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Are there differential word length effects in the two visual fields?☆

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Abstract

This study examined whether differential word length effects in the two visual fields imply hemisphere-dependent modes of word recognition. Length was defined as the number of constituent characters of Chinese foreign names (Experiments 1 and 2), as the number of constituent morphemes of three-character words (Experiments 3 and 4), and as that of constituent words of phrases (Experiments 5 and 6). Two types of experimental tasks were adopted, one required linguistic judgments on overall items (Experiments 1, 3, and 5) and the other was target detection tasks performed on the same set of stimuli (Experiments 2, 4, and 6). Five of the six experiments failed to find any kind of interaction between length and visual field. An interaction was observed only for the detection of characters embedded in foreign names, that is, when lexical access is least involved in the task, suggesting that word recognition plays a minimum role in the phenomenon. Other observations suggested that modes of word recognition are more frequency-dependent than hemisphere-dependent, and that Chinese compound words and phrases, although hardly distinguishable, do behave differently.

Keywords: Cerebral lateralization; Chinese characters; Modes of word recognition; Visual fields; Visual lexicon; Word length effects

1. Introduction

A rich body of research has been dedicated to interhemispheric collaboration as well as hemispheric differences in processing the same visual stimuli. On how the two cerebral hemispheres might differ in recognizing written words, Young and Ellis (1985; Ellis, Young, & Anderson, 1988) proposed that the left hemisphere (LH) has access to lexical representations prior to the letter-by-letter encoding whereas the right hemisphere (RH) does not, and that, as a result, the LH normally encodes words as a whole unit while the RH inevitably encodes words in a serial manner. These speculations are based upon observations of differential word length effects in the two visual fields—performance in the right visual field (RVF) did not vary with the length of words whereas performance in the left visual field (LVF) declined with longer words (Bub & Lewine, 1988; Ellis et al.; Iacoboni & Zaidel, 1996; Young & Ellis).

The above-described interaction between length and visual field occurred only if the stimuli were words. If pseudowords were presented, performance in both visual fields declined with string length, suggesting that both hemispheres processed the strings in a letter-by-letter manner (Iacoboni & Zaidel, 1996; Young & Ellis, 1985, Experiment 7). Given that both hemispheres encode nonsense strings in a serial manner, the RH likely has still stronger tendency to serial processing than the LH. This conjecture comes from studies using vertically presented consonant–vowel–consonant (CVC) nonsense syllables (e.g., Eng & Hellige, 1994, Experiment 2; Hellige, Taylor, & Eng, 1989; Luh & Levy, 1995) or consonant–consonant–consonant (CCC) strings (Eng & Hellige, 1994). When vertical CVC or CCC strings were presented to either visual field, top letters were better identified than bottom letters regardless of the visual field. Yet this top–bottom difference was more salient in

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the LVF than in the RVF, as assessed by a qualitative error score developed by Levy, Heller, Banich, and Burton (1983).

It seems that the RH is not good at processing longer words and easily misses last letters in a nonsense string. The LH, on the other hand, seems less sensitive to the number of constituent letters in a word and less sensitive to the serial position of letters in a vertical string. Whether the verbal string is word or not, the LH seems to allocate processing resource more evenly across the whole item. Two difficulties arise. The first difficulty is one of data interpretation. Given that the slope of the score-length (or score-serial position) function is less steep in the RVF-LH, instead of arguing for a more parallel processing in the LH, one can also argue for a more efficient serial processing in the LH—the more efficient the serial processing, the flatter the regression line. The second difficulty concerns the coherence or parsimony of a hypothesis. The Word Length × Visual Field interaction was said to reflect differential modes of lexical access in the two hemispheres. Words and nonwords should therefore show qualitatively distinctive data patterns. Since it is uncertain whether the above-reviewed difference between word processing and nonword processing is qualitative in nature, it is therefore uncertain whether the presence of lexical entries, as suggested by Young and Ellis (1985; Ellis et al., 1988), is a necessary and crucial component in order to account for the Word Length × Visual Field interaction.

In fact, it is yet uncertain if the observed interaction between word length and visual field is really due to differential hemispheric processing or instead is due to other factors such as differential visual acuity. The conventional layout of the stimulus card has the word centered at a set degree of visual angle to the left or right of the fixation point. The first letters of the RVF words fall close to the center, whereas those of the LVF words fall in peripheral vision. This difference in relative distance from the fixation point is heightened by increases in word length. Earlier findings of a Word Length × Visual Field interaction were thus attributed to two factors, first, the greater importance of initial letters to word recognition, and second, greater visual acuity for initial letters of longer RVF words than for those of longer LVF words (Bouma, 1973; Melville, 1957). Although Young and Ellis (1985, Experiment 3) tried to minimize the above-mentioned problem by controlling the eccentricity of the left-hand edge of words so that visual acuity was the same for the initial letters of short and long words in both visual fields and although they found a word length effect in the LVF but not in the RVF, their findings were not replicated (Schwartz, Montagner, & Kirsner, 1987).

The problem of differential visual acuity can be solved by using Chinese words as stimuli because Chinese words are normally presented in a vertical format and all constituent characters can be equidistant from the fixation point. Young and Ellis (1985, Experiment 8) also presented words vertically so that all constituent letters were equidistant from fixation in both fields; they found length effects for both RVF and LVF words. The researchers argued that the processing of RVF words normally triggered a visual lexicon, now the use of an unusual, vertical format disengaged the top-down whole-word encoding procedures normally used in the RVF-LH and instead invoked a serial encoding process that normally takes place in the LVF-RH. If this were the case, then RVF performance for vertically presented Chinese words should remain length independent because the vertical format is the standard format for Chinese words and should not invoke forced character-by-character processing.

Some might hesitate to test a model of reading Roman scripts by using the Chinese script. For decades researchers (especially those in Chinese societies) were enthusiastic to demonstrate that Chinese orthography is unique. It now seems prudent and parsimonious to maintain that the Chinese script conforms to the same general cognitive principles as Roman scripts do, as far as the bottom-up processing of word identification (Fang & Wu, 1989), the process of pronunciation (Fang, Horng, & Tzeng, 1986), the laterality patterns in the two visual fields (Fang, 1997; Hoosain, 1991), and clinical observations on cerebral organization (Tzeng & Hung, 1988) are concerned. If hemisphere-dependent modes of lexical access really exist, using various scripts, Roman or Chinese, should manifest rather than obscure this fact.

According to previous experiments using vertically presented Chinese words, no length effect was found in either visual field for one- and two-character words (Fang, 1997, Experiment 4) or for two- and four-character words (Fang, 1994, Experiment 2), and a length effect was obtained in both visual fields for two- to five-character words (Fang, 1994, Experiment 1). No Word Length × Visual Field interaction has been found with Chinese words. Does this mean that differential English word length effects in the two visual fields should be regarded as an artifact?

Although Fang (1997, Experiment 4) failed to obtain a Length × Visual Field interaction with vertically presented words of one or two characters long, one cannot be sure whether "word length" actually served *as* the functional variable. According to the combined norm adopted by Fang (cf. Liu, Chuang, & Wang, 1975; Wu & Liu, 1987), one- and two-character words, respectively, comprised 6.4 and 68.6% of the total frequency counts. Although one can reasonably expect native Chinese readers to treat a two-character word as a typical word, Chinese readers are more likely to treat a one-character word as merely a character—they do not automatically distinguish characters that represent free morphemes from those that represent bound morphemes. This latter prediction was confirmed by data of Fang's (1997) Experiment 3. Likely the difference between stimulus type was far more salient than the difference between stimulus length in Fang's Experiment 4.

Although in another study, Fang (1994) also failed to obtain a Length × Visual Field interaction with vertically presented items of two to five characters long, "word length" might not be adequately manipulated as an effective variable because the longer the item was, the harder it became to distinguish compound words from phrases. The current study tried to include Chinese items of three or more characters while systematically manipulating length in terms of number of constituent signs, number of constituent morphemes, and number of constituent words.

The purpose of this study is to verify the proposition of Ellis and his colleagues (Young & Ellis, 1985; Ellis et al., 1988) that the visual lexicon plays a role in differential (word) length effects in the two visual fields. A series of six experiments were conducted to further examine possible Length × Visual Field interactions by exploring the nature of the length and by varying the type of the task. The stimuli used in Experiments 1–6 are listed in the tables of Appendix A. Three types of stimuli were used. Experiments 1 and 2 defined length in terms of number of constituent signs and used biographical or geographical foreign names of two to four characters long. Experiments 3 and 4 defined length in terms of number of morphemes and used two types of three-character words, namely, monomorphemic words and trimorphemic words. In Experiments 5 and 6, length varied in both number of signs and number of meaning units. Experiment 5 used phrases that were one, two, and three words in length. As shown in the third table of Appendix A, each word in a phrase was represented by a single character. Experiment 6 included phrases that were two and three words long, which is a subset of the third table of Appendix A. Experiment 6 did not include one-word phrases because it adopted a target-detection task and such task would have become a character-matching task if one single-character word were presented.

Conventional tasks with which the Word Length × Visual Field interaction was demonstrated included the semantic decision task (Ellis et al., 1988, Experiment 4) and the lexical decision task (Ellis et al., 1988, Experiments 1–3; Iacoboni & Zaidel, 1996). These tasks required the participant to pay attention to the entire word and more or less demanded access to lexical knowledge. Such tasks were loosely referred to as the global tasks in this paper. Words or phrases, like many other objects, contain levels of embedded structure. The experimental task can direct participants' attention toward the entire item, the global level, or toward the constituent elements, the local level. Manipulating the attended level of the same stimuli can affect performance in various tasks. For example, detecting a word (e.g., BLOCK) was faster than detecting its constituent letter (e.g., B in BLOCK) (Johnson, 1975), and, given a hierarchical letter (e.g., a large H made up of small Ss), identifying the global letter was easier than identifying the local letters (Navon, 1977). Studies with patients as well as with normal people suggested that the two hemispheres made differential contributions to the processing of global information and that of local information, and that global processing was more associated with the RH whereas local processing was more associated with the LH (e.g., Lamb, Robertson, & Knight, 1990; Martin, 1979; Van Kleeck, 1989).

Failure to demonstrate a Length × Visual Field interaction with vertically presented Chinese items could be due to that the previously adopted lexical decision task (Fang, 1994) and the identification task (Fang, 1997) mainly required processing of global information. This study thus adopted both global tasks and a local task. The global tasks included a semantic categorization task (Experiment 1), a lexical decision task (Experiment 3), and a phrase completeness judgment task (Experiment 5). The local task is a target detection task (Experiments 2, 4, and 6). The target detection task differed from the global tasks in two ways. First, it required the participant to pay more attention to constituent characters of the words or phrases. Second, it required less, if any, access to lexical knowledge specific to the words or phrases. If both global tasks and local tasks fail to bring out a Length × Visual Field interaction, likely such interaction does not really exist.

2. Experiment 1: Multi-character names—categorization task

According to Young and Ellis (1985), word length is graphemic in nature and can be defined in terms of number of constituent letters. Further studies showed that the LVF performance was only affected by the number of letters in a word, was not affected by the physical length of a word (Bruyer & Janlin, 1989) and was not affected by the number of syllables in a word (Young & Ellis, Experiment 4). Although the number of characters in a Chinese word inevitably confounds with the number of syllables, such confounding should not affect the validity of reasoning concerning graphemic length.

Fang (1994) manipulated the number of constituent characters in Chinese words and failed to obtain a Word Length × Visual Field interaction. But one cannot refute Young and Ellis's (1985) findings solely based on this negative result because Fang used compound words as stimuli and consequently the number of constituent characters confounded with the number of constituent morphemes. Fang (1997) avoided this confounding by using monosyllabic and disyllabic monomorphemic Chinese words and failed to obtain a Word Length × Visual Field interaction. Such failure can be easily attributed to the narrow range of length manipulation. But longer noncompound words rarely exist in Chinese and they do not match shorter words in frequency or other properties. In order to examine whether the differential graphemic length effects in the two visual fields really exit with longer Chinese items, Experiments 1 and 2 used transliterated foreign names of two, three, and four syllables long. A global task was adopted in Experiment 1 and a local task was adopted in Experiment 2.

The interaction between graphemic length and visual field has been observed with the naming task (Bub & Lewine, 1988; Young & Ellis, 1985), the lexical decision task (Ellis et al., 1988, Experiments 1–3; Iacoboni & Zaidel, 1996), and the semantic decision task (Ellis et al., 1988, Experiment 4). In order to obtain naming latency data, one needs to match initial sounds of stimuli of various lengths. But this requirement renders difficulties given the limited number of suitable transliterated names. A good lexical decision task for transliterated names is nearly impossible to design because acceptable novel names can be easily created by recombining the characters. The semantic decision task is most feasible and was therefore chosen as the global task in this experiment. The participant's major task was to decide whether the stimulus was a geographical name or a biographical name.

2.1. Method

2.1.1. Stimuli

The stimuli were 45 geographical names and 45 biographical names (see the first table of Appendix A). All were of non-Mandarin origin and had been transliterated into Chinese characters in a conventional way. Fifteen of each type of names were two, three, and four characters in length. The mean word frequencies for the two-character names, the three-character names, and the four-character names were 5.93, 5.93, and 5.90 (per 2,100,000 character counts, based on combined frequency counts surveyed by Liu et al. (1975) and by Wu & Liu (1987)), respectively. Stimuli were shown to each participant once only and were presented to the LVF, to the RVF, and bilaterally equally often across participants. The names were vertically oriented and vertically centered. The midpoint of each item was 3.9° to the left or right of fixation. All items were 1.3° wide. The two-character, three-character, and four-character names were 2.5°, 4.0°, and 5.4° high, respectively. For all display conditions, a randomly chosen digit .35° wide and .70° high was simultaneously presented on the fixation point.

An additional set of nine geographical and nine biographical names of various lengths and various visual field conditions was prepared for practice trials.

2.1.2. Procedure

A 2 × 3 × 3 × 5 (Stimulus Type × Number of Characters × Visual Field × Trial) within group design was adopted, totaling 90 trials. All conditions were randomly mixed. The 90 trials were separated into three blocks of 30 trials and the block order was randomized across participants.

The stimuli were presented in a Gerbrands four-field tachistoscope (Gerbrands, Arlington, MA). Each trial consisted of the following sequence: a verbal ready signal given by the experimenter, a 500-ms presentation of a central cross serving as the fixation point, the test display for a fixed duration, and finally a checkerboard noise mask for 10 ms. The participant's task on each trial was to indicate as quickly and as accurately as possible whether the stimulus was a geographical name or a biographical name by pressing one of the two keys and then to verbally report the central digit. Half of the participants responded "geographical name" with the left hand and "biographical name" with the right, this being reversed for the remaining participants. To lower the possibility of pure guessing, if the participant had pressed the correct key, he or she was also asked to report the name. Participants almost always reported the name accurately. The order of digit report and name report was not prescribed. The participant was instructed to fixate at the central point of the visual field throughout the trial and was informed that the position of the stimulus would be random, and that any attempt to anticipate the occurrence would hinder performance. The importance of accurately reporting the digit was also emphasized. The mean error rate of digit naming was .06. Only trials with both accurate digit naming and accurate name report (after correct key pressing) were included in data analyses.

To keep performance equally far from the ceiling and the floor, the stimulus exposure duration was determined for each participant during the practice trials. In the practice session, the exposure duration was first set at 200 ms and was then adjusted by steps of 10 ms until the participant made one or two errors in five trials under the restriction that the duration never exceeded 200 ms. Once the exposure duration was set for a participant, it was maintained fixed during the experimental session. The median exposure duration across all participants was 200 ms, with a range of 70-200 ms.

2.1.3. Participants

Twenty-three students (15 men and 8 women) at National Tsing Hua University (NTHU), Hsinchu, Taiwan, served as volunteers. All were right-handed, as assessed by a short questionnaire, and had normal or corrected-to-normal vision.

2.2. Results

The results were analyzed separately for accuracy and latency. For each set of data, two analyses of variance (ANOVAs) were conducted, the first with participants treated as a random effect (F) and the second with items treated as a random effect (F_i). Given a source of variance, the F_i value (i.e., the result of the item analysis) is reported only if its corresponding F value (i.e., the result of the participant analysis) reached significance or was close to significance. Table 1 shows both the mean accuracy rates and the mean reaction times of the categorical judgment in the left, the right, and both visual fields for the two-, three-, and four-character names.

2.2.1. Accuracy rate

The mean accuracy rates were .75, .74, and .86 for the LVF, the RVF, and the both visual field (BVF) condition, respectively. The main effect of visual field was significant in both the participant analysis and the item analysis, $F(2,44) = 8.75$, $F_i(2,173) = 12.42$, p's $< .001$. But this was solely due to the fact that performance in the bilateral condition exceeded that in the unilateral conditions, $F(2,44) = 20.35$, $p < .005$. Performance in the two visual fields, however, did not differ, $F < 1$. The mean accuracy rates for the two-, three-, and four-character names were .81, .84 and. 70, respectively. The main effect of number of characters was significant in both the participant analysis and the item analysis, $F(2,44) = 24.15$, $F_i(2,87) = 5.67$, p's $< .005$. Further comparisons showed that performance for the two-character names and that for the three-character names did not differ, $F(2,44) = 2.13$, whereas performance for names of four characters long was worse than that for the two former groups, $F(2,44) = 28.59$, $p < .005$. The interaction between visual field and number of characters was not significant, $F < 1$.

2.2.2. Reaction time

The mean latencies were 1078, 1065, and 1025 ms for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was nonsignificant, $F(2,44) = 1.98$, $p > .10$. The mean latencies for the two-, three-, and four-character names were 1022, 1023, and 1123 ms, respectively. The main effect of number of characters was significant in both the participant analysis and the item analysis, $F(2,44) = 15.02$, $F_i(2,87) = 4.22$, p's $< .05$. Further comparisons showed that performance for the two-character names and that for the three-character names did not differ, $F(2,44) < 1$, whereas performance for names of four characters long was worse than that for the two former groups, $F(2,44) = 22.56$, $p < .005$. The interaction between visual field and number of characters was not significant, $F < 1$.

Both the accuracy data and the latency data showed that performance for four-character names was worse than that for two- and three-character names in the RVF, the LVF, and the BVF condition. No interaction between graphemic length and visual field was obtained. Experiment 2 looked for the interaction with basically the same set of stimuli but a target detection task was adopted.

3. Experiment 2: Multi-character names—target detection task

3.1. Method

3.1.1. Stimuli

The 45 geographical names and the 45 biographical names (15 of each type were two, three, and four characters in length) used in Experiment 1 served as test

Table 1
Mean accuracy rates and mean reaction times as a function of stimulus length and visual field in Experiments 1, 3, and 5

Stimulus	Accuracy rate			Reaction time		
	LVF	RVF	BVF	LVF	RVF	BVF
Experiment 1—Categorization task						
Two-character name	.76	.77	.90	1020	1057	990
Three-character name	.84	.80	.88	1062	1022	984
Four-character name	.66	.66	.78	1153	1115	1100
Experiment 3—Lexical decision task						
Monomorphemic word	.89	.86	.97	794	759	730
Trimorphemic word	.84	.90	.94	795	784	782
Experiment 5—Phrase completeness judgment task						
One-word phrase	.89	.88	.90	839	851	801
Two-word phrase	.73	.66	.71	920	943	1009
Three-word phrase	.56	.45	.54	1176	1157	1110

stimuli in the target-present condition. These 90 items were shown to each participant once only and were presented to the LVF, the RVF, and both visual fields equally often across participants. Furthermore, the first and the last constituent character of a name served as the target equally often across participants. To reduce the participant's tendency to pay exclusive attention to the initial and the final ends of an item, an additional set of 8 three-character geographical names, 8 three-character biographical names, 10 four-character geographical names, and 10 four-character biographical names was selected to serve as filler trials in which the center character (or one of the center characters) was the target. As a consequence, there were a total of 126 trials in the target-present condition, including 90 crucial trials and 36 filler trials. The 36 filler trials were equally distributed among the three visual field conditions.

The target-absent condition also consisted of 126 trials, the test stimuli of which included 15 two-character geographical names, 15 two-character biographical names, 23 three-character geographical names, 23 three-character biographical names, 25 four-character geographical names and 25 four-character biographical names. The 126 target-absent trials were equally distributed among the three visual field conditions. The target items in these trials were chosen from the constituent characters of all 252 test stimuli but characters peculiar to particular names were excluded.

The target item was presented on the fixation point and was 1.3° wide and 1.3° high. Stimulus cards for test stimuli consisted of the test item in either or both visual fields and a random digit on the fixation point, and were arranged in the same way as in Experiment 1. A separate set of cards was constructed along the same principles for practice trials.

3.1.2. Procedure

A $2 \times 2 \times 3 \times 3$ (Target Presence $\times$ Target Position $\times$ Number of Characters $\times$ Visual Field) within group design was adopted. All conditions were randomly mixed. The 252 trials were separated into six blocks of 42 trials and the block order was randomized across participants.

The stimuli were presented in a Gerbrands four-field tachistoscope. Each trial consisted of the following sequence: a verbal ready signal given by the experimenter, a 500-ms presentation of a central cross serving as the fixation point, the target display for 500 ms, the test display for 200 ms, and finally a checkerboard noise mask for 10 ms. The participant's task on each trial was to indicate as quickly and as accurately as possible whether the target was present in the test display or not by pressing one of the two keys and then to verbally report the central digit on the test display. Half of the participants responded "yes" with the left hand and "no" with the right, this being reversed for the remaining participants. The participant was instructed to fixate at the central point of the visual field throughout the trial and was informed that the position of the stimulus would be random, and that any attempt to anticipate the occurrence would hinder performance. The importance of accurately reporting the digit was also emphasized. The mean error rate of digit naming was less than .02. Only crucial trials in the target-present condition with both accurate key pressing and accurate digit naming were included in data analyses.

3.1.3. Participants

Twenty-three students (13 men and 10 women) at NTHU participated to fulfill a course requirement. None of them had participated in Experiment 1. All were right-handed, as assessed by a short questionnaire, and had normal or corrected-to-normal vision.

3.2. Results

The results were analyzed separately for accuracy and latency. Only performance for the 90 crucial trials in the target-present condition was included in analyses. Table 2 shows both the mean accuracy rates and the mean reaction times for detecting constituent characters as a function of target position, visual field, and number of characters.

3.2.1. Accuracy rate

The mean accuracy rates were .96 and .93 for the initial and the final target position, respectively. An item's first character was significantly easier to detect than its last character, $F(1,22) = 11.22$, $F_i(1,87) = 6.95$, p's $< .01$. The mean accuracy rates were .94, .94, and .96 for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was not significant, $F(2,44) = 1.71$, $p > .10$. The mean accuracy rates for the two-, three-, and four-character names were .96, .96, and .92, respectively. The main effect of graphemic length was significant, $F(2,44) = 10.35$, $F_i(2,87) = 6.19$, p's $< .005$, indicating that performance in the four-character condition was worse than that in the two other conditions.

The Visual Field $\times$ Target Position interaction was marginally significant for the participant analysis, $F(2,44) = 3.22$, $p < .05$, but was nonsignificant for the item analysis, $F_i(2,174) = 1.51$, $p > .20$. The mean accuracy rates for the initial and the final character detection were .97 and .90, respectively, in the LVF; were both .94 in the RVF; and were .98 and .94, respectively, in the BVF condition. Further comparisons showed that target position had no effect in the RVF but first characters were significantly easier to detect than last characters in the LVF condition, $F(1,66) = 18.30$, $p < .005$, and the BVF condition, $F(1,66) = 5.97$, $p < .05$. There

Table 2
Mean accuracy rates and mean reaction times as a function of target position, stimulus length and visual field in Experiments 2, 4, and 6

Target position	Accuracy rate						Reaction time					
	Initial			Final			Initial			Final		
Stimulus length	LVF	RVF	BVF	LVF	RVF	BVF	LVF	RVF	BVF	LVF	RVF	BVF
Experiment 2—Geographical and biographical names												
Two characters	.97	.95	1.0	.95	.92	.98	676	719	717	743	740	700
Three characters	.99	.99	.97	.92	.97	.91	694	720	692	750	777	713
Four characters	.93	.90	.96	.84	.92	.93	703	768	766	786	780	802
Experiment 4—Three-character words												
Monomorphemic	.96	.98	.99	.94	.93	.97	799	807	749	857	844	810
Trimorphemic	.92	.94	.99	.91	.94	.98	808	795	808	867	875	855
Experiment 6—Phrases												
Two words	.87	.90	.87	.85	.93	.89	881	897	855	890	919	948
Three words	.79	.86	.86	.77	.73	.87	926	968	926	952	968	1011

was no significant effect of visual field regardless of target position.

The Number of Characters × Visual Field interaction was significant, $F(4,88) = 2.64$, $F_i(4,174) = 2.76$, p's $< .05$. The mean accuracy rates for the two-, three-, and four-character names were .96, .96, and .89, respectively, in the LVF; were .93, .98, and .91, respectively, in the RVF, and were .99, .94, and .95, respectively, in the BVF condition. Further comparisons revealed the following: (1) In the LVF, the mean accuracy rate for the four-character names was significantly lower than that for the two other groups, $F(2,132) = 14.09$, $p < .005$. (2) In the RVF, the mean accuracy rate for the three-character names was significantly higher than the two other groups, $F(2,132) = 7.19$, $p < .05$. (3) In the BVF condition, the mean accuracy rate for the two-character names was significantly higher than the two other groups, $F(2,132) = 7.76$, $p < .05$. (4) Performance in the two visual fields did not differ from each other regardless of stimulus length. (5) Performance in the bilateral condition exceeded that in the unilateral conditions for names of two and four characters long, $F(2,132) = 7.00$ and $F(2,132) = 8.65$, respectively, p's $< .05$, but not for names of three characters long, $F(2,132) = 3.11$, $p > .05$. The Number of Characters × Target Position interaction and the three way interaction was not significant, F's < 1.

3.2.2. Reaction time

The mean latencies were 717 and 755 ms for the initial and final target position, respectively. The main effect of target position was significant, $F(1,22) = 25.45$, $F_i(1,87) = 11.47$, p's $< .005$. The mean latencies were 725, 751, and 732 ms for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was significant, $F(2,44) = 4.02$, $F_i(2,174) = 3.32$, p's $< .05$. Further comparison showed that target detection in the LVF was faster than that in the RVF, $F(2,44) = 7.88$, $p < .05$, and no other visual field difference was found. The interaction between visual field and target position was significant, $F(2,44) = 5.35$, $F_i(2,174) = 6.83$, p's $< .01$. The mean reaction times for the initial and final character detection were 691 and 760 ms, respectively, in the LVF, were 736 and 765 ms, respectively, in the RVF, and were 725 and 739 ms, respectively, in the BVF condition. Further comparisons showed that whereas target position had no effect in the BVF conditions, the initial character took significantly less time to detect than the final character in the LVF, $F(1,66) = 30.39$, $p < .005$, and in the RVF, $F(1,66) = 5.47$, $p < .05$. There was also a significant LVF advantage for the detection of initial characters, $F(1,88) = 12.64$, $p < .005$. No other visual field difference was observed.

The mean latencies for the two-, three-, and four-character names were 716, 724, and 767 ms, respectively. The main effect of number of characters was significant, $F(2,44) = 22.02$, $F_i(2,87) = 3.38$, p's $< .05$. Further comparisons showed that the mean latency for four-character names was significantly longer than that for two- and three-character names, $F(2,44) = 26.57$, $p < .005$, whereas mean latencies for the latter two groups did not differ. The Number of Characters × Visual Field interaction and the Number of Characters × Target Position interaction were not significant, $F(4,88) = 2.33$ and $F < 1$, respectively, p's $> .05$. The three-way interaction was not significant, either, $F = 1$.

The implications of these results will be further discussed in a later section.

4. Experiment 3: Three-character words—lexical decision task

As previous studies mainly examined possible effects of graphemic length in each visual field, Experiments 3 and 4 tried to find out whether length of meaning (i.e., number of constituent morphemes) could also differentially affect performance in the two visual fields. Experiment 3 used a lexical decision task and Experiment 4, a target detection task.

4.1. Method

4.1.1. Stimuli

The stimuli were 60 three-character words and 60 three-character pseudowords. The 60 words included 30 monomorphemic words and 30 trimorphemic words (see the second table of Appendix A). The mean word frequencies were 3.8 and 3.7 per 2,100,000 character counts for the monomorphemic words and the trimorphemic words, respectively (Liu et al., 1975; Wu & Liu, 1987). Thirty of the pseudowords were constructed by exchanging a constituent character of two monomorphemic words so that they were in accord with morphological rules of monomorphemic words. For example, the pseudoword 滑斯盧 was derived from the two monomorphemic source words, 滑鐵盧 [*hua-tie-lu*]. meaning *Waterloo* or *waterloo*, and 開斯米 [*kai-si-mi*], meaning *cashmere*. The other 30 of the pseudowords were constructed by exchanging a constituent morpheme of two trimorphemic words so that they were in accord with morphological rules of trimorphemic words. For example, the pseudoword 無機形 was derived from the two trimorphemic source words, 無機物 [*wú-ji-wù*], meaning *inorganic substance*, and 正方形 [*zheng-fang-xing*], meaning *regular square shape*. The real words that served as stimuli and the source words from which the pseudowords were derived did not overlap. All stimuli were shown to each participant once only. The 60 words were presented to the LVF, the RVF, and both visual fields equally often across participants. All stimuli were vertically oriented and vertically centered. The midpoint of each item was 3.9° to the left or right of fixation. All items were 1.3° wide and 4.0° high. The randomly-selected digit, .35° wide and .70° high, was simultaneously presented on the fixation point. An additional set of 10 words and 10 pseudowords was prepared for practice trials.

4.1.2. Procedure

A $2 \times 2 \times 3 \times 10$ (Lexicality × Number of Morphemes × Visual Field × Trial) within group design was adopted, totaling 120 trials. The 120 trials were separated into two blocks according to the number of morphemes. Trials within each block were presented in a random order and the block order was randomized across participants.

The apparatus and the procedure were the same as in Experiment 1. Each trial consisted of the following sequence: a verbal ready signal, a fixation point for 500 ms, the test display for a fixed duration, and finally a noise mask for 10 ms. The participant's task on each trial was to indicate as quickly and as accurately as possible whether the stimulus was a word by pressing one of the two keys and then to verbally report the central digit. To lower the possibility of pure guessing, if the participant had indicated that the word was real, he or she was also asked to report the word. Participants almost always reported the word accurately. The order of digit naming and word naming was not prescribed. The mean error rate of digit naming was less than .03. Only trials with both accurate digit naming and accurate word naming (after correct key pressing) were included in data analyses.

The stimulus exposure duration was determined in the same way as in Experiment 1. The median exposure duration across all participants was 110 ms, with a range of 90–200 ms.

4.1.3. Participants

Twenty-two students (13 men and 9 women) at NTHU served as volunteers. None had participated in Experiments 1 and 2. All were right-handed, as assessed by a short questionnaire, and had normal or corrected-to-normal vision.

4.2. Results

Only the 60 real word trials were included in analyses. Separate ANOVAs were conducted for accuracy and latency. The mean proportions of correct decision and the mean decision latencies are listed in Table 1 as a function of number of morphemes and visual field.

4.2.1. Accuracy rate

The mean accuracy rates were .86, .88, and .95 for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was significant, $F(2,42) = 10.74$, $F_i(2,116) = 9.46$, p's $< .005$. Further analyses showed that bilaterally presented words were easier to identify than unilaterally presented words, $F(2,42) = 7.22$ and $F_i(2,116) = 8.97$, p's $< .05$, and that performance in the two unilateral conditions did not differ, $F < 1$. The mean accuracy rates were .91 and .89 for the monomorphemic and the trimorphemic words, respectively. The main effect of number of morphemes was not significant, $F(1,21) = 1.43$, $p > .10$.

There was a significant Number of Morphemes × Visual Field interaction for the participant analysis, $F(2,42) = 4.98$, $p < .05$, but this interaction was not significant for the item analysis, $F_i(2,116) = 1.92$, $p > .10$. The mean accuracy rates for monomorphemic words were .89, .86, and .97 in the LVF, the RVF, and the BVF condition, respectively; the BVF performance exceeded the LVF performance, $F(2,105) = 8.28$, $p < .05$, while performance in the LVF and the RVF did not differ. The mean accuracy rates for trimorphemic words were .84, .90, and .94 in the LVF, the RVF, and the BVF condition, respectively; no significant difference was found between any two visual field conditions but performance in the BVF condition exceeded that of the two unilateral conditions taken together, $F(2,105) = 8.45$, $p < .05$. Such differential degree of tendency to bilateral advantage solely accounted for the significant two-way interaction. No length effect was found in any of the viewing conditions.

4.2.2. Reaction time

The mean reaction times were 794, 771, and 756 ms for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was not significant, $F(2,42) = 2.01$, $p > .10$. The mean reaction times were 761 and 787 ms for monomorphemic and trimorphemic words, respectively. The main effect of number of morphemes was not significant, $F(1,21) = 3.36$, $p > .08$. The Number of Morphemes × Visual Field interaction was also nonsignificant, $F < 1$.

5. Experiment 4: Three-character words—target detection task

5.1. Method

5.1.1. Stimuli

The 30 monomorphemic words and 30 trimorphemic words used in Experiment 3 served as test stimuli in the target-present condition. These 60 words were shown to each participant once only and were presented to the LVF, the RVF, and both visual fields equally often across participants. Furthermore, the first and the last constituent character of a word served as the target equally often across participants. To reduce the participant's tendency to pay exclusive attention to the initial and the final ends of a word, an additional set of 15 monomorphemic words and 15 trimorphemic words was selected to serve as filler trials in which the center character was the target. As a consequence, there were 90 trials in the target-present condition, including 60 crucial trials and 30 filler trials. The 30 filler trials were equally distributed to the three visual field conditions.

The target-absent condition also consisted of 90 trials, the test stimuli of which included 45 monomorphemic words and 45 trimorphemic words, all of three characters long. The 90 target-absent trials were equally distributed to the three visual field conditions. The target items in the target-absent condition were chosen from the constituent characters of all 180 test words but characters peculiar to particular words were excluded.

The target item was presented on the fixation point and was 1.3° wide and 1.3° high. Stimulus cards for test stimuli consisted of the test item in either or both visual fields and a random digit on the fixation point, and were arranged in the same way as in Experiment 3. A separate set of cards was constructed along the same principles for practice trials.

5.1.2. Procedure

A 2 × 2 × 2 × 3 (Target Presence × Target Position × Number of Morphemes × Visual Field) within group design was adopted. The 180 trials were separated into two blocks according to the number of morphemes. Trials within each block were presented in a random order and the block order was randomized across participants.

The apparatus and the procedure were the same as for Experiment 2. Each trial consisted of a verbal ready signal, a 500-ms fixation point, a 500-ms target display, a 200-ms test display, and finally a 10-ms noise mask. The participant's task on each trial was to indicate as quickly and as accurately as possible whether the target character appeared in the test display by pressing one of the two keys and then to verbally report the central digit. The mean error rate of digit naming was less than .03. Only trials with both accurate key pressing and accurate digit naming were included in data analyses.

5.1.3. Participants

Twenty-four students (13 men and 11 women) at NTHU served as volunteers. None had participated in the previous experiments. All were right-handed, as assessed by a short questionnaire, and had normal or corrected-to-normal vision.

5.2. Results

Only the 60 crucial trials in the target-present condition were included in analyses. Separate ANOVAs were conducted for accuracy and latency. The mean proportions of correct decision and the mean decision latencies are listed in Table 2 as a function of target position, number of morphemes, and visual field.

5.2.1. Accuracy rate

The mean accuracy rates were .96 and .95 for initial and final character detection, respectively. The main effect of target position was nonsignificant, $F(1,23) = 2.05$, $p > .10$. The mean accuracy rates were .93, .95, and .98 for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was significant, $F(2,46) = 5.32$, $F_i(2,116) = 6.65$, p's $< .01$. Further comparisons showed that performance in the BVF condition exceeded that in the unilateral conditions, $F(2,46) = 9.31$, $p < .05$, but performance in the two visual fields did not differ. The mean accuracy rates were .96 and .95 for monomorphemic and trimorphemic words, respectively, The main effect of number of morphemes was nonsignificant, $F(1,23) = 1.42$, $p > .10$. The two- and three-way interactions were all nonsignificant, F's < 1.

5.2.2. Reaction time

The mean reaction times were 794 and 851 ms for initial and final character detection, respectively, the former being significantly faster than the latter, $F(1,23) = 23.69$, $F_i(1,58) = 8.50$, p's $< .01$. The mean reaction times were 833, 831, and 805 ms for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was not significant, $F(2,46) = 2.80$, $p > .07$. The mean reaction times were 811 and 835 ms for monomorphemic and trimorphemic words, respectively. The main effect of number of morphemes was nonsignificant, $F < 1$.

The Number of Morphemes × Visual Field interaction was not significant, $F(2,46) = 2.32$, $p > .10$. The Target Position × Visual Field interaction, the Target Position × Number of Morphemes interaction, and the three-way interaction were also nonsignificant, F's < 1.

6. Experiment 5: Phrases—completeness judgment task

Suppose that differential length effects in the two visual fields really exist and that the effective variable could be either graphemic length or length of meaning. Failure to observe a Length × Visual Field interaction in previous experiments could then be attributed to a lack of power of the experimental tasks. If both graphemic length and length of meaning increase hand in hand, additive effects might be expected to surface. Experiments 5 and 6 thus manipulated length in terms of both number of graphemic units and that of meaning units. Since length of compound words cannot be adequately manipulated, length of phrases defined in terms of number of constituent words were manipulated instead.

6.1. Method

6.1.1. Stimuli

The stimuli included 72 phrases and 72 pseudophrases. Among the 72 phrases, 24 were made up of one word and were of one character long, 24 were made up of two words and were of two characters long, and the remaining 24 were made up of three words and were of three characters long (see the third table of Appendix A). The mean word frequencies for the one-word phrases, the two-word phrases, and the three-word phrases were 455, 478, and 553 per 2,100,000 character counts, respectively (Liu et al., 1975; Wu & Liu, 1987). The pseudophrases obeyed syntactic rules but violated morphological rules by preserving word orders while omitting an affix in at least one constituent word. Among the 72 pseudophrases, 24 were made up of a single character, which either represents a bound morpheme that cannot serve as a word, or represents a word that cannot be said alone in modern Mandarin. For example, the character 很 [*hen*], meaning *very*, cannot be uttered alone without a succeeding adjective. In contrast with 很, 很多 [*hen duo*], meaning *very much*, is a sentence. Another 24 pseudophrases were composed of two characters that together would convey a meaning but do not form an acceptable fragment of speech. For example, the two characters 丟 [*diu*], meaning *throw*, and 石 [*shi*], meaning *stone*, hinted a meaning that is the sum of the two but they do not represent a phrase because a suffix 頭 [*tou*] is missing. The intact form is 丟石頭 [*diu shitou*], meaning *throw a stone* or *throw stones*. The remaining 24 pseudophrases were composed of three characters that suggested a meaning but were distorted in morphological forms. For example, the combination of the three characters 別 [*bie*], meaning *don't*, 講 [*jiang*]. meaning *tell*, and 謊 [*huang*], meaning *lie*, hinted a meaning. However, the right way to say it is either 別講謊話 [*bie jiang huanghua*], meaning *don't tell lie-word* or 別說謊 [*bie shuohuang*], meaning *don't lie.*

Stimuli were shown to each participant once only and were presented to the LVF, the RVF, and both visual fields equally often across participants. All items were vertically oriented and vertically centered. The midpoint of each item was 3.5° to the left or right of fixation. All items were .70° wide. The one-, two-, and three-character items were .9°, 1.9°, and 2.8° high. A randomly chosen digit .35° wide and .70° high was simultaneously presented on the fixation point.

An additional set of 60 items, 10 for each type of phrases and 10 for each type of pseudophrases, was constructed for practice trials.

6.1.2. Procedure

A 2 × 3 × 3 × 8 (Acceptability × Number of Words × Visual Field × Trial) within group design was adopted, totaling 144 trials, the order of which was completely randomized across participants.

The stimuli were presented on a computer screen. Each trial consisted of the following sequence: a beep as a signal for ready, a 500-ms presentation of a central cross serving as the fixation point, the test display for 200 ms, and finally a patterned mask covering the stimulus area in both visual fields for 10 ms. The participant's task on each trial was to indicate as quickly and as accurately as possible whether the stimulus was acceptable as a phrase by pressing one of the two keys and then to verbally report the central digit. The mean error rate of digit naming was .05. To lower the possibility of pure guessing, if the participant had indicated that the stimulus was a phrase, he or she was also asked to report the phrase. Participants almost always reported the phrase accurately. Only trials with both accurate digit naming and accurate phrase report (after correct key pressing) were included for data analyses. Detailed aspects of the procedure were the same as for Experiments 1 and 3.

6.1.3. Participants

Twenty-two students (11 men and 11 women) at NTHU participated for a small payment. None had participated in the previous experiments. All were right-handed, as assessed by a short questionnaire, and had normal or corrected-to-normal vision.

6.2. Results

Only the 72 trials for acceptable phrases were included in analyses. Separate ANOVAs were conducted for accuracy and latency. The mean proportions of correct decision and the mean decision latencies are listed in Table 1 as a function of phrase length and visual field.

6.2.1. Accuracy rate

The mean accuracy rates were .73, .66, and .72 for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was not significant, $F(2,42) = 1.77$, $p > .10$. The mean accuracy rates were .89, .70, and .52 for the one-, two-, and three-word phrases, respectively. The main effect of number of words was significant, $F(2,42) = 80.87$, $F_i(2,69) = 31.67$, p's $< .001$. Further comparisons showed that the accuracy rate for one-word phrases was higher than that for two-word phrases, $F(2,42) = 42.08$, which in turn was higher than that for three-word phrases, $F(2,42) = 37.77$, p's $< .001$. The interaction between number of words and visual field was not significant, $F < 1$.

6.2.2. Reaction time

The mean reaction times were 978, 984, and 973 ms for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was not significant, $F < 1$. The mean reaction times were 830, 957, and 1148 ms for the one-, two-, and three-word phrases, respectively. The main effect of number of words was significant, $F(2,42) = 119.21$, $F_i(2,69) = 46.63$, p's $<$ .001. Further comparisons showed that the decision latency for three-word phrases was longer than that for two-word phrases, $F(2,42) = 85.11$, which in turn was longer than that for one-word phrases, $F(2,42) = 37.63$, p's $< .001$.

The interaction between number of words and visual field was significant for the participant analysis, $F(4,84) = 3.85$, $p < .01$, but was not significant for the item analysis, $F_i(4,138) = 1.87$, $p > .10$. Further analyses revealed no significant simple main effect of visual field regardless of phrase length, F's < 1. The decision latency for three-word phrases was significantly longer than that for two-word phrases in all visual field conditions, $F(2,126) = 59.45$, $F(2,126) = 41.54$, and $F(2,126) = 9.25$, for the LVF, the RVF, and the BVF conditions, respectively, p's $< .05$. The decision latency for two-word phrases was significantly longer than that for one-word phrases in the RVF and the BVF conditions, $F(2,126) = 7.68$, and $F(2,126) = 39.25$, respectively, p's $< .05$; a similar tendency in the LVF condition was close to significance, $F(2,126) = 5.95$, $p < .057$. Both analyses of main effects and analyses of the interaction revealed parallel findings.

7. Experiment 6: Phrases—target detection task

7.1. Method

7.1.1. Stimuli

The 24 two-word phrases and the 24 three-word phrases used in Experiment 5 served as test stimuli in the target-present condition. The two-word phrases and the three-word phrases were of two and three characters long, respectively. These 48 phrases were shown to each participant once only and were presented to the LVF, the RVF, and both visual fields equally often across participants. Furthermore, the first and the last constituent character of an item served as the target equally often across participants. To reduce the participant's tendency to pay exclusive attention to the initial and the final ends of a phrase, an additional set of 12 three-word phrases was selected to serve as filler trials in which the center character was the target. The 12 filler trials were equally distributed to the three visual field conditions. As a consequence, there were a total of 60 trials in the target-present condition.

The target-absent condition also consisted of 60 trials, the test stimuli of which included 24 two-word phrases (each of two characters long) and 36 three-word phrases (each of three characters long). The 60 target-absent trials were equally distributed to the three visual field conditions. The target items in the target-absent condition were chosen from the constituent characters of all 120 test stimuli.

The target item was presented on the fixation point and was .7° wide and .9° high. The test display that followed consisted of the test item in either or both visual fields and a random digit on the fixation point, and was arranged in the same way as in Experiment 5. A separate set of stimuli was constructed along the same principles for practice trials.

7.1.2. Procedure

A $2 \times 2 \times 2 \times 3$ (Target Presence $\times$ Target Position $\times$ Number of Words $\times$ Visual Field) within group design was adopted. The order of the 120 trials was completely randomized across participants.

The stimuli were presented on a computer screen. The general procedure was the same as for Experiments 2 and 4. Each trial consisted of the following sequence: a beep as a signal for ready, a fixation point for 500 ms, the target display for 500 ms, the test display for 200 ms, and finally a patterned mask covering the stimulus area in both visual fields for 10 ms. The participant's task on each trial was to indicate as quickly and as accurately as possible whether the target character appeared in the test display by pressing one of the two keys and then to verbally report the central digit. Mean error rate of digit naming was less than .04. Only trials with both accurate key pressing and accurate digit naming were included for data analyses.

7.1.3. Participants

Twenty-one students (10 men and 11 women) at NTHU participated for a small payment. None had participated in the previous experiments. All were right-handed, as assessed by a short questionnaire, and had normal or corrected-to-normal vision.

7.2. Results

Only the 48 crucial trials in the target-present condition were included in analyses. Separate ANOVAs were conducted for accuracy and latency. The mean proportions of correct decision and the mean decision latencies are listed in Table 2 as a function of target position, phrase length, and visual field.

7.2.1. Accuracy rate

The mean accuracy rates were .86 and .84 for initial and final character detection, respectively. The main effect of target position was not significant, $F(1,20) = 1.14$, $p > .10$. The mean accuracy rates were .82, .86, and .87 for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was not significant, $F(2,40) = 2.32$, $p > .10$. The mean accuracy rates were .88 and .81 for two- and three-word phrases, respectively. Performance for two-word phrases was significantly better than that for three-word phrases for the participant analysis, $F(1,20) = 17.25$, $p < .005$, but not for the item analysis, $F_i(1,46) = 3.51$, $p > .05$. The two- and three-way interactions were all nonsignificant.

7.2.2. Reaction time

The mean reaction times were 909 and 950 ms for initial and final character detection, respectively, the former being significantly faster than the latter, $F(1,20) = 5.62$, $F_i(1,46) = 4.41$, p's $< .05$. The mean reaction times were 915, 938, and 935 ms for the LVF, the RVF, and the BVF condition, respectively. The main effect of visual field was not significant, $F < 1$. The mean reaction times were 900 and 958 ms for two- and three-word phrases, respectively, the former being significantly shorter than the latter, $F(1,20) = 19.50$, $F_i(1,46) = 9.76$ p's $< .005$. The two- and three-way interactions were all nonsignificant.

8. General discussion

Recall that Young and Ellis (1985; Ellis et al., 1988) observed a Length × Visual Field interaction when words were presented but failed to obtain such an interaction when pseudowords were presented, and that they accordingly proposed differential modes of word recognition in the two hemispheres. Words were said to be recognized as a unitary whole by the LH but could only be encoded in a serial manner by the RH. Let us now examine results of the three experiments that adopted a global task (i.e., Experiments 1, 3, and 5). Each of these experimental tasks required access of lexical knowledge. The summarized results are shown in Table 3. Only effects that were significant in both the participant analysis and the item analysis are listed.

First, there was a length effect in Experiment 1, where shorter foreign names were processed faster and more accurately than names that were unusually long (i.e., four characters or four syllables in length). Second, no length effect was found in Experiment 3, where all words of three characters long were equally easy to process, regardless of the number of constituent morphemes involved. This finding was in agreement with Batt, Underwood, and Bryden's (1995) observations that morphemic structure of unilaterally presented words did not affect the pattern of visual attention (measured in terms of fixation durations and gaze duration). In their study, stimuli were either monomorphemic words or bimorphemic words and morphemic length did not interact with visual field. As previously mentioned, number of syllables did not affect performance (Young & Ellis, Experiment 4). Findings in Experiments 1 and 3 were thus in agreement with Young and Ellis' speculation that, if a word length effect was ever found, the length in question was likely graphemic in nature. Third, a length effect was observed in Experiment 5, where more words took longer and were more difficult to process. This is in agreement with the notion that words are the unit of lexical access. And fourth, in each of these three experiments, whether length effects were present or not, parallel results were found in both the LVF and the RVF, and for both accuracy data and reaction time data. None of these experiments revealed an interaction between visual field and length, no matter how length was defined. In the scope of conventional experimental paradigms, the Length × Visual Field interaction has not once been replicated with vertically presented Chinese items.

If we consider all four experiments that have ever been done to compare Chinese words of various graphemic lengths, we observe either a length effect or an effect of visual field, but never both. In two of the four experiments, length varied from 2 to 5 characters. Items of fewer characters were identified better and faster, but no visual field effect was found. Mean word frequency in

Table 3
Summarized findings of Experiments 1, 3, and 5

Experiment	1	3	5
Task	Categorization	Lexical decision	Completeness judgment
Length	2, 3, 4 characters	1, 3 morphemes	1, 2, 3 words
VF effect			
Accuracy	BVF > LVF = RVF	BVF > LVF = RVF	None
RT	None	None	None
Length effect			
Accuracy	2 = 3 > 4 characters	None	1 > 2 > 3 words
RT	2 = 3 < 4 characters	None	1 < 2 < 3 words
Interaction			
Accuracy	None	None	None
RT	None	None	None

these two experiments was 1.65 (Fang, 1994, Experiment 1) and 5.92 (current study, Experiment 1), respectively. In the other two experiments, comparison was made between two- and four-character words (Fang, 1994, Experiment 2) or between one- and two-character words (Fang, 1997, Experiment 4), and an RVF advantage was all that was found. The mean word frequency was 15.35 in the former experiment and was 24.33 in the latter. The importance of word frequency outweighed that of word length. Familiar words seemed to be processed as a unitary whole in both hemispheres only the left hemisphere was more efficient, while unfamiliar words seemed to be processed character-by-character in both hemispheres with equal efficiency. Familiar (likely earlier-acquired) words lateralized toward the left hemisphere while unfamiliar (likely later-acquired) words did not lateralize (cf. Wuillemin, Richardson, & Lynch, 1994). What might have triggered different modes of word recognition was more likely the frequency (or the age of acquisition) of the word instead of the cerebral hemisphere involved. Hemisphere-dependent modes of lexical access were not found.

For a long time linguists debated whether a distinction can be made at all between Chinese compound words and Chinese phrases and various linguistic attempts have been made (Zhou, Ostrin, & Tyler, 1993). This series of studies adds a behavioral criterion to the word-phrase distinction. As previously observed, highly familiar compound words yielded a right visual field advantage but no word length effect. In contrast, Experiment 5 in this study showed that Chinese phrases made of highly familiar words (with a mean word frequency of 498.33) yielded a phrase length effect but no visual field effect.

Let us now examine whether differential length effects occurred in the two visual fields if a local task rather than a conventional global task was adopted. The summarized results of the three experiments that adopted a target detection task (i.e., Experiments 2, 4, and 6) are shown in Table 4. Only effects that were significant in both the participant analysis and the item analysis are listed. Now that participants were asked to detect constituent characters of vertically presented words or phrases, the amount of the advantage of initial character detection over final character detection was also calculated and compared among conditions. The amount of this top–bottom difference or first-character advantage was calculated by subtracting the accuracy score of final character detection from that of initial character detection, and by subtracting the latency score of initial character detection from that of final character detection. It represents a difference score and is denoted as *D* in Table 4. Respective *D* values can be calculated from Table 2. The bottom part of Table 4 shows the results of planned comparisons made for each type of stimuli in Experiments 2, 4, and 6.

Since interactions were obtained only in Experiment 2, let us first look at the results of Experiments 4 and 6. In Experiment 4, the target character represented either the first (or the last) syllable of a monomorphemic, trisyllabic word or the first (or the last) morpheme of a trimorphemic word. Whether the target represented a syllable or a morpheme did not make any difference, since length did not have an effect and did not interact with visual field or with target position. Although the first character was detected faster than the last character, the amount of the first-character advantage did not differ in the two visual fields, $t(88) = 1.27$, $p > .05$ for both monomorphemic words and trimorphemic words. The results of Experiments 3 and 4 consistently showed that the two hemispheres recognized words with equal efficiency. One is not able to make a parallel-serial distinction nor a global–local distinction between the two hemispheres.

In Experiment 6, the target was either the first word or the last word in a phrase. Although target detection was generally slower in three-word phrases than in two-word phrases, length of phrase did not interact with visual field or with target position. Although initial words were detected faster than final words, such ten-

Table 4
Summarized findings of Experiments 2, 4, and 6

Experiment	2	4	6
Task	Target detection	Target detection	Target detection
Length	2, 3, 4 characters	1, 3 morphemes	2, 3 words
Target position			
Accuracy	Initial > Final	None	None
RT	Initial < Final	Initial < Final	Initial < Final
VF effect			
Accuracy	None	BVF > LVF = RVF	None
RT	LVF < RVF	None	None
Length effect			
Accuracy	2 = 3 > 4 characters	None	None
RT	2 = 3 < 4 characters	None	2 < 3 words
Interaction			
Accuracy	LVF: 2 = 3 > 4 characters RVF: 3 > 2 = 4 characters BVF: 2 > 3 = 4 characters 2, 4 characters: BVF > LVF = RVF 3 characters: BVF = LVF = RVF	None	None
Interaction			
RT	LVF, RVF: Initial < Final BVF: Initial = Final Initial: LVF < RVF Final: LVF = RVF	None	None
Amount of first-character advantage (D)			
Accuracy	Two-character: $D_{LVF} = D_{RVF}$ Three-character: $D_{LVF} > D_{RVF}$ Four-character: $D_{LVF} > D_{RVF}$	One-morpheme: $D_{LVF} = D_{RVF}$ Three-morpheme: $D_{LVF} = D_{RVF}$	Two-word: $D_{LVF} = D_{RVF}$ Three-word: $D_{LVF} < D_{RVF}$
RT	Two-character: $D_{LVF} > D_{RVF}$ Three-character: $D_{LVF} = D_{RVF}$ Four-character: $D_{LVF} > D_{RVF}$	One-morpheme: $D_{LVF} = D_{RVF}$ Three-morpheme: $D_{LVF} = D_{RVF}$	Two-word: $D_{LVF} = D_{RVF}$ Three-word: $D_{LVF} = D_{RVF}$

dency remained equal for both visual fields, t's < 1 for two- and three-word phrases. Although accuracy data revealed no main effect of target position, the last word in three-word phrases was least accurately detected in the RVF, resulting in greater first-word advantage in the RVF, $t(88) = 2.18$, $p < .05$. Suppose that a target detection task did not require lexical access and suppose that lexical access nevertheless automatically happened. Given phrases made of two or three words, lexical access to multiple entries were likely to occur. Although the two hemispheres performed equally well in general, the greater D value in the RVF nevertheless hinted that the LH allocated processing resource less evenly across visual words or lexical entries, in opposite to previous findings with words and nonsense strings. Although it is considered notoriously difficult to make a distinction between a compound word and a phrase, Experiments 5 and 6 consistently showed that a phrase behaved differently from a word, at both the global level and the local level.

In a series of five experiments summarized above, the RH did not show a stronger tendency to adopt a serial strategy upon dealing with tasks that were more or less associated with word recognition or lexical access. Likely word recognition tasks adopted in average laboratory situations are not serially demanding in nature. However, when participants were forced to perform a serial verbal task that demanded unusually high sequential resolution, it was the LH that was consistently better at stringing letters into words (Tzeng & Wang, 1984). It is unlikely that the kind of Length × VF interaction we have been looking for, if found, can provide valid argument for differential modes of word recognition in the two hemispheres.

The results of Experiment 2 were quite consistent with those of studies using CVC and CCC strings (Eng & Hellige, 1994; Hellige et al., 1989; Luh & Levy, 1995). First, initial characters were detected more accurately than final characters in the LVF as well as in the RVF, and such tendency is stronger in the LVF, $t(88) = 2.24$, $p < .05$, and $t(88) = 4.92$, $p < .001$, for three- and four-character names, respectively, although $t < 1$ for two-character names. Second, initial characters were detected faster than final characters in the LVF as well as in the RVF, and such tendency was also stronger in the LVF, $t(88) = 2.76$, $p < .01$, and $t(88) = 4.26$,

$p < .001$, for two- and four-character names, respectively, although $t < 1$ for three-character names. Third, target detection was less accurate when the target was embedded in longer names, and this length effect was more consistent in the LVF. Target detection also took longer when the target was embedded in longer names, but length and visual field did not interact in reaction time data.

If the above findings were related to differential modes of lexical access in the two hemispheres, what was observed in a target detection task should have been more obvious in a semantic categorization task, but this was not the case. Moreover, what was observed with proper names should have been more obvious with words and phrases, but this was not the case, either. Length and target position interacted with visual field only when lexical access was least involved in this series of six experiments. It is therefore unlikely that differential length effects in the two visual fields would imply differential word recognition modes in the two hemispheres.

If the findings in Experiment 2 and the findings of studies using CVC and CCC strings (Eng & Hellige, 1994; Hellige et al., 1989; Luh & Levy, 1995) were associated with differential efficiency of processing local elements in the two hemispheres, participants obviously did not treat the embedding structures of words and phrases in the same way they treated other signs that possess a hierarchical organization. First, while greater top–bottom difference in the LVF was observed for English letter strings and Chinese foreign names, the *D* scores remained equal in the two visual fields for three-character words and phrases. Second, when the *D* score did differ in the two visual fields when phrases served as stimuli, it was the RVF that yielded a greater *D* score. Although Chinese foreign names and English letter strings are different from each other in many ways, they are similar in one way: their constituent elements convey only sound but no meaning. And they are different from words in a similar way: they do not qualify as a good member in the lexicon. Although proper names can be used to refer while nonsense strings cannot, they both lack a meaning or sense, which words other than proper names have. A finding concerning how each of the two hemispheres deals with a multi-element display therefore is better confined to nonlexical signs.

Appendix A

The two-, three-, and four-character names used in Experiments 1 and 2

Geographical names			Biographical names		
Chinese	English	Frequency	Chinese	English	Frequency
Two-character condition (mean = 5.93, SD = 6.34, Md = 4)					
蒙古	Mongolia	26	牛頓	Newton	25
約旦	Jordan	14	甘地	Gandhi	8
捷克	Czechoslovakia	12	林肯	Lincoln	8
開羅	Cairo	10	蕭邦	Chopin	7
雅典	Athens	6	杜威	Dewey	7
丹麥	Denmark	6	列寧	Lenin	5
挪威	Norway	6	但丁	Dante	3
秘魯	Peru	5	巴哈	Bach	2
芬蘭	Finland	4	拜倫	Byron	2
敦煌	Tunhuang	4	哥德	Goethe	2
華沙	Warsaw	4	海頓	Haydn	2
爪哇	Java	3	尼采	Nietzsche	2
肯亞	Kenya	1	沙特	Sartre	2
拉薩	Lhasa	0	梵谷	Van Gogh	2
長崎	Nagasaki	0	塞尚	Cézanne	0
Three-character condition (mean = 5.93, SD = 5.77, Md = 3.5)					
夏威夷	Hawaii	19	達爾文	Darwin	18
土耳其	Turkey	19	貝多芬	Beethoven	13
芝加哥	Chicago	13	愛迪生	Edison	10
蘇格蘭	Scotland	12	哥白尼	Copernicus	9
阿富汗	Afghanistan	11	俾斯麥	Bismarck, von	5
匈牙利	Hungary	6	艾森豪	Eisenhower	5

Appendix A (*continued*)

Geographical names			Biographical names		
Chinese	English	Frequency	Chinese	English	Frequency
威尼斯	Venice	5	忽必烈	Kublai (Khan)	3
慕尼黑	Munich	4	伽利略	Galileo	2
尼泊爾	Nepal	4	黑格爾	Hegel	2
高加索	Caucasia	2	海明威	Hemingway	2
牙買加	Jamaica	2	畢卡索	Picasso	2
雅加達	Jakarta	1	柏拉圖	Plato	2
邁阿密	Miami	1	史懷哲	Schweitzer	2
諾曼第	Normandy	1	泰戈爾	Tagore	2
溫哥華	Vancouver	0	笛卡兒	Descartes	1
Four-character condition (Mean = 5.90, SD = 5.92, Md = 3.5)					
馬來西亞	Malaysia	25	愛因斯坦	Einstein	19
西伯利亞	Siberia	16	戈巴契夫	Gorbachev	11
巴基斯坦	Pakistan	13	莎士比亞	Shakespeare	11
南斯拉夫	Yugoslavia	10	希區考克	Hitchcock	8
阿拉斯加	Alaska	6	阿拉法特	Arafat	5
哥倫比亞	Colombia/Columbia	6	馬克吐溫	Mark Twain	4
澳大利亞	Australia	5	墨索里尼	Mussolini	4
尼加拉瓜	Nicaragua	4	富蘭克林	Franklin	3
瓜地馬拉	Guatemala	3	佛洛依德	Freud	3
耶路撒冷	Jerusalem	3	蘇格拉底	Socrates	3
加爾各答	Calcutta	2	阿基米德	Archimedes	2
格林威治	Greenwich	2	馬可波羅	Marco Polo	2
薩爾瓦多	El Salvador	2	托爾斯泰	Tolstoy	2
蘇門答臘	Sumatra	2	麥克阿瑟	MacArthur	1
蒙地卡羅	Monte Carlo	0	海倫凱勒	Helen Keller	0

The monomorphemic and trimorphembic words used in Experiments 3 and 4

Stimulus	Gloss	Frequency	Stimulus	Gloss	Frequency
Monomorphemic condition (mean = 3.8, SD = 4.73, Md = 1.5)					
高爾夫	Golf	18	安琪兒	Angel	1
荷爾蒙	Hormone	16	比基尼	Bikini	1
麥當勞	McDonalds	11	白蘭地	Brandy	1
模特兒	Model	10	卡路里	Calorie	1
海洛因	Heroin	9	歐巴桑	Madam	1
巧克力	Chocolate	8	蒙太奇	Montage	1
康乃馨	Carnation	7	保麗龍	Styrofoam	1
馬拉松	Marathon	4	烏托邦	Utopia	1
維他命	Vitamin	4	凡士林	Vaseline	1
咖啡因	Caffeine	3	華爾滋	Waltz	1
尼古丁	Nicotine	3	威士忌	Whisky	1
鬱金香	Tulip	3	壓克力	Acrylic fiber	0
伏特加	Vodka	3	蒲公英	Dandelion	0
麥克風	Microphone	2	木乃伊	Mummy	0
三明治	Sandwich	2	沙其馬	A kind of pastry	0
Trimorphemic condition (mean = 3.7, SD = 3.91, Md = 2)					
獎學金	Scholarship	15	口香糖	Chewing gum	2
地平線	Horizon	13	幻燈片	Lantern slide	2

Appendix A (*continued*)

Stimulus	Gloss	Frequency	Stimulus	Gloss	Frequency
三輪車	Pedicab	12	避雷針	Lightning rod	2
全壘打	Home run	8	啄木鳥	Woodpecker	2
紫外線	Ultraviolet rays	8	軟木塞	Cork	1
惡作劇	Mischief	7	搖錢樹	A golden thumb	1
座右銘	Motto	6	百葉窗	Jalousie	1
無神論	Atheism	4	單行道	One-way road	1
壓歲錢	New Year gift money	4	明信片	Postcard	1
五斗櫃	Chest of drawers	3	老花眼	Presbyopia	1
公德心	Public spirit	3	不鏽鋼	Stainless steel	1
交響樂	Symphony	3	鐘乳石	Stalactite	1
未知數	Unknown	3	向日葵	Sunflower	1
親和力	Affinity	2	龍捲風	Tornado	1
獨木舟	Canoe	2	微波爐	Microwave oven	0

The one-, two-, and three-word phrases used in Experiments 5 and 6

Stimulus	Gloss	Frequency	Stimulus	Gloss	Frequency
One-word condition (mean = 455, SD = 1104, Md = 136)					
要	Want	5394	窗	Window	110
走	Walk	1421	米	Rice	94
手	Hand	984	夢	Dream	94
山	Mountain	685	香	Fragrant	93
魚	Fish	326	油	Oil	74
飛	Fly (v.)	300	尺	Ruler	73
停	Stop	215	廟	Temple	61
跳	Jump	199	餓	Hungry	60
火	Fire	191	痛	Pain	39
玩	Play	170	燈	Lamp	47
冷	Cold	150	笨	Stupid	8
雲	Cloud	134	乖	Well-behaved	5
Two-word condition (mean = 478, SD = 1163, Md = 146)					
快	Quick	609	黑	Black	261
來	Come	7519	貓	Cat	64
好	Good	3043	接	Catch	234
酒	Wine	352	球	Ball	147
想	Want to	1868	搬	Carry, move	192
溜	Sneak off	25	土	Earth	69
請	Please	705	割	Cut	39
坐	Sit	1075	草	Grass	147
洗	Wash	131	養	Raise	132
頭	Hair, head	703	雞	Chicken	87
聽	Listen	715	加	Add	411
歌	Song	87	糖	Sugar	32
鎖	Lock	25	切	Cut, slice	56
門	Door	639	肉	Meat	145
愛	Be apt to	636	炒	Stir-fry	14
哭	Cry, weep	204	菜	Vegetable	97

Appendix A (*continued*)

Stimulus	Gloss	Frequency	Stimulus	Gloss	Frequency
借	Borrow, lend	127	軟	Soft	46
錢	Money	573	毛	Bristle, hair	89
拿	Hold	507	修	Repair	84
筆	Pen	177	錶	(Wrist) watch	35
剪	Cut	39	挖	Dig	30
布	Cloth	277	井	Well (n.)	32
短	Short	256	揉	Knead	6
詩	Poem	196	麵	Dough	17
Three-word condition (Mean = 553, SD = 1159, Md = 146)					
說	Speak	6575	端	Carry, hold	179
真	True	1043	熱	Hot	313
話	Word	791	湯	Soup	48
大	Big	4790	貼	Paste	39
灰	Gray	33	紅	Red	269
狼	Wolf	14	紙	Paper	257
去	Go	4664	喝	Drink	293
看	Look	2123	濃	Strong	46
海	Sea	403	茶	Tea	146
沒	Not	3199	老	Old, aged	246
帶	Bring	676	黃	Tawny, yellow	146
傘	Umbrella	19	狗	Dog	104
小	Little	2152	亂	Recklessly	181
花	Stained	451	砍	Fell	33
臉	Face	332	樹	Tree	234
換	Change	112	學	Learn	130
新	New	1117	唱	Sing, act	191
車	Car	359	戲	Chinese opera	201
蓋	Cover	119	賣	Sell	194
薄	Thin	62	假	Fake, sham	71
被	Quilt	1652	畫	Painting	123
肯	Agree	261	煮	Cook, boil	36
吃	Take, eat	848	乾	Not watery	76
藥	Medicine	88	飯	Cooked rice	144
繞	Go round	70	爬	Climb	106
遠	Long	512	矮	Low	40
路	Way	585	牆	Wall	133
偷	On the sly	63	補	Mend	30
抄	Copy	20	破	Broken	31
書	Book	663	碗	Bowl	111
挑	Pick, find	66	舊	Old, used	160
錯	Wrong	146	藍	Blue	27
字	Character	514	襖	Chinese-style coat	5
怕	Be afraid of	375	摘	Pick, pluck	21
吹	Be exposed to	138	嫩	Tender	18
風	Wind	369	芽	Bud	14

References

Batt, V., Underwood, G., & Bryden, M. P. (1995). Inspecting asymmetric presentations of words differing in informational and morphemic structure. *Brain and Language, 49*, 202–223.

Bouma, H. (1973). Visual interference in the parafoveal recognition of initial and final letters of words. *Vision Research, 13*, 767–782.

Bruyer, R., & Janlin, D. (1989). Lateral differences in lexical access: Word length vs. stimulus length. *Brain and Language, 37*, 258–265.

Bub, D. N., & Lewine, J. (1988). Different modes of word recognition in the left and right visual fields. *Brain and Language, 33*, 161–188.

Ellis, A. W., Young, A. W., & Anderson, C. (1988). Modes of word recognition in the left and right cerebral hemispheres. *Brain and Language, 35*, 254–273.

Eng, T. L., & Hellige, J. B. (1994). Hemispheric asymmetry for processing unpronounceable and pronounceable letter trigrams. *Brain and Language, 46*, 517–535.

Fang, S. P. (1994). English word length effects and the Chinese character–word difference: Truth or myth? *Chinese Journal of Psychology, 36*, 59–80.

Fang, S. P. (1997). Morphological properties and the Chinese character–word difference in laterally patterns. *Journal of Experimental Psychology: Human Perception and Performance, 23*, 1439–1453.

Fang, S. P., Horng, R. Y., & Tzeng, O. J. L. (1986). Consistency effects in the Chinese character and pseudocharacter naming tasks. In H. Kao, & R. Hoosain (Eds.), *Linguistics, psychology, and the Chinese language* (pp. 11–21). Hong Kong: University of Hong Kong Press.

Fang, S. P., & Wu, P. (1989). Illusory conjunctions in the perception of Chinese characters. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 434–447.

Hellige, J. B., Taylor, A. K., & Eng, T. L. (1989). Inter-hemispheric interaction when both hemispheres have access to the same stimulus information. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 711–722.

Hoosain, R. (1991). *Psycholinguistic implications for linguistic relativity: A case study of Chinese*. Hillsdale, NJ: Erlbaum.

Iacoboni, M., & Zaidel, E. (1996). Hemispheric independence in word recognition: Evidence from unilateral and bilateral presentations. *Brain and Language, 53*, 121–140.

Johnson, N. F. (1975). On the function of letters in word identification: Some data and a preliminary model. *Journal of Verbal Learning and Verbal Behavior, 14*, 17–29.

Lamb, M. R., Robertson, L. C., & Knight, R. T. (1990). Component mechanisms underlying the processing of hierarchically organized patterns: Inferences from patients with unilateral cortical lesions. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 471–483.

Levy, J., Heller, W., Banich, M. T., & Burton, L. A. (1983). Are variations among right-handed individuals in perceptual asymmetries caused by characteristic arousal differences between hemispheres? *Journal of Experimental Psychology: Human Perception and Performance, 9*, 329–359.

Liu, I. M., Chuang, C. J., & Wang, S. C. (1975). *Frequency count of 40,000 Chinese words*. Taipei: Lucky Books.

Luh, K. E., & Levy, J. (1995). Interhemispheric cooperation: Left is left and right is right, but sometimes the twain shall meet. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 1243–1258.

Martin, M. (1979). Hemispheric specialization for local and global processing. *Neuropsychologia, 17*, 33–40.

Melville, J. P. (1957). Word length as a factor in differential recognition. *American Journal of Psychology, 70*, 316–318.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology, 9*, 353–383.

Schwartz, S., Montagner, S., & Kirsner, K. (1987). Are there different methods of lexical access for words presented in the left and right visual fields? *Brain and Language, 31*, 301–307.

Tzeng, O. J. L., & Hung, D. L. (1988). Cerebral organization: Clues from scriptal effects on lateralization. In I. M. Liu, H. C. Chen, & M. J. Chen (Eds.), *Cognitive aspects of the Chinese language* (pp. 119–139). Hong Kong: Asian Research Service.

Tzeng, O. J. L., & Wang, W. S.-Y. (1984). Search for a common neurocognitive mechanism for language and movements. *American Journal of Physiology, 246*, 904–911.

Van Kleeck, M. H. (1989). Hemispheric differences in global versus local processing of hierarchical visual stimuli by normal participants: New data and a meta-analysis of previous studies. *Neuropsychologia, 27*, 1165–1178.

Wu, J. T., & Liu, I. M. (1987). Frequency counts of Chinese words, characters, and mono-syllables (Grant No. NSC75-0301-H002-24). Taipei, Taiwan: National Science Council.

Wuillemin, D., Richardson, B., & Lynch, J. (1994). Right hemisphere involvement in processing later-learned languages in multilinguals. *Brain and Language, 46*, 620–636.

Young, A. W., & Ellis, A. W. (1985). Different methods of lexical access for words presented in the left and right visual hemifields. *Brain and Language, 24*, 326–358.

Zhou, X., Ostrin, R. K., & Tyler, L. K. (1993). The noun-verb problem and Chinese aphasia: Comments on Bates et al. (1991). *Brain and Language, 45*, 86–93.