p-ratings would depend on the meaning-dependent semantic-graphemic (S-G) overlap. In particular, a strong iconic effect was expected since an iconic meaning would be expected to maximize the S-G overlap for the *seal* style making this style the prototype, the core of the category to which the other styles would be compared. In contrast, the experiential familiarity (see Gernsbacher, 1984) of the Japanese, rather than the S-G overlap, would be expected to account for their p-ratings. That is, the special linguistic-cultural experience associated with each *kanji* style (see Langman & Saito, 1984) would be more important than the iconicity.

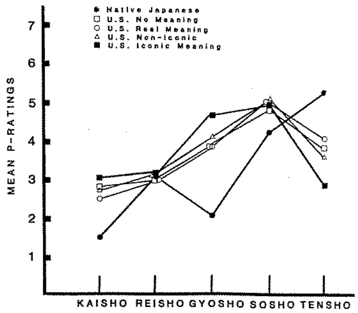


FIGURE 2 (FROM LANGMAN & SAITO, 1984)

The authors' hypotheses were supported by the results (see Fig.2). There was a strong iconic effect: American subjects, who were given iconic meanings for the *kanji*, rated the pictographic *seal* style most prototypical. For the other three meaning conditions, overall visual similarity seemed to account for the p-ratings. As for the Japanese subjects, experiential familiarity accounted for their p-ratings. Indeed, in marked contrast to the American subjects, they rated the *seal* style (the least familiar style) least prototypical while the most familiar *block* style, *Kaisho*, was rated most prototypical. Moreover, in contrast to the American subjects who rated the less cursive styles, *block* and *Reisho* (*scribe's* style), almost the same, the Japanese subjects rated these two styles differently and often remarked that the rarely used *scribe* style was "strange" or "wrong." On the other hand, in contrast to the Americans who rated the *Gyosho* (*semi-cursive*) style far less prototypical than the *block* style, the Japanese rated these two styles nearly the same, reflecting the underlying similarities in the motor-graphemic[2] aspects of the *kanji* (i.e., they write *block* and *semi-cursive*, but never *scribe* suggesting the motor similarities unavailable for the Americans played a part in their p-ratings) (see Wang, 1981, p. 233; Freyd, 1987, pp. 428–29).

While these significant differences in p-ratings are provocative, without more fundamental evidence in the form of behavioral or neurophysiological data, the validity of these p-ratings and the analysis of the category structure underlying them remain open to question. Therefore, as a first step, the authors attempted to demonstrate changes in the amount of recovery of the generalization (Test) stimuli as a function of their similarity/dissimilarity to the habituation stimulus in terms of differences in the p-ratings. In other words, electrophysiological evidence was sought to support the validity of psychological judgments. As the stimuli, the authors chose one of the quasi-linguistic stimuli (i.e., "frog") used in Saito and Langman (1984). This *kanji* was selected to avoid the problems of familiarity, multiple meanings and pronunciations. (See Appendix II). As for the electrophysiological evidence, the authors used event-related potentials.

Event-related Potentials

Human event-related potentials consist of EEG activity which is time-locked to the presentation of a stimulus. By presenting the stimulus a number of times (usually more than 10) and then averaging this time-locked EEG activity, the background random EEG activity approaches zero revealing the event-related potentials. These potentials (waveforms) are made up of a number of identifiable components based on the latencies and polarity (negative or positive) of their peak amplitudes. As an index of cognitive processing (e.g., context updating, orienting, task relevance, processing demand, etc.), P300 (that is, a positive component peaking around 300 ms after the onset of the stimulus first discovered by Sutton and his associates; Sutton, Braren, Zubin, & John, 1965) has been extensively investigated using a variety of experimental paradigms. For example, ERP investigations of linguistic processing have been many and varied from the early tests of semantic differences (Brown, Marsh, & Smith, 1973, 1976; Megela & Teyler, 1977) to tests of the semantic differential (Chapman, McCrary, Chapman, & Bragdon, 1978), and most recently the work by Kutas and Hillyard in sentence processing (Kutas & Hillyard, 1980a, 1980b, 1980c, 1982, 1983, & 1984). Of course, the experimental paradigms used in these studies have their own strengths and weaknesses. For example, while we rapidly read sentences in multi-word chunks, in ERP studies of sentence processing individual words are artificially presented one at a time on a screen. In addition, in order to obtain a sufficient signal-to-noise ratio of the ERP to the background EEG activity, the same stimulus sequences must be repeated at least 10 to 20 times. Finally, it is difficult to control for all the various factors that may influence an ERP: word length, word frequency, concreteness, abstractness, imagery, experiential familiarity, visual similarity, phonetic similarity, polysemy, etc. Thus, the reason for using quasi-linguistic stimuli.

The Habituation Paradigm

The habituation (dishabituation) paradigm (cf. Thompson & Spencer, 1966; Groves & Thompson, 1970; Roemer, Shagass, & Teyler, 1984) consists of presenting an "expected" (habituating or training) stimulus in a series followed by a randomly distributed "unexpected" (generalization or test) stimulus which may then be followed by a re-presentation of the training stimulus to test for dishabituation, recovery of the previously habituated response after the presentation of a test stimulus. The repetition of the expected training stimulus leads to a decrement (habituation) in the neurophysiological activity being measured: SCR (skin conductance response) (Siddle, Kyriacou, Heron, & Mathews, 1979; Siddle, 1985;

Verbaten, 1983; Woestenburg, Verbaten, & Slangen, 1983), spike activity (animal models) (Teyler, Chiaia, & DiScenna, 1984) or ERP activity (Megela, Teyler & Hesse, 1977; Megela & Teyler, 1979; Psatta, 1981) (but see Roemer *et al.*, 1984). In contrast, the unexpected test stimulus produces a recovery (generalization or, more correctly, the lack of generalization to the training stimulus) in the level of activity that depends on its similarity to the training stimulus. The greater the similarity, the smaller the recovery; the smaller the similarity, the greater the recovery. This has been demonstrated for the intensity of sound and flashes of light (Megela & Teyler, 1979), frequency of sound (Sams, Alho, & Näätänen, 1985), and category membership (Polich, 1985). After this test stimulus, the training stimulus may be presented again to test for dishabituation (recovery of the previously habituated response). Dishabituation has been demonstrated for SCR (Siddle, Remington, Kuiack & Haines, 1983; Siddle, 1985), but according to Roemer *et al.* (1984), dishabituation has yet to be demonstrated for human ERPs.

Among the many available paradigms, this is one of the simplest in that no overt responding (i.e., button pushing, counting, oral reading, etc.) is required (see Sams et al., 1985, for example). In this respect, the event-related potential correlates of habituation, generalization, and dishabituation are expected to reflect the more basic processes of stimulus evaluation and categorization rather than response selection and execution (Donchin, 1981). In effect, the paradigm is a kind of psychophysiological titration where the habituating stimulus serves as the titrant (a stable "ground") and the unexpected or Test stimulus as the titrand (the "figure") with the amount of recovery (ERP component amplitude) serving as the indicator.

ERP Studies of Habituation

While there have been a number of studies involving habituation of the human cortical ERP, according to Roemer *et al.* (1984), no study to date has successfully demonstrated or examined all nine of Groves and Thompson's (1970) parametric features of habituation (see Note 5). A common failing has been an interstimulus interval (ISI) which is too short (less than 3 sec) confounding habituation with recovery effects. Other problems involve the substantial time requirements to test varying ISI's (Parameter 4) and the difficulty unentangling rate of presentation effects and the effects of dishabituation. For example, if one uses an ISI of 2 sec and attempts to show dishabituation (recovery of the habituated response), there is the problem of the interval of 4 sec (plus the stimulus durations) between the pretest stimulus and the posttest stimulus during which time recovery of the response occurs naturally, and this natural recovery confounds the clear demonstration of dishabituation.

Despite the deficiencies mentioned above, there have been many studies utilizing a variety of stimulus-change paradigms, paradigms which may be considered special cases of the classical habituation paradigm. For example, one stimulus (the frequent or expected stimulus) is presented a number of times followed by another rare or unexpected stimulus, and changes in the ERP activity (usually P300) are measured and analyzed. However, as there had been no studies using quasi-linguistic[3] stimuli, the authors had no firm expectations concerning the outcomes. Yet, decrements in stimulus-related ERP activity with repeated presentations and graded recovery to different stimuli had been demonstrated by Megela and Teyler (1979) for non-linguistic stimuli and for words having similar and dissimilar meanings presented in a AAAAAAABB sequence. Thus, the authors expected that there might be changes in the amplitude and latency of the endogenous (Donchin, Ritter, & McCallum, 1978) P300 component as a function of the similarity/dissimilarity (p-ratings) between the habituation (same) stimulus and the test (different) stimuli. That is, the authors sought to demonstrate parametric changes as evidence by the differential recovery after habituation in the amplitudes and latencies of the event-related potentials (P300) primarily as a function of the p-ratings (i.e., the semantic-graphemic overlap associated with each style).

Method

Subjects: The subjects were 8 native Japanese university students who were all right-handed (5 males and 3 females) and ranged in age from 19 to 22 years. They received no remuneration or credit for their participation.

Stimuli: The stimuli, the five standard styles of calligraphy for the category "frog" (Figure 3), were taken from Saito and Langman (1984), and 35 mm slides of these *kanji* were backprojected onto a screen in a sound-attenuated room so they appeared as white on a semi-illuminated field.

Procedure: After having established that the subjects were right-handed by a suitable questionnaire (Hatta and Nakatsuka, 1975), they were introduced to the five stimuli and told that they all had the same meaning despite their different styles. This meaning was "frog" and was reinforced by showing them several line drawings of different kinds of frogs in different orientations. This was done to make the experience of the meaning of the *kanji* the same for all the subjects. They were then given a brief oral description of the experiment, while the electrodes (Pz, C3, C4, EOG referenced to A1) were being applied. While a formal signed informed consent form was not the practice in Japan at the time of this study — all subsequent studies by the authors, however, have employed them — each subject knew that he could terminate his participation in the experiment at any time without penalty. There was a microphone in the sound-attenuated room so that the subject could communicate with the experimenter at any time. In addition, every six trials there was a 2-minute rest period during which the experimenter talked with the subject to inquire as to his/her condition and to give him feedback concerning the quality of the signals (e.g., "Please don't move your eyes so much," or "You are doing fine."). At the end of a block, the subject was given a 3-5 minute break, and cold water or other refreshments were offered to combat fatigue.

Figure 3 shows the experimental protocol. Trains of 9 stimuli were presented with a stimulus duration of 500 ms, a fixed intersimulus interval (ISI) of 3 seconds and a random

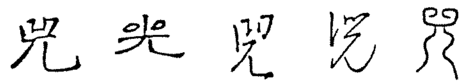
EXPERIMENTAL PARADIGM:

Trial 1 Habituation Generalization Stimulus Trial 2

KAISHO$_1$ ------- K$_2$ -------- K$_3$ -------- K$_4$ -------- K$_5$ -------- K$_6$ -------- K$_7$ -------- K$_8$ -------- K$_9$ ---------------- K$_1$ •••
3 sec 4-7 sec

Stimulus Duration =500 ms, ISI =3 sec, REISHO$_7$ R$_8$ R$_9$
GYOSHO$_7$ G$_8$ G$_9$
One block=30 Trials, Three blocks=1 Experiment SOSHO$_7$ S$_8$ S$_9$
TENSHO$_7$ T$_8$ T$_9$

Stimuli are obsolete Chinese Kanji written in the five standard styles of calligraphy, in this experiment only one Kanji was used with the meaning of "FROG," this meaning was chosen to be iconic with reference to *TENSHO*, the five stimuli are listed below.



	KAISHO	REISHO	GYOSHO	SOSHO	TENSHO
P-RATINGS-	4.1	3.4	4.0	5.1	1.7

The EEG was recorded from the locations indicated on the following diagram.

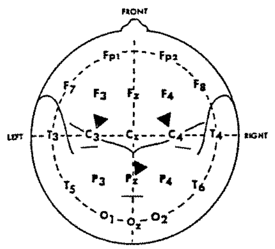


FIGURE 3 (AFTER LANGMAN & MOROTOMI, 1986)

intertrial interval (ITI) of 5-7 seconds. A total of 90 trials were presented in three 30-trial blocks (which were randomized across subjects) with a 2-minute rest of 15 trials and a 3-5 minute rest between blocks (used to check the quality of the ERP signals). The first 5 stimuli always consisted of the *Kaisho* style and served as the habituation stimuli (Hab-stimuli (K-1): H-1 to H-5). The last Hab-stimulus directly preceding the four test stimuli (Test-stimuli: *Reisho*, *Gyosho*, *Sosho*, and *Tensho*) was designated the pretest stimulus (Pretest stimulus) (cf. Megela and Teyler, 1979) and was the standard to which these Test-stimuli were compared. This Pretest stimulus consisted of a random average of *Kaisho* at positions 6, 7, 8 (Hab-6, -7, -8). The four Test-stimuli were pseudorandomly presented in 7, 8, and 9, so that within a block of 30 trials there were six presentations of each of the four Test-stimuli. Thus, there were a total of 18 presentations for averaging (6 trials x 3 blocks). Due to excessive EOG, only twelve artifact-free trials could be obtained for each subject, and one subject's data contained too much artifact and had to be deleted. In addition, due to excessive noise in the data, a further two subjects' data had to be deleted. Therefore, the following results and conclusions are based on only five subjects and 12-trial averages.

Results

Figure 4 shows the superimposed averaged waveforms (12 trials per average) for the five subjects for the first presentation of the habituation stimulus (Hab-1), the Pretest

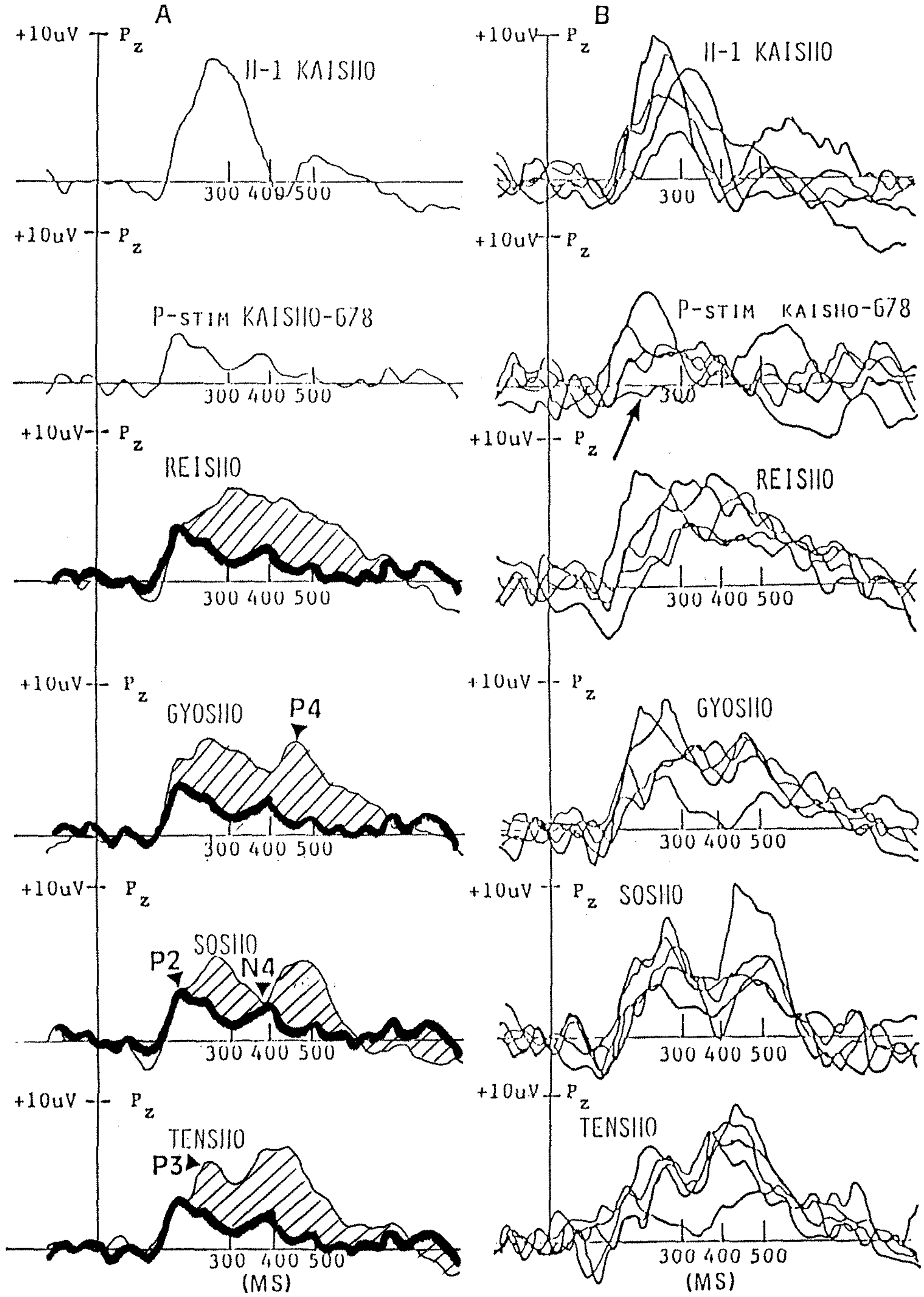


FIGURE 4

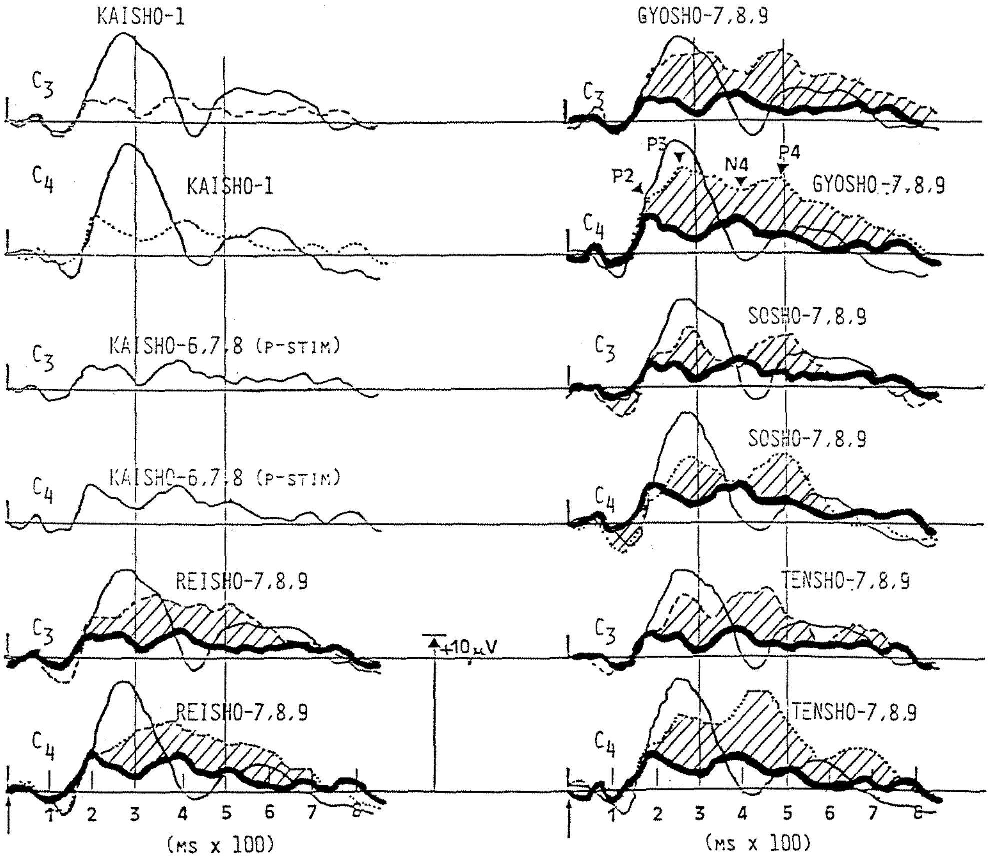


FIGURE 6 CONTINUED

stimulus (average of Hab-6, -7-, -8), and the four Test stimuli (average of Test-7, -8-, -9) obtained at the Pz electrode; the corresponding grand averages are also shown. Figure 5 shows the grand average waveforms for the C3 and C4 electrodes for the same stimuli. Due to the difficulty in interpreting the waveforms based on only 12 trials per average and a central-parietal topography, a sixth subject was run using three midline electrodes (Fz, Cz, and Pz) and a different rest schedule (i.e., a 1-minute rest every six trials). This resulted in a significant decrease in the EOG artifact which permitted the generation of ERP waveforms based on 18-trial averages which appeared to yield more detail (See Figure 6). For the Test stimuli, the Hab-1 waveform has been superimposed on the respective Test stimuli waveforms to aid in comparisons.

In the three figures (Figs. 4, 5, and 6), one notices that there appear to be distinct patterns for each of the stimulus types. Especially interesting is the similarity between the waveforms for the sixth subject and the grand average waveforms indicating the reproducibility of the data.

The following analyses will be primarily non-statistical due to the small number of subjects (n=5), but some statistically significant findings were obtained.

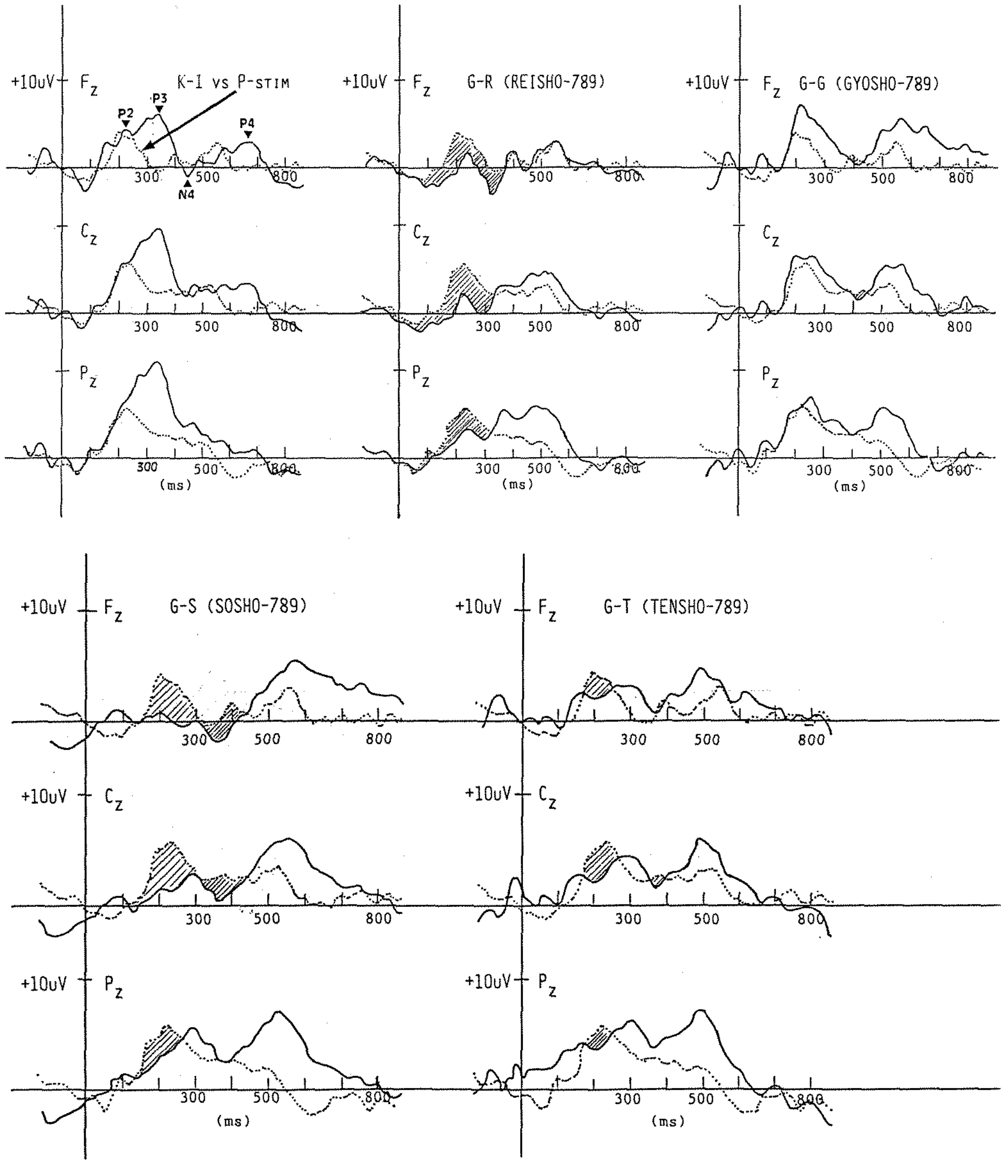


FIGURE 6

Habituation

The first major finding was a clear and statistically significant decrement in the P300 amplitude from the Hab-1 to the Pretest stimulus at Pz $F(4,1)=45.4$, $p<0.003$, and at C3 and C4, $F(4,1,)=45.2$, $p<0.003$ (see Figures 7, 8, and 9). In these and all subsequent analyses, normalized data (% increase or decrease with respect to the Hab-1 P300 amplitude, taken to be 100%) instead of the absolute amplitude in μV was used (cf. Megela and Teyler, 1979). The amount of decrement at Pz and Cz was nearly the same for both the sixth subject and the other five subjects represented by the grand average waveforms. As for the P300

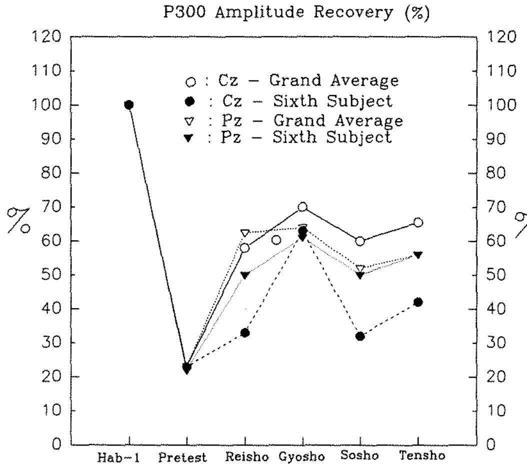


FIGURE 7

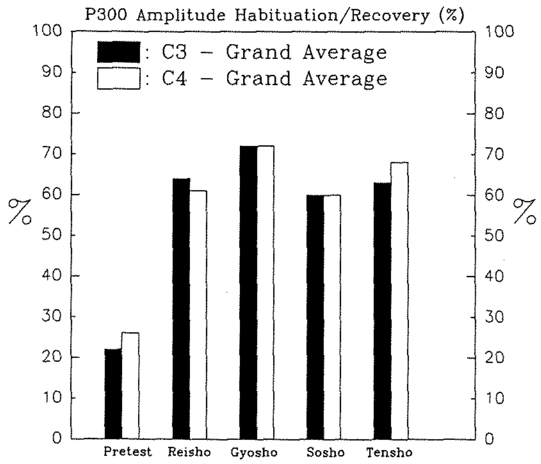


FIGURE 8

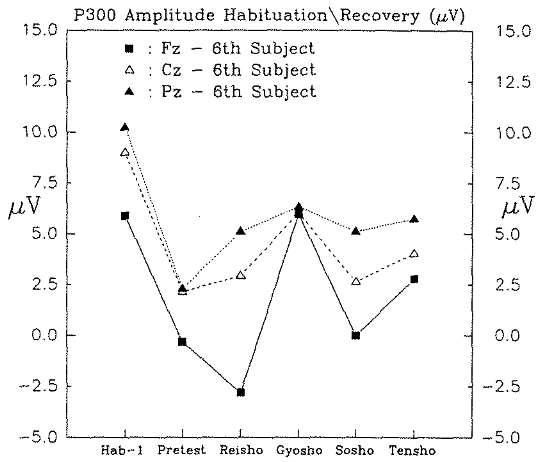


FIGURE 9

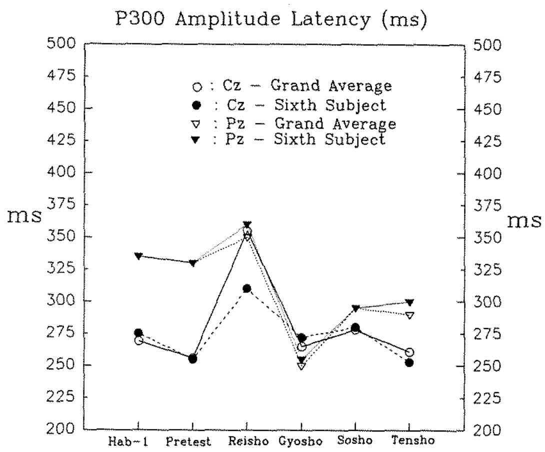


FIGURE 10

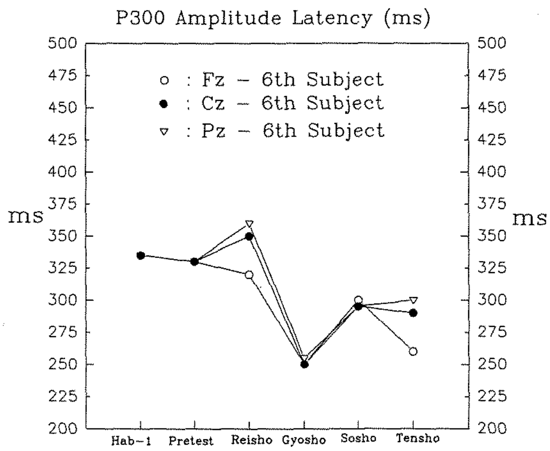


FIGURE 11

latencies, the grand average waveforms at C3 and C4 are shown in Figure 10, and those for the sixth subject at Fz, Cz, and Pz are in Figure 11. The grand average latencies for Hab-1 and Pretest are essentially the same as those for the Test stimuli (*Gyosho*, *Sosho*, and *Tensho*), while that for *Reisho* appears to be slightly longer.

Generalization

As a significant stimulus decrement consistent with a classic habituation was found for the P300 amplitude, an analysis of this ERP component was performed in order to demonstrate changes in its amplitude or latency as a function of the p-ratings of the four different Test stimuli. Figures 7, 8, and 9 contain a summary of the differential recovery for the four Test stimuli. There is a clear recovery compared to the Pretest level for all four of the Test stimuli which does seem different at Pz. At Cz (the average of C3 and C4), the mean values (n=5) are Hab-1=24%, *Reisho*=62.5%, *Gyosho*=70%, *Sosho*=60%, and *Tensho*=65.5%. As for the P300 latencies, in Figure 10 at Pz, the latencies appear to about the same with the latency for *Reisho* slightly longer.

The results for P4, likewise, displayed a clear recovery with respect to Pretest (*Kaisho-678*). Moreover, there appeared to be a wider difference in the amount of recovery in comparison with the results for P300 (cf. Figure 5, *Reisho* vs. *Sosho* vs. *Tensho*).

Discussion

Despite the relatively modest amount of data gathered, several significant findings were obtained. First there was a clear decrement in the P300 amplitude from Hab-1 to the Pretest stimulus consistent with a process of habituation (Groves & Thompson, 1970, Roemer *et al.*, 1984). Moreover, since the ISI was 3 seconds, this lessens the possibility that this decrement was due to the effects of a recovery cycle (cf. Roemer *et al.*, 1984). Similar findings were obtained in the first author's dissertation (Langman, 1991) at four midline electrodes (Fz, Cz, Pz, Oz) and two lateral electrodes corresponding to Wernicke's area and its right hemisphere homologue.

Second, there was substantial recovery of the P300 amplitude for all the Test stimuli at all the electrode sites which seemed uniform rather than stimulus dependent. Again, this agrees with the first author's dissertation (1991). A significant difference, however, was the presence of a P400 at around 400-450 ms post stimulus onset. This P400 appeared to index differences in the semantic-graphemic overlap of the *kanji*. In particular, the strongly iconic *Tensho* displayed the shortest latency at about 450 ms (and an N400-like depression at 350 ms) while also displaying the most recovery. In contrast, *Reisho* displayed the least amount of recovery while having the longest latency at about 510 ms (and no observable negative deflection). If we may use the difference in the p-ratings between the habituation stimulus (*Kaisho*-4.1) and the four Test stimuli as a gross indicator of their similarity, we then obtain the following order of similarity: *Gyosho* (.1)>*Reisho* (.6)>*Sosho* (1.0)>*Tensho* (2.4) which is similar to the order of recovery of P400 (i.e., *Reisho*<*Gyosho*<*Sosho*<*Tensho*). Of course, given the limitations of the experiment, these preliminary findings permit only tantalizing speculations. However, the strength of the paradigm was indicated and then confirmed in the first author's dissertation and subsequent studies (Langman and Yaguchi, in progress).

Epilogue

This little study seen against the background of the virtual revolution in computer-aided electrophysiology appears quite crude. There were only a few number of electrodes

(3), only six stimulus types (Hab-1, Pretest, and 4 Test stimuli) out of a possible 20 (i.e., Hab-1 to Hab-9, Pretest (ave. of Hab-567), ave. of Hab-678, ave. of Hab-789, the 4 Test stimuli, the 4 corresponding dishabituation stimuli), no probe stimulus (stimulus type number 21) to control for attentional effects, and only 6 subjects. Despite these weaknesses, this study represented the first step for the first author in his quest to carry out his dissertation research in Japan, completely separated from his dissertation committee at Kent State University, Kent, Ohio, U.S.A. Based upon these preliminary findings, a dissertation proposal was sent to the committee and the university who granted their unprecedented approval after the proposal was modified to incorporate some refinements. These refinements were made possible by a grant awarded to the second author which was used to upgrade his lab. Subsequently, the dissertation study was completed and the Ph.D. degree was awarded to the first author in August 1991, approximately 5 years after this study was completed. That study was the logical extension of this study and incorporated 6 recording electrodes, and measurements for Hab-1, Pretest (Hab-567), Test-1, 2, 3, 4, Dishab-1, 2, 3, 4, and a Probe stimulus, making possible not only a demonstration of habituation and generalization (recovery), but, more importantly, the demonstration of dishabituation. That is, evidence for the differential influence of the intervening Test stimulus on the following re-presentation of the habituation stimulus was obtained. As before, the second author was instrumental in providing not only free access to his laboratory, but also provided subjects and incidental supplies such as special recording tape for the 28-channel FM tape recorder. Moreover, he assisted the first author in learning how to use the new signal acquisition and analysis system. In short, the second author served as the first author's ad hoc dissertation advisor.

Robert A. Heinlein, the famous American science fiction writer, who unselfishly helped many of his fellow writers, said that those he helped didn't need to pay him back. Rather, they should pay "forward" to the next generation. In this regard, it is fitting that the first author is now a part-time visiting researcher in Dr. Kiyoshi Yaguchi's laboratory at Akita University. And he now is serving as a co-director for the graduation theses of two of Dr. Yaguchi's 4th-year students. Again, their studies are extensions of this study and the dissertation and involve the habituation paradigm and letters of the alphabet and faces. However, the equipment that they have access to now makes possible the utilization of 31 electrodes, the analysis of more than 1000 stimulus types, topographic mapping, principal components analysis, and even dipole localization. Compared to the authors' equipment 10 years ago, it is like moving from a Model-T Ford to a Formula-1 racing car. Still, the basic paradigm remains unchanged, and the newly collected data only reinforces our past findings. And the students marvel as the analyses begin to dissect out the habituation, generalization, and dishabituation.

Watching these students, the first author remembers fondly his first excitement as the data appeared on the green CRT after being extracted from the slowly turning reels of tape. And he considers himself lucky to have worked with the second author who trained under Prof. Kitajima. Therefore, it is quite fitting that these words appear in this Festschrift written in his honor by his students, for his influence lives on as it is appropriately passed

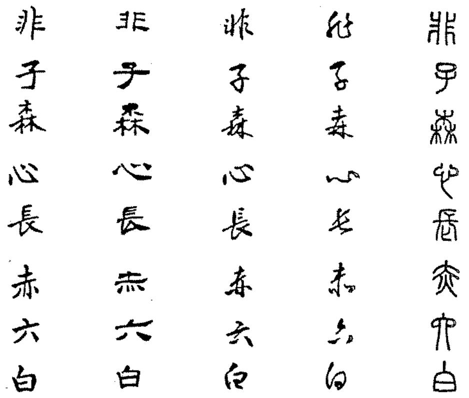
APPENDIX I The Eight Japanese Categories and Their Associated Meanings. (Used in Experiments 1 and 2)

Meaning			Style of Calligraphy*
Real	Iconic	Non-iconic	K R G S T
hi/non-, un-(prefix)	similar	rifle	
kodomo/child	a flower	to sell	
mori/forest	family	a knife	
kokoro/heart	nose	year	
nagai/long (adj.)	growth	honest	
akai/red	above	promise	
roku/six	compass (a divider)	breakfast	
shiroi/white	a bucket	to remember	

*K=Kaisho (Block Style), R=Reisho (Scribe's Style), G=Gyosho (Semi-cursive Style), S=Sosho (Cursive Style), and T=Tensho (The Seal Style). (From Langman & Saito, 1984)

APPENDIX II The Eight Chinese Categories and Their Associated Meanings. (From Saito & Langman, 1984)

Meaning			Style of Calligraphy*
Real	Iconic	Non-iconic	K R G S T
eki/to pile up	flyilg birds	to think	
hi/rustic	to lay an egg	Thursday	
ji/bison	frog	distinct	
sho/fence	a bow and arrow	to apologize	
ju/to do a favor for someone	a cat and mouse	frequently	
kafu/asmoll box	a train coupler	angry	
shitsu/abig koto	ribs (bones)	towake up	
yoku/to catch a bird with string	a pair of scissors	a jacket	



*K=Kaisho (Block Style), R=Reisho (Scribe's Style), G=Gyosho (Semi-cursive Style), S=Sosho (Cursive Style), and T=Tensho (The Seal Style).
ARROW HEADS=STIMULI USED IN SORTING PORTION OF EXPERIMENTS 1 AND 2.

"forward" from his students to their students and to their students' students...

Notes

1. The *Tensho* style is the oldest calligraphic style which for the majority of *kanji* in use has no clear pictographic association. Thus, the *kanji* in this study represent specially selected *kanji* which do have a very pictographic association for the *Tensho* style.
2. All *kanji* have a fixed stroke order, and it is very common for a Japanese to trace a character on his palm in attempting to recall the "spelling" which can include up to 30+ individual strokes. Thus, each *kanji* may have a stored tactile-kinesthestic image can affect a native speaker's (writer's) psychological judgments of similarity.
3. Quasi-linguistic refers to the case in which a symbols with no meaning is nonlinguistic, but as the amount of semantic-graphemic overlap is varied by providing various kinds of meanings (i.e., iconic, non-iconic, abstract, etc.), the amount of linguisticness is also varied.

BIBLIOGRAPHY

Alho, K., Lavikainen, J., Reinikainen, K., Sams, M., & Näätänen, R. (1990). Event-related brain potentials in selective listening to frequent and rare stimuli. *Psychophysiology*, Vol.27, **1**, 73-86.

Barsalou, L. W. (1987). The instability of graded structure: Implications for the nature of concepts. In U. Neisser (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization.* Cambridge: Cambridge University Press.

Bentin, S. (1987). Event-related potentials, semantic processes, and expectancy factors in word recognition. *Brain and Language*, **31**, 308-327.

Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-related potentials, lexical decision and semantic priming. *Electroencephalography and clinical Neurophysiology*, **60**, 343-355.

Brown, W. S., Marsh, J. T., & Smith, J. C. (1973). Contextual meaning effects on speech-evoked potentials. *Behavioral Biology*, **9**, 755-761.

Brown, W. S., Marsh, J. T., & Smith, J. C. (1976). Evoked potential waveform differences produced by the perception of different meanings of an ambiguous phrase. *Electroencephalography and clinical Neurophysiology*, **41**, 113-23.

Chapman, M. C., McCrary, J. W., Chapman, J. A., & Bragdon, H. R. (1978). Brain responses related to semantic meaning. *Brain and Language*, **5**, 195-205.

Cheng, C.-M., & Yang, M.-.J. (1989). Lateralization in the visual perception of Chinese characters and words. *Brain and Language*, 36, 669-689.

Courchesne, E., Courchesne, R. Y., & Hillyard, S. A. (1978). The effect of stimulus deviation on P3 waves to easily recognized stimuli. *Neuropsychologia*, **16**, 189-199.

Dennis, M. (1987). Using language to parse the young damaged brain. *Journal of Clinical and Experimental Neuropsychology*, **9**, 723-753.

Donchin, E. (1981). Surprise!...Surprise?. *Psychophysiology*, Vol.18, **5**, 493-513.

Donchin, E., Heffley, E., Hillyard, S. A., Loveless, N., Maltzman, I., Öhman, A., Rösler, F., Ruchkin, D., & Siddle, D. (1984). Cognitive and event-related potentials II. The orienting reflex and P300. In R. Karrer, J. Cohen, & P. Tueting (Eds.), *Brain and Information: Event-related Potentials.* New York: Ann. NY Acad. of Sci. Vol.425, pp. 39–57.

Donchin, E., Ritter, W., & McCallum, W. C. (1978). Cognitive psychophysiology. The endogenous components of the ERP. In E. Callaway, P. Tueting, & S. Koslow (Eds.), *Event-related Brain Potentials in Man.* New York: Academic Press, pp. 349–432.

Elman, J. L., Takahashi, K., & Tohsaku, Y.-H. (1981). Lateral asymmetries for the identification concrete and abstract kanji. *Neuropsychologia,* **19**, 407–412.

Fang, S. P., & Wu, P. (1989). Illusory conjunctions in the perception of Chinese characters. *Journal of Experimental Psychology: Human Perception and Performance*, Vol.15, No.**3**, 434–447.

Fischler, I., Jin, Y.-S., Boaz, T. L., Perry, N. W., Jr., & Childers, D. G. (1987). Brain potentials related to seeing one's own name. *Brain and Language*, **30**, 245–262.

Freyd, J. J. (1987). Dynamic mental representations. *Psychological Review*, Vol.94, No.**4**, 427–438.

Gaillard, A. W. K., & Ritter, W. (Eds.), (1983). Tutorials in *Event-Related Potential Research: Endogenous Components.* Amsterdam: North-Holland.

Gernsbacher, M. A. (1984). Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. *Journal of Experimental Psychology: General*, Vol.113, No.**2**, 256–281.

Gotai Jirui (A Dictionary of Five Calligraphy Variants). (1981). Compiled by the Hosho Kaihen Shobu. Tokyo: Seito Shobo (in Japanese).

Grossman, M. (1981). A bird is a bird is a bird: Making reference within and without superordinate categories. *Brain and Language,* **12**, 313–331.

Grossman, M., & Wilson, M. (1987). Semantic categorization by brain-damaged patients. *Brain and Cognition,* **6**, 55–71.

Groves, P. M. & Thompson, R. F. (1970). Habituation: A dual process theory. *Psychological Review,* **77**, 419–450.

Harbin, T. J., Marsh, G. R. & Harvey, M. T. (1984). Differences in the late components of the event-related potential due to age and to semantic and non-semantic tasks. *Electroencephalography and clinical Neurophysiology,* **59**, 489–496.

Hatta, T., & Nakatsuka, Z. (1975). H. N. Handedness Inventory. In S. Ono (Ed.), *Papers in Celebration of the 63rd Birthday of Professor K. Ohnishi.* Osaka City University, pp. 210–215.

Holcomb, P. J. (1988). Automatic and attentional processing: An event-related brain potential analysis of semantic priming. *Brain and Language,* **35**, 66–85.

Jasper, H. H. (1958). The ten-twenty electrode system of the international federation. *Electroencephalography and clinical Neurophysiology,* **10,** 371–375.

Johnson, R. Jr. (1988). The amplitude of the P300 component of the event-related potential:

Review and synthesis. In P. K. Ackles, J. R. Jennings, & M. G. H. Coles (Eds.), *Advances in psychophysiology* (Vol.II, pp. 69-138). Greenwich, CT: JAI Press.

Johnson, R., Jr., & Donchin, E. (1982). Sequential expectancies and decision making in a changing environment: An electrophysiological approach. *Psychophysiology,* **19,** 183-200.

Kirk, R. E. (1982). *Experimental Design: Procedures for the Behavioral Sciences.* Monterey: Brooks/Cole.

Kramer, A. F., & Donchin, E. (1987). Brain potentials as indices of orthographic and phonological interaction during word matching. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* Vol.13, **1**, 76-86.

Kutas, M. (1987). Event-related brain potentials (ERPs) elicited during rapid serial visual presentation of congruous and incongruous sentences. In R. Johnson, Jr., J. W. Rohrbaugh, & R. Parasuraman (Eds.), *Current Trends in Event-Related Potential Research (EEG Suppl. 40),* Elsevier Science Publishers B. V. (Biomedical Division).

Kutas, M., & Donchin, E. (1978). Variations in the latency of P300 as a function of variations in semantic categorizations. In D. Otto (Ed.), *Multidisciplinary Perspectives in Event-Related Brain Potential Research.* Washington D. C.: U.S. Government Printing Office.

Kutas, M., & Hillyard, S. A. (1980a). Reading between the lines: Event-related brain potentials during natural sentence processing. *Brain and Language,* **11**, 354-373.

Kutas, M., & Hillyard, S. A. (1980b). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science,* **207,** 203-205.

Kutas, M., & Hillyard, S. A. (1980c). Event-related potentials to semantically inappropriate and surprisingly large words. *Biological Psychology,* **11,** 99-115.

Kutas, M., & Hillyard, S. A. (1982). The lateral distribution of event-related potentials during sentence processing. *Neuropsychologia,* **20,** 579-590.

Kutas, M., & Hillyard, S. A. (1983). Event-related potentials to grammatical errors and semantic anomalies. *Memory and Cognition,* **11,** 539-550.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature,* **307,** 161-163.

Kutas, M., & Hillyard, S. A. (1989). An electrophysiological probe of incidental semantic association. *Journal of Cognitive Neuroscience,* Vol.1, **1**, 38-49.

Kutas, M., McCarthy, G., & Donchin, E. (1977). Augmenting mental chronometry: The P300 as a measure of stimulus evaluation time. *Science,* **207,** 203-205.

Kutas, M., & Van Petten, C. (1988). Event-related brain potential studies of language. In P. K. Ackles, J. R. Jennings, & M. G. H. Coles (Eds.), *Advances in Psychophysiology* (Vol.3). Greenwich, CT: JAI Press

Kutas, M., Van Petten, C., & Besson, M. (1988). Event-related potential asymmetries during the reading of sentences. *Electroencephalography and clinical Neurophysiology*, **69**, 218-233.

Lakoff, G., (1987). Cognitive models and prototype theory. In U. Neisser (Ed.), *Concepts and Conceptual Development: Ecological and Intellectual Factors in Categorization.* New York: Cambridge University Press.

Langman, P. (1991). A demonstration of habituation, generalization, and dishabituation using ERP correlates of obsolete chinese *KANJI*. (Ph D thesis)

Langman, P., & Morotomi, T. (1986). Evoked potential correlates of *kanji* processing: The interaction between meaning and configuration. Poster Presentation at the XXth Congress of the International Association of Logopedics and Phoniatrics, Tokyo.

Langman, P., & Saito, H. (1984). Cross-linguistic categorization of *Kanji* characters. *Japanese Psychological Research,* **26,** 93-102.

Logan, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? *Cognitive Psychology,* Vol.22, **1,** 1-35.

Loveless, N. (1983). The orienting response and evoked potentials in man. In D. Siddle (Ed.), *Orienting and Habituation: Perspectives in Human Research.* John Wiley & Sons, New York, pp. 71-108.

Mateer, C. A. (1983). Localization of language and visuospatial functions by electrical stimulation. In A. Kertesz (Ed.), *Localization in Neuropsychology.* New York: Academic Press, pp. 121-140.

McCloskey, M., & Glucksberg, S. (1979). Decision processes in verifying category membership statements: Implications for models of semantic memory. *Cognitive Psychology*, **11,** 1-37.

Megela, A. L., Teyler, T. J., & Hesse, G. W. (1977). ERP response decrement and recovery as a function of stimulus type and scalp location. *Physiology and Behavior,* **19,** 15-22.

Megela, A. L., & Teyler, T. J. (1979). Habituation and the human evoked potential. *Journal of Comparative and Physiological Psychology.* 93, No.**6,** 1154-1170.

Mervis, C.B., & Pani, J. R. (1980). Acquisition of basic object categories. *Cognitive Psychology*, **12**, 496-522.

Näätänen, R., & Gaillard, A. W. K. (1983). The orienting reflex and the N2 deflection of the event-related potential (ERP). In A. W. K. Gaillard and W. Ritter (Eds.), *Tutorials in Event-Related Potential Research: Endogenous Components.* Amsterdam: North Holland, pp. 119-141.

Näätänen, R., & Picton, T. W. (1986). N2 and automatic versus controlled processes. In W. C. McCallum, R. Zappoli, & F. Denoth (Eds.), *Cerebral Psychophysiology: Studies in Event-Related Potentials (EEG Suppl. 38).* Elsevier Science Publishers B. V. (Biomedical Division).

Näätänen, R., Simpson, M., & Loveless, N. E. (1982). Stimulus deviance and evoked potentials. *Biological Psychology,* **14,** 53-98.

Norusis, M. J. (1985). *SPSS^x Advanced Statistics Guide.* New York: McGraw-Hill.

Öhman, A. (1979). The orienting response, attention, and learning: An information processing perspective. In H. D. Kimmel, E. H. van Olst, & J. F. Orlebeke (Eds.), *The Orienting Reflex in Humans.* Hillsdale, NJ: Erlbaum, pp. 443-471.

Paradis, M., Hagiwara, H., & Hildebrandt, N. (1985). *Neurolinguistic Aspects of the Japanese Writing System.* New York: Academic Press.

Polich, J. (1985). Semantic categorization and event-related potentials. *Brain and Language,* **26,** 304-321.

Polich, J., McCarthy, G., Wang, W. S., & Donchin, E. (1983). When words collide: Orthographic and phonological interactions during word processing. *Biological Psychology,* **16,** 155-180.

Psatta, D. M. (1981). Visual evoked potential habituation in mental deficiency. *Biological Psychiatry,* Vol.16, No.8, 729-740.

Ritter, W., Simson, R., Vaughan, Jr., H. G., & Macht, M. (1982). Manipulation of event-related potential manifestations of information processing stages. *Science,* Vol.218, **26,** 909-911.

Ritter, W., Ford, J. M., Gaillard, A. W. K., Harter, M. R., Kutas, M., Näätänen, R., Polich, J., Renault, B., & Rohrbaugh, J. (1984). Cognition and event-related potentials: I. The relation of negative potentials and cognitive processes. In R. Karrer, J. Cohen, P. Tueting (Eds.), *Brain and Information: Event-related Potentials.* New York: NY Acad. Sci. Vol.425, pp. 24-38.

Ritter, W., Vaughan, H. G., & Simson. (1983). On relating Event-related potential components to stages of information processing. In A. W. K. Gaillard and W. Ritter, (Eds.), *Tutorials in Event-Related Potential Research: Endogenous Components.* Amsterdam: North Holland, pp. 143-158.

Roemer, R. A., Shagass, C., & Teyler, T. J. (1984). Do human evoked potentials habituate? In H. V. S. Peeke and L. Petrinovich (Eds.), *Habituation, Sensitization, and Behavior.* New York: Academic Press.

Rosch, E. H. (1975). Cognitive representations of semantic categories. *Journal of Experimental Psychology: General,* **104,** 192-233.

Rosch, E. H., & Mervis, C. B. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology,* **7,** 573-605.

Rosch, E. H., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology,* **8,** 382-439.

Rosch, E. H., Simpson, C., & Miller, R. S. (1976). Structural bases of typicality effects. *Journal of Experimental Psychology: Human Perception and Performance,* **2,** 491-502.

Rösler, F. (1983). Endogenous ER "Ps" and cognition: Probes, prospects, and pitfalls in matching pieces of the mind-body puzzle. In A. W. K. Gaillard and W. Ritter, (Eds.), *Tutorials in Event-Related Potential Research: Endogenous Components.* Amsterdam: New Holland, pp. 9-35.

Rösler, F. (1986). P300 complex: A manifestation of reactive or anticipatory processes of the brain? In W. C. McCallum, R. Zappoli, & F. Denoth (Eds.), *Cerebral Psychophysiology: Studies in Event-Related Potentials (EEG Suppl. 38).* Elsevier Science Publishers, New Holland, pp. 138-142.

Roth, W. T. (1983). A comparison of P300 and skin conductance response. In A. W. K. Gaillard and W. Ritter, (Eds.), *Tutorials in Event-Related Potential Research: Endogenous Components.* Amsterdam: North Holland. pp. 177-199.

Ruchkin, D. S., & Sutton, S. (1983). Positive slow wave and P300: Association and disassociation. In A. W. K. Gaillard and W. Ritter (Eds.),*Tutorials in Event-Related Potential Research: Endogenous Components.* Amsterdam: North Holland. pp. 233-250.

Rugg, M. D. (1984). Event-related potentials and the phonological processing of words and non-words. *Neuropsychologia,* Vol.22, No.**4,** 435-443.

Saito, H., & Langman, P. (1984). Intra-linguistic categorization of obsolete *Kanji. Japanese Psychological Research, 26,* No.**3,** 134-142.

Sams, M., Alho, K., & Näätänen, R. (1984). Short-term habituation and dishabituation of the mismatch negativity of the ERP. *Psychophysiology,* Vol.21, **4,** 434-441.

Sams, M., Alho, K., & Näätänen, R. (1985). The mismatch negativity and information processing. In F. Klix, R. Näätänen, & K. Zimmer (Eds.), *Psychophysiological Approaches to Human Information Processing,* pp. 161-176. North-Holland: Elsevier.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review,* **84,** 127-190.

Siddle, D. A. (1985). Effects of stimulus omission and stimulus change on dishabituation of the skin conductance response. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* Vol.11, No.**2,** 206-216.

Siddle, D. A. T., Kyriacou, C., Heron, P. A., & Mathews, W. A. (1979). Effects of changes in verbal stimuli on the skin conductance response component of the orienting response. *Psychophysiology, 16,* No.**1,** 34-40.

Siddle, D. A. T., Remington, B., Kuiack, M., & Haines, E. (1983). Stimulus omission and dishabituation of the skin conductance response. *Psychophysiology,* **20**, 136-145.

Siegel, S. (1956). *Nonparametric Statistics.* New York: McGraw-Hill.

Smith, M. E., & Halgren, E. (1987). Event-related potentials elicited by familiar and unfamiliar faces. In R. Johnson, Jr., J. W. Rohrbaugh, & R. Parasuraman (Eds.), *Current Trends in Event-Related Potential Research (EEG Suppl. 40),* Elsevier Science Publishers B. V. (Biomedical Division).

Smith, M. E., & Halgren, E. (1987). Event-related potentials during lexical decision: Effects of repetition, word frequency, pronounceability, and concreteness. In R. Johnson, Jr., J. W. Rohrbaugh, & R. Parasuraman (Eds.), *Current Trends in Event-Related Potential Research (EEG Suppl. 40),* Elsevier Science Publishers B. V. (Biomedical Division).

Sokolov, E. N. (1969). The modeling properties of the nervous system. In M. Cole & I. Malzman (Eds.), *Handbook of Contemporary Soviet Psychology.* New York: Basic Books.

Sokolov, E. N. (1975). The neuronal mechanisms of the orienting reflex. In E. N. Sokolov & O. S. Vinogradova (Eds.), *Neuronal Mechanisms of the Orienting Reflex.* New York: Wiley.

Squires, K. C., Petuchowski, S., Wickens, C., & Donchin, E. (1977). The effects of stimulus sequence on event-related potentials: A comparison of visual and auditory sequences. *Perception & Psychophysics,* **22,** 31-40.

Stelmack, R. M., Plouffe, L. M., & Winogron, H. W. (1983). Recognition memory and the orienting response: An analysis of the encoding of pictures and words. *Biological Psychology,* **16,** 49-63.

Stuss, D. T., Picton, T. W., & Cerri, A. M. (1988). Electrophysiological manifestations of typicality judgement. *Brain and Language,* **33,** 260-272.

Sutton, S., Braren, M., Zubin, J., & John, E. R. (1965). Evoked potential correlates of stimulus uncertainty. *Science,* 150, 1187-1188.

Swaminathan, T. R. (1989). *P300 and habituation: Validation and application.* (unpublished Doctoral dissertation, 1989, Kent State University).

Teyler, T. J., Chiaia, N., & DiScenna, P. (1984). Habituation of CNS evoked potentials: Intrinsic habituation examined in neocortex, allocortex and mesencephalon. In H. V. S. Peeke and L. Petrinovich (Eds.), *Habituation, Sensitization and Behavior.* New York: Academic Press.

Thompson, R. F. and Spencer, W. A. (1966). Habituation: A model phenomenon for the study of neuronal substrates of behavior. *Psychological Review,* **173,** 16-43.

Tversky, B., and Hemenway, K. (1984). Objects, parts, and categories. *Journal of Experimental Psychology: General,* **113,** 169-193.

Tzeng, O. J. L., Hung, D. L., Cotton, B., & Wang, W. S.-Y. (1979).Visual lateralization effect in reading Chinese characters. *Nature,* **282,** 499-501.

Verbaten, M. N., (1983). The influence of information on habituation of cortical, autonomic and behavioral components of the orienting response (OR). In A. W. K. Gaillard and W. Ritter (Eds.). *Tutorials in Event-Related Potential Research: Endogenous Components.* Amsterdam: North Holland. pp. 201-216.

Verbaten, M. N., Roelofs, J. W., Sjouw, W., & Slangen, J. L. (1986). Habituation of early and late visual ERP components and the orienting reaction: the effect of stimulus information. *International Journal of Psychophysiology,* **3,** 287-298.

Verleger, R. (1988). Event-related potentials and cognition: A critique of the context updating hypothesis and an alternative interpretation of P3. *Behavioral and Brain Sciences,* **11,** 343-427.

Wang, W. S. -Y. (1981). Language structure and optimal orthography. In O. J. L. Tzeng and H. Singer (Eds.), *Perception of Print: Reading Research in Experimental Psychology*. Hillsdale, NJ: Lawrence Erlbaum. pp. 223-235.

Whitlow, J. W., Jr., & Wagner, A. R. (1984). Memory and Habituation. In H. V. S. Peeke and L. Petrinovich (Eds.), *Habituation, Sensitization, and Behavior.* New York: Academic Press. pp. 103-153.

Wierzbicka, A. (1984). Apples are not a "kind of fruit": The semantics of human categorization. *American Ethologist,* Vol.11, 313-328.

Winer, B. (1962). *Statistical Principles in Experimental Design.* New York: McGraw-Hill.

Woestenburg, J. C., Verbaten, M. N., & Slangen, J. L. (1983). Stimulus information and habituation of the visual event related potential and the skin conductance reaction under task-relevance conditions. *Biological Psychology,* **16,** 225-240.

FIGURE LEGENDS

Figure 1. Quasi-linguistic category consisting of the five styles of calligraphy, (from Langman and Saito, 1984). The *block* style is the most common style and is used for books and most printed matter. The *semi-cursive* style is used for writing letters and notes. The *cursive* style is used for fast writing and poetry. The *scribe* style is rather rare and is used only on money and sometimes for advertising and special newspaper headlines. It is not written by the ordinary Japanese. The *seal* style is the rarest and is only used for the names of shops, in advertising, or for one's personal stamp (one's legal "signature" in Japan) without which one cannot buy a car or a house, for example. *Seal* characters are written only by skilled calligraphers.

Figure 2. Mean prototypicality ratings (p-ratings) for the 5 *kanji* categories as a function of the kind of meaning provided. Note the significant effect of iconicity for the American subjects who rated the *Tensho-seal* style most prototypical in contrast to the Japanese subjects who rated it least prototypical. (From Langman and Saito, 1984).

Figure 3. Experimental protocol. The habituating (Hab-stim) or training stimulus was presented 5, 6, or 7 times consecutively in a pseudo-random order followed by the presentation of one of 5 generalization or test stimuli again in a pseudo-random order. The duration of the stimuli was 500 ms with a constant interstimulus interval (ISI) of 3 seconds. The intertrial interval randomly varied from 5–7 seconds. There were a total of 90 trials distributed over 3 blocks with interblock intervals of 2–3 minutes.

Figure 4. A. Grand average waveforms (n=5 x 12 trials=60 trials per grand average) for the stimuli at Pz. Thick dark line indicates the Pretest baseline (i.e., the average of H-678 or *Kaisho*-678). Crosshatching indicates the amount of recovery for the test stimuli. B. Superimposed individual waveforms for the 5 subjects.

Figure 5. Grand average waveforms for the 5 subjects for C3 and C4. Thin line is H-1, dotted line is the test stimulus, and the thick line is the Pretest baseline. Crosshatching indicates recovery compared to baseline.

Figure 6. Waveforms (average=18 trials) for the 6th subject at Fz, Cz, and Pz. Dotted line indicates baseline. P300 appears to be maximum at Pz (P3b), while it is markedly decreased at all three electrode sites for *Reisho* in contrast to *Gyosho*. There is a distinct recovery at all sites which is maximum at Pz.

Figure 7. Percent habituation/recovery for the grand average waveforms vs. the that for the 6th subject at Cz (average of C3 and C4) and Pz. There is a distinct habituation and the pattern of recovery is similar.

Figure 8. Habituation and recovery of P300 amplitude (% of H-1) for C3 and C4. No apparent left/right differences are present.

Figure 9. Recovery of P300 amplitude (μV) for Fz, Cz, Pz. Fz appears to have clearly lower amplitudes (especially *Reisho*) except for *Gyosho*.

Figure 10. P300 latencies for the grand average waveforms and 6th subject. There is a clear decrease from H-1 to Pretest (H-678), while there is an increase for *Reisho*. For *Tensho*, there appears to be a slight difference for Cz (300 ms) and Pz (260 ms) for both the grand average and 6th subject.

Figure 11. P300 latencies for the 6th subject at Fz, Cz, and Pz. There appear to be only differences for *Reisho* and *Tensho* with the shortest latencies at Fz and the longest at Pz.