Chapter 4

Experiment 2

In experiment 1, the sense effects on the N400s can be interpreted either from the representation account or from the hemispheric processing account. However, it was not clear which account (representations of senses vs. hemispheric processing) truly affected the results we obtained in the lexical decision task. Similar to the results in Pylkkänen et al.'s MEG study on polysemy representation, the current study also suggested single representation for senses and that the pattern in the RH in experiment 1 was due to asymmetrically hemispheric processing.

In order to make sure lexical access involved during decision-making process, experiment 2 was meant to push subjects to a deeper level of lexical processing. In the studies on word recognition both in English (e.g. Vitevitch & Luce, 1998) and in Chinese (Cheng, 2006), researchers have demonstrated that different levels of processing in perception of words would lead to opposing results. With the change of difficulty of the task, subject in experiment 2 have to decide whether the targets belonged to verbs or nouns, which required the precise retrieval of semantic information from stimuli. By changing the task to judge word classes, subjects have to make their decisions not simply relying on word familiarity but on the retrieval of lexical information.

The purpose of Experiment 2 was to resolve the question left in experiment 1: whether the sense effect of ERPs in experiment 1 resulted from the representations of senses or from the nature of hemispheric processing? If the representation of Chinese senses had single entry, there was the possibility to observe sense facilitation in disparate levels of word processing. However, if the representation was separate-entry, we would find the same pattern in the RH as experiment 1.

4.1 Experiment 2

4.1.1Participants

Thirty-eight graduate and undergraduate students (18 to28 years of age, mean age 22.39) took part in the experiment. Other requirements were the same as experiment one: male, right-handedness, no history of neurological or psychiatric disorders, and normal or corrected-to-normal vision. Written consent was obtained from all participants.

4.1.2 Materials

Experiment 2 manipulated visual field (RVF vs. LVF) and the number of senses of the first character constituent of Chinese disyllabic compounds. Materials consisted of 120 compounds, two-way designed (few/ many senses; RVF/LVF) and counterbalanced with word class. Few-sense words were those whose first character senses were from 1 to 3 (mean 1.97) whereas many-sense words were those whose first character senses were over 6 (mean 11.38). Possible confounding factors such as word frequency, NS1, NS2 were controlled.

The task in experiment 2 required participants to judge whether the target belonged to verbs or nouns. Nevertheless, in Chinese, there exists controversy over the distinction of verbs and nouns. To avoid this problem, the resolutions included: (1) to label the word class according to the system established in Academia Sinica balanced corpus of modern Chinese and (2) to give pilot pretests to another group of people to exclude these possibly confused choices. These subjects were asked to use their language intuition to write down their word-class judgments in a paper sheet containing 120 targets. Words that having ambiguous answers were replaced by other valid target words.

4.1.3 Procedure

Each trial began with a white cross presented centrally for 500 ms. Presentation of the target words then showed up for 150 ms. The disyllabic compound targets were vertically arranged in the left or right visual hemifield with inner edge two degrees of visual angle from fixation. Presentation of numbers from one to nine may also appear pseudorandomly in the center of the screen in order to control participants' eyesight. At the end of each trial would have a capital B presented in the center to allow eye blinking for 1500 ms. Participants were asked not to blink their eyes since the beginning of each trial until the appearance to the capital B to minimize the interference of eye movement. There were four blocks of experimental session and a practice run before the start of the experiment. A two-to-three minute break was given in between blocks.

Participants were instructed to judge whether the compound presented was a noun or a verb. For odd-number subjects, they were asked to press the response box with both of their index fingers when the targets were verbs and with both of their middle fingers when the targets were nouns. For even-number subjects, the instruction was the opposite. To control the central fixation of eyes, numbers from one to nine may also show up as experiment 1. Odd-number subjects should press the response box with both of their index fingers when number 6 to 9 was presented centrally on the screen and with both of their middle fingers when number 1 to 4 was on the screen. For even-number subjects, instruction reversed. Response time and event-related potentials data were both collected during the process.

4.2 Results

Thirty eight participants took part in experiment 2. Those having behavioral accuracy below 70 percent and ERPs accepted trials below 16 were excluded from ANOVA analyses. Data from twenty-eight of participants are used in the following behavioral and ERP analyses.

4.2.1 Behavioral data

Mean correct reaction times and accuracy from 28 participants were presented in Table 4. A 2×2 (number of senses × visual field) analysis of variance (ANOVA) was performed on correct RTs and accuracy. For RTs, no significant main effect of number of senses ($F(1, 27) = 0.5$, $p = .48$) and interaction ($F(1, 27) = 1.33$, $p = .26$) was observed. A main effect of visual field reached marginally significance ($F(1, 27) = 3.38$, $p = .077$). Stimuli presented to RVF/ LH had the tendency to produce shorter response time than those presented to LVF/ RH. For accuracy, not any main effect or interaction was obtained.

	Visual field	
Number of senses	RVF/LH	LVF/RH
Few		
RT (SD)	784.96(106.99)	801.44 (102.07)
Accuracy	0.93	0.93
Many		
RT (SD)	794.27 (106.75)	791.68 (108.59)
Accuracy	0.93	0.93

Table 4. Mean Reaction Times (in ms), Standard Deviation, and Accuracy for the 2 × 2 design (the number of senses × visual field) in Experiment 2.

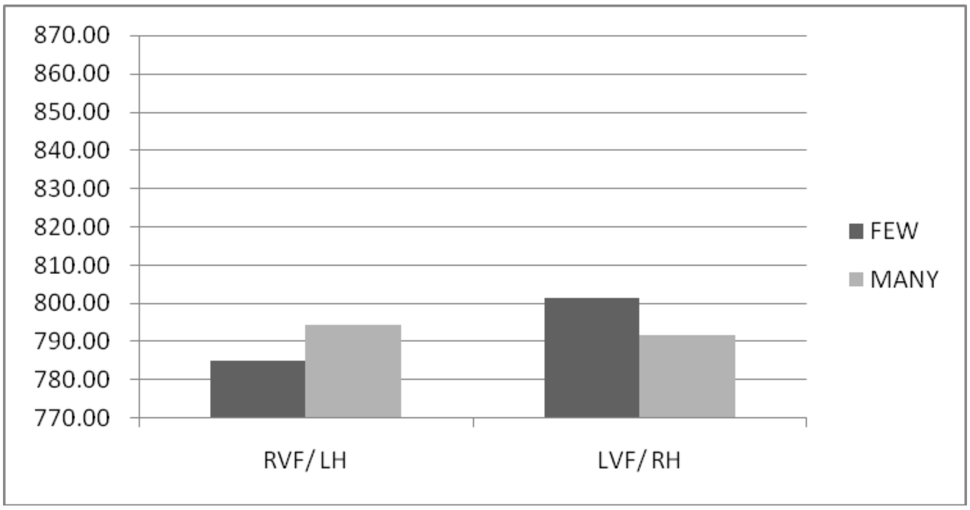


Figure 19. Bar chart of **RTs** for 2 × 2 design of visual field (VF) and the number of senses

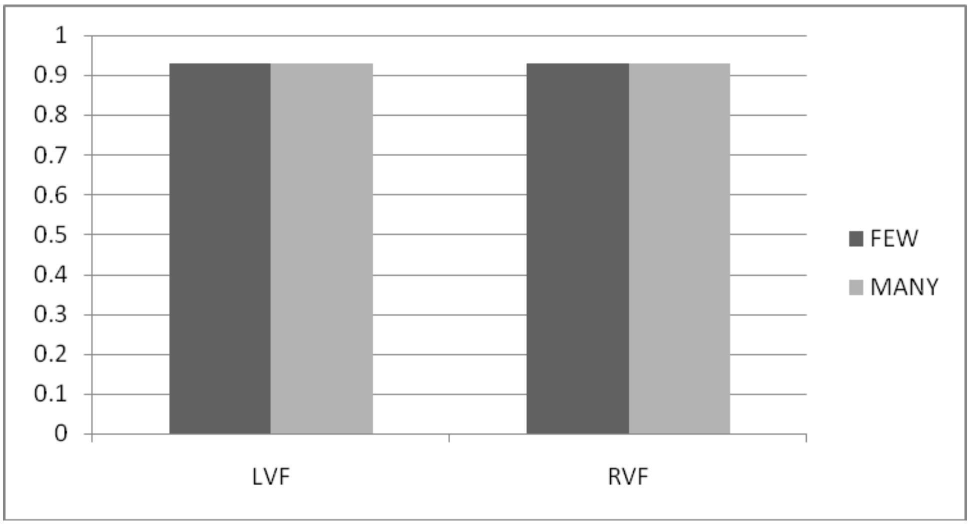


Figure 20. Bar chart of **accuracy** for 2 × 2 design of visual field (VF) and the number of senses

4.2.2 ERP data

Temporal time windows of interest were N170 (150-180 ms), P200 (220-260 ms), and N400 (350-500 ms). The mean amplitude of each time window from selected electrodes would serve as dependent measures in a repeated measures analysis of variance (ANOVA).

N170 (150-180 ms)

The mean amplitude of N170 was analyzed by ANOVA with factors of visual field (LVF/RVF), number of senses, and electrodes (P3/P4, P5/P6, P7/P8, PO5/ PO6). We obtained a significant visual field × electrodes interaction $F(7,189) = 45.34$, $p < .001$. Post-hoc comparison indicated that visual field simple main effects reached statistical significance in all electrodes (p's<.001). In electrodes on the left, P3, P5, P7, PO5, right visual field presentation elicited much greater negativity than left visual presentation and vice versa in electrodes on the right, P4, P6, P8, and PO8.

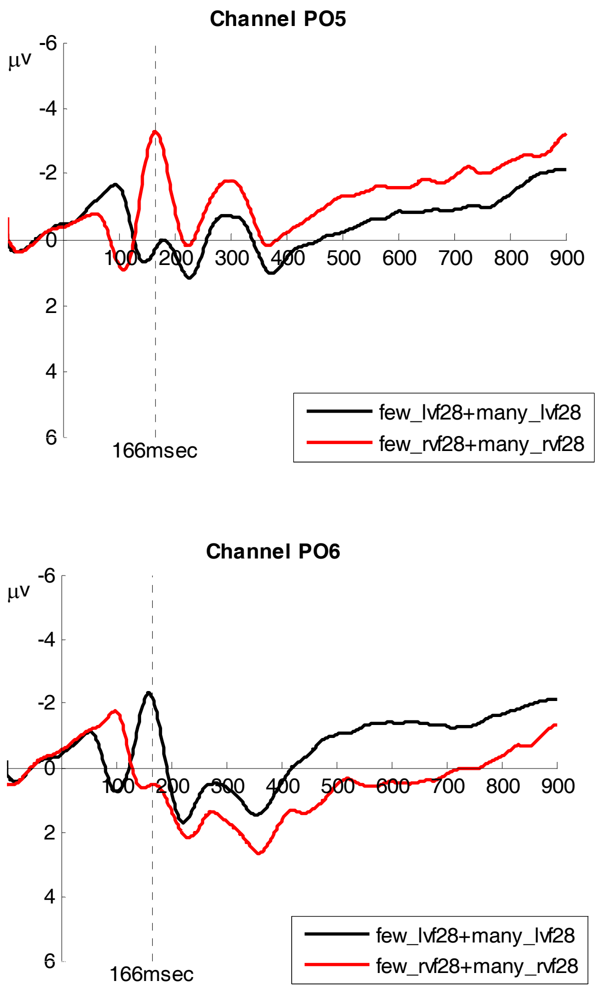
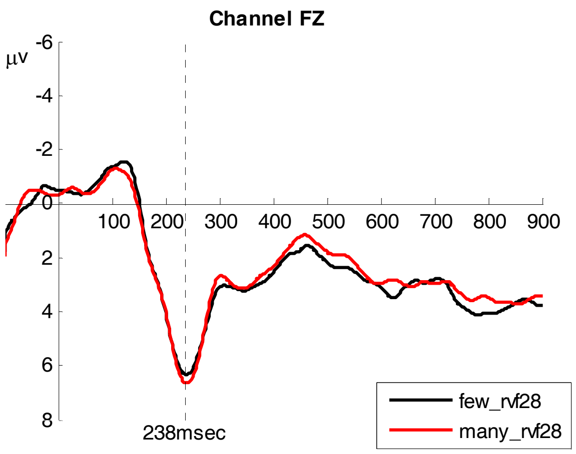


Figure21. N170 effects at PO5, PO6.

Frontal P200 (220-260 ms)

The frontal P200 was measured by using mean amplitudes within 220 to 260 ms and subjected to analyses of variance consisting of within-subject factors of visual field (LVF/ RVF), the number of senses (few/ many), 6 electrodes (F3, FZ, F4, FC3, FCZ, FC4). There was no main effect of the number of senses (F (1, 27) =.07, p=.79) and its interaction with visual field (F (1, 27) = 1.55, p=.22).



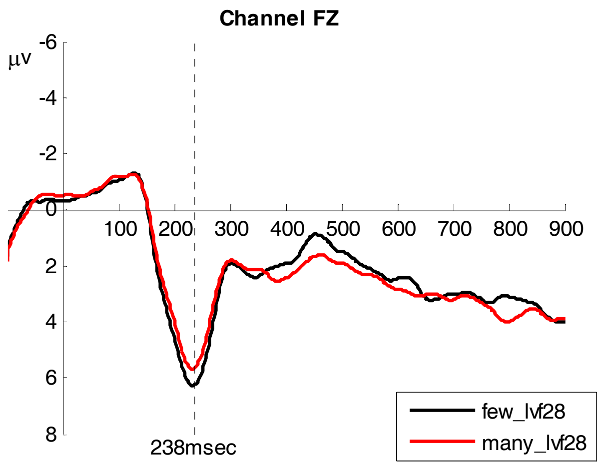


Figure22. P200 at FZ for the RVF (upper) and LVF (lower) presentation.

N400 (350-500 ms)

Mean amplitudes of all conditions were measured from 350 to 500ms and subjected to ANOVA with factors of visual field, the number of senses, electrodes, hemispheres. The midline analysis revealed marginal significance of two way interaction between the number of senses and visual field (F (1, 27) =3.83, p=.06). In the lateral analysis, there was marginal significance of visual field by number of senses interaction (F (1, 27) = 3.18, p=.086) and a marginally significant 4-way interaction of visual field, number of senses, electrodes and hemispheres (F (4, 108) =2.53, p=.072). Post-hoc comparisons showed that in the LVF/ RH few senses tended to be more negative than many senses (p<.05) while in the RVF/ LH, few and many senses did not reveal any difference (p=.73).

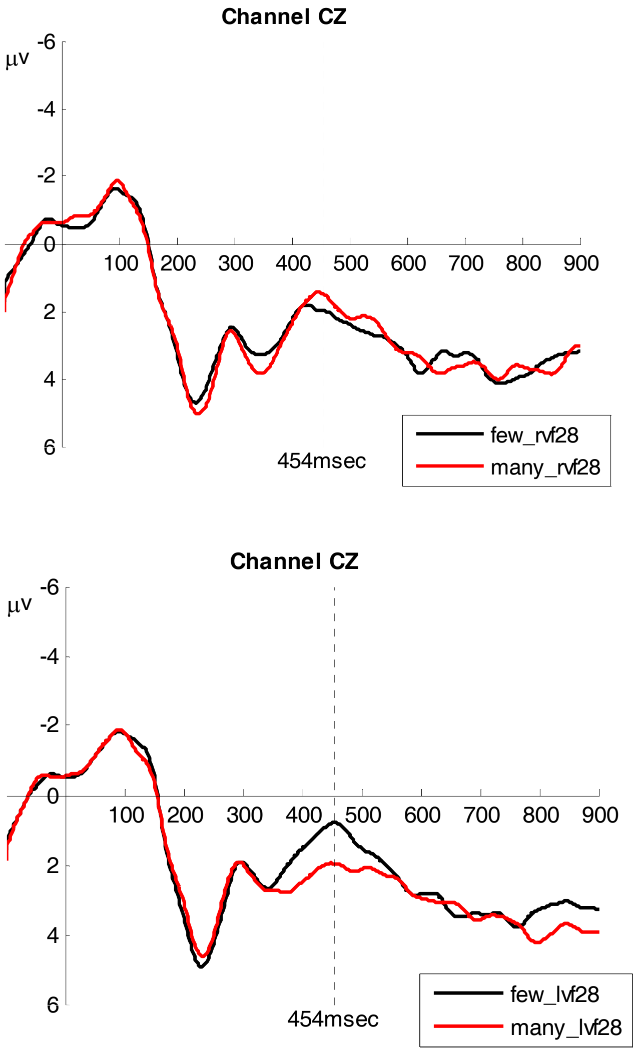


Figure23. N400 at CZ for the RVF (upper) and LVF (lower) presentation.

4.3 Discussion

By changing the depth of the task, the goal of experiment 2 was to find out if, under the assumption of single entry representation for senses, there was the chance to discover the sense facilitation effects in the RH. Suppose the representation of Chinese senses had single entry, the pattern should be like that in the LH in experiment 1 where words of many senses elicited less negativity than words of few senses around 400 ms. If not, then we can assume that the representation of senses in the RH had separate entries.

Experiment 2 was designed to push the participants to undergo a deeper level of lexical processing. In the comparison of the average RTs in the LDT and the word class judgment task, it took averagely 793.09 ms for participants in experiment 2 to make their decisions while it took a shorter period of time of 706.37 in experiment 1. This provided evidence that the given task in experiment 2 was more difficult than the LDT in experiment 1 and that subjects were undergoing deeper levels of lexical processing. Therefore, response time was approximately 100 ms longer in the word class judgment process. In Chinese, though there existed controversy over the distinction of verbs and nouns, the pilot pretest before the formal experimentation had tried to diminish the risk of confusion. Besides, the overall high scores of accuracy (average=0.93 in each condition) suggested that subjects did not have difficulty in making their judgments. The design of the task might not be a perfect one since some people might argue the complexity of the structure of Chinese word composition. Nonetheless, the preparation of materials and experimental procedure had already tried to moderate any perplexity.

In the behavioral data, no significant main effect of number of senses ($p=.48$) and interaction ($p=.26$) was observed. Nevertheless, the ERP data demonstrated that there was marginal significance of two-way interaction (visual field x number of senses) and a marginally significant 4-way interaction. Post-hoc comparison showed that there were significant sense facilitation effects in the RH ($p<.05$) and no effect in the LH ($p=.73$). ERP waveforms showed that words of few senses elicited more negativity than words of many senses around 400 ms in the RH, but the two conditions did not differ from each other in the LH.

The results confirmed our previous assumption in that we could discover the single entry representation for senses in a deeper level of lexical processing. The pattern in the RH in experiment 1 was due to the hemispheric processing of semantic information when subjects could make their decisions based on looser criteria. Since the characteristics of the RH processing were to maintain possible, alternate meanings, it was allowed to make free associations in the RH when lexical processing was in a superficial level. On the other hand, the characteristic of the LH processing was much focused and fast, we expected that there was no sense effect in this area when the depth of the task was changed to be deeper.

In sum, the result also confirmed our previous assumption in the LH and RH. In that in a deeper level of task, no sense effect would be observed in the RVF/ LH because it was engaged in fine semantic processing and lexical relatedness of senses should be quickly retrieved. On the other hand, the RH, engaged in coarse semantic processing, had the possibility to display semantic retrieval process in a more specific task which generally showed slow participants' reaction times (e.g. Beeman& Chiarello, 1998; Burgess & Simpson, 1988).

Even though the data suggested hemispheric processing of semantic relatedness in the LVF/ RH in the word class judgment task, the ERP results simply reached marginal significance. For example, The N400 found in experiment 2 was marginally significant in the midline visual field × number of senses two-way interaction and in the lateral line visual field × number of senses × electrodes × hemispheres four-way interaction. The behavioral data obtained during word class judgment task did not reveal any difference between few and many senses. Average response times (793.2 vs. 792.9 ms) and accuracies (.93 vs. .93) of responses did not significantly differ for few and many senses. These led to the speculation of the word category effect to dilute the sense effect in experiment 2. To further clarify this speculation and the influence in our designed task, a brief introduction concerning word class literature was made and separate ANOVAs were performed for nouns and verbs respectively.

Nouns and verbs

The neural representations of nouns and verbs have been a central issue in cognitive neuroscience. Many studies, in general, suggested that the neural systems for lexical processing of nouns and verbs were anatomically distinct. For example, in children's lexical development, the acquisition of nouns seems to be earlier and easier than that of verbs (Gentner, 1982). In aphasic findings, case studies indicated that patients with lesions located in left anterior and middle temporal lobe, outside so called language areas, had difficulty in the production of nouns whereas patients with lesions areas in left frontal premotor cortex had difficulty in the production of verbs (Damasio & Damasio, 1992; Damasio et al., 1993). Evidence from event-related potentials also disclosed electrocortical differences between nouns and verbs over widespread cortical areas (Pulvermüller et al., 1999). These studies generally postulated that a neurobiological model of language representation with neural assemblies having distinct cortical topographies as biological counterparts of words.

Therefore, verbs were assumed to elicit stronger electrocortical activity around primary frontal, prefrontal areas associated with motor, premotor functions. Nouns, associated with concrete and well-imaginable meanings related to visual modality, were assumed to elicit larger electrocortical activity around visual cortices.

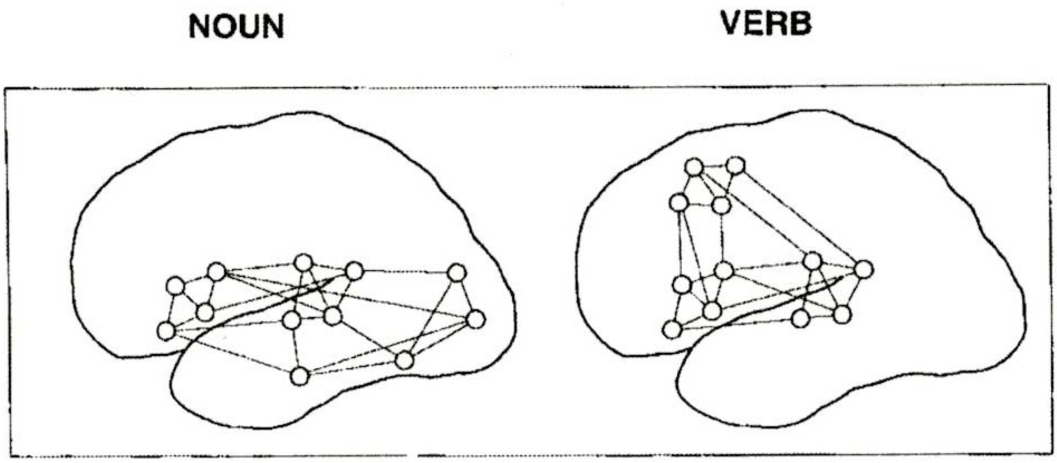


Figure24. Sketch of possible cortical representations of nouns and verbs (Pulvermüller, 1992, 1996, 1999)

Though many studies were in support of the view that the dissociation of nouns was derived from their distinct neural representations, there was also evidence indicating that the conclusions were oversimplified. For example, Tyler et al. (2001, PET) found no significant action differences for nouns and verbs in lexical decision and semantic categorization task. Similarly, in an fMRI Chinese study, Li et al. (2004) pointed out that nouns and verbs were found to activate a wide range of overlapping brain areas and suggested distributed networks for either word class. One recent Chinese study on concreteness also showed similar distribution over the scalp for both nouns and verbs (Tsai et al., 2008).

With the review of two interpretations for word category, the study was not meant to resolve the controversy of neural representations for nous and verbs. Instead, from the marginal significance of the data in experiment 2, we speculated that the word class effect may come into play in the results, which led to the failure to reach significance in overall data. Researchers in support of the hypotheses that distinct neural assemblies associated with nouns and verbs found distributional differences for these two parts of speech with the former in the central-to-parietal and the latter in the frontal area. Based on these findings, we suggested reanalyzing the data with the addition word class as one within-subject factor.

4. 4 Re-analyses

Results 2 based on analyses of results 1 and took counterbalanced word class into consideration. To further examine the sense effect in nouns and verbs condition, separate analyses of ANOVA were carried out according to different word classes.

4. 4.1 Behavioral data

A 2×2×2 (number of senses × visual field × word class) analysis of variance (ANOVA) was performed on correct RTs and accuracy. For RTs, results showed marginally significant effects for visual field ($F(1, 27) = 3.38$, $p=.077$) and word class ($F(1, 27) = 2.97$, $p=.096$) and for number of senses × word class interaction ($F(1, 27) = 2.94$, $p=.098$). Stimuli presented to the RVF/ LH tended to responded more quickly than to the LVF/ RH. Stimuli of nouns had shorter response time than stimuli of verbs. For accuracy analysis, nouns had significant higher accuracy than verbs (word class ($F(1, 27) =5.41$, $p<.05$).

	Visual field	
Number of senses	RVF/LH	LVF/RH
Few		
Noun	767.31 (88.82)	780.68 (93.68)
Verb	802.61 (115.32)	822.20 (120.31)
Many		
Noun	790.62 (99.59)	789.09 (105.11)
Verb	797.91 (117.59)	794.27 (108.39)

Table 5. Mean Reaction Times (in ms), Standard Deviation for the 2 × 2 × 2 design (number of senses × visual field × word class) in Experiment 2

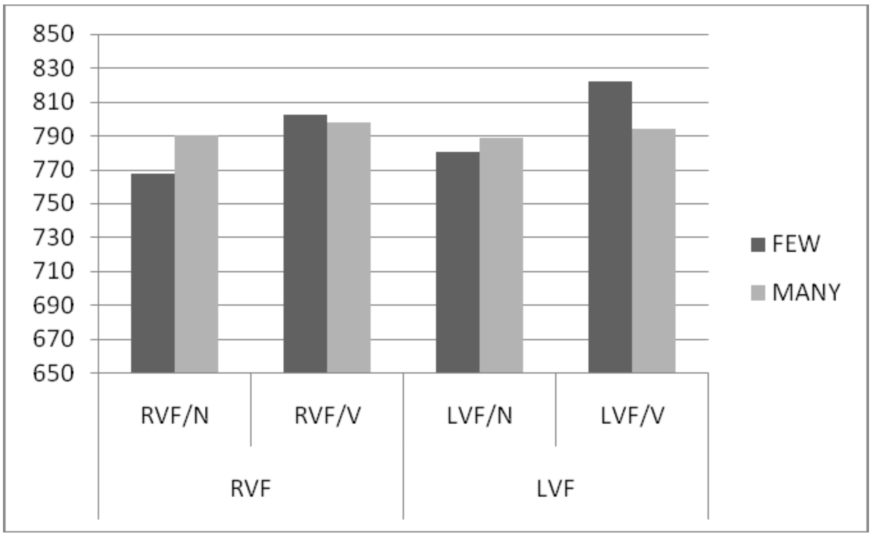


Figure25. Bar chart of RTs for the sense effect in visual field and word class

	Visual field	
Number of senses	RVF/LH	LVF/RH
Few		
Noun	0.95	0.94
Verb	0.91	0.92
Many		
Noun	0.95	0.95
Verb	0.91	0.91

Table 6. Accuracy for the 2 × 2 × 2 design (number of senses × visual field × word class) in Experiment 2

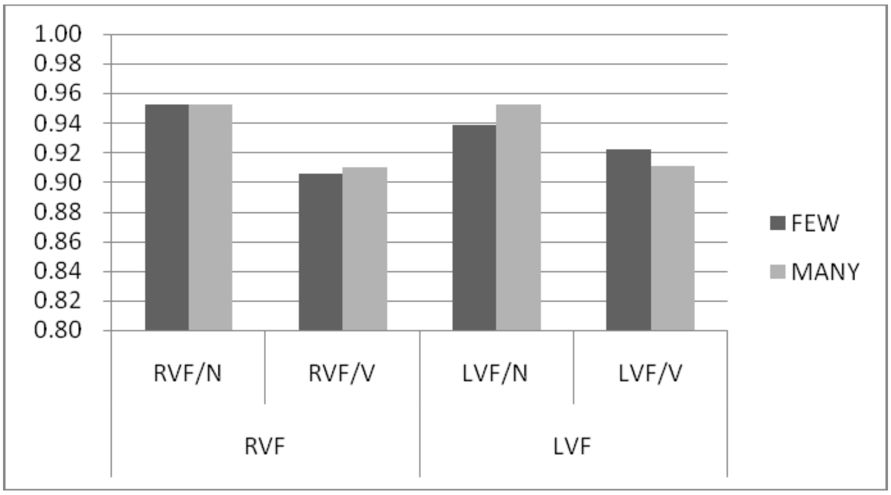


Figure26. Bar chart of accuracy for the sense effect in visual field and word class

4.4.2 ERP data

The grand mean ERPs elicited by few and many senses in RVF/ LH and LVF/ RH were presented in nouns (Figure 21, 22) and verbs (Figure 23, 24) separately.

Nouns

In the midline, there was a marginally significant number of senses × electrodes interaction ($F(4, 108) = 2.8$, $p<.08$). Lateral analyses indicated that there was a significant visual field × number of senses × electrode interaction ($F(1, 27) = 3.65$, $p<.05$). Planned comparison showed that only when stimuli presented to the LVF/ RH, few senses were more negative in C, CP, P (p's <.05 to <.01).

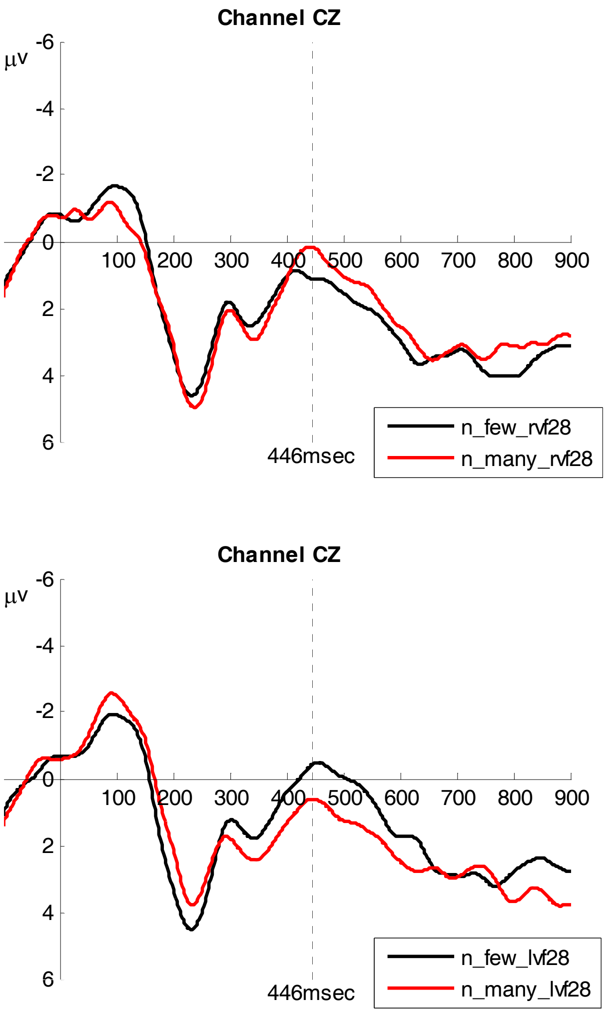


Figure27. N400 at CZ for the RVF (upper) and LVF (lower) presentation in **nouns**

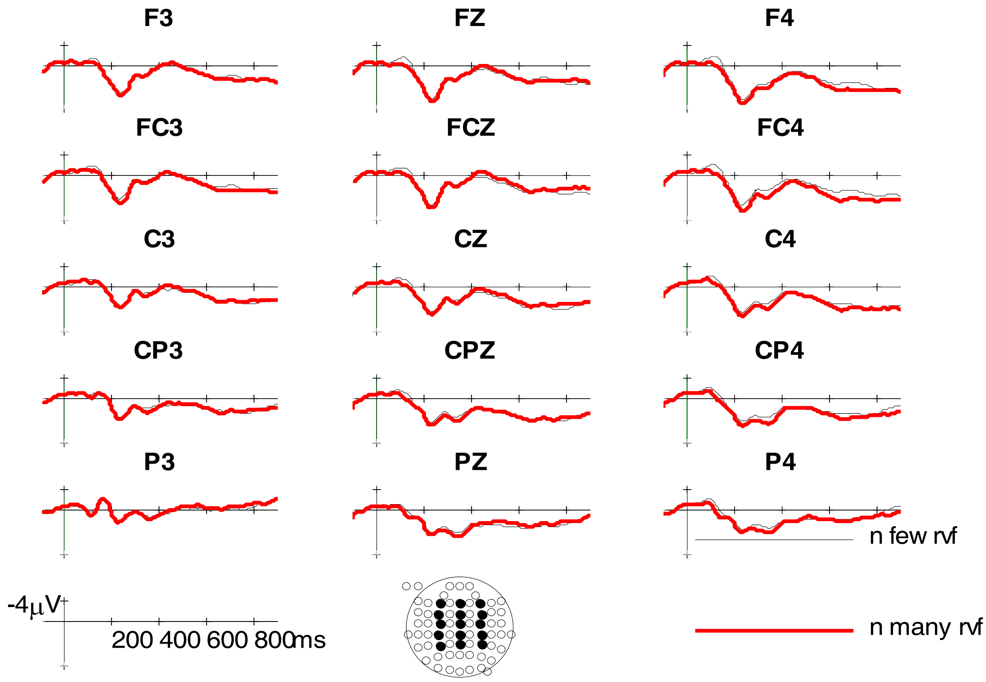


Figure28. Grand average of ERPs elicited by few/many senses of **nouns** in the **RVF**

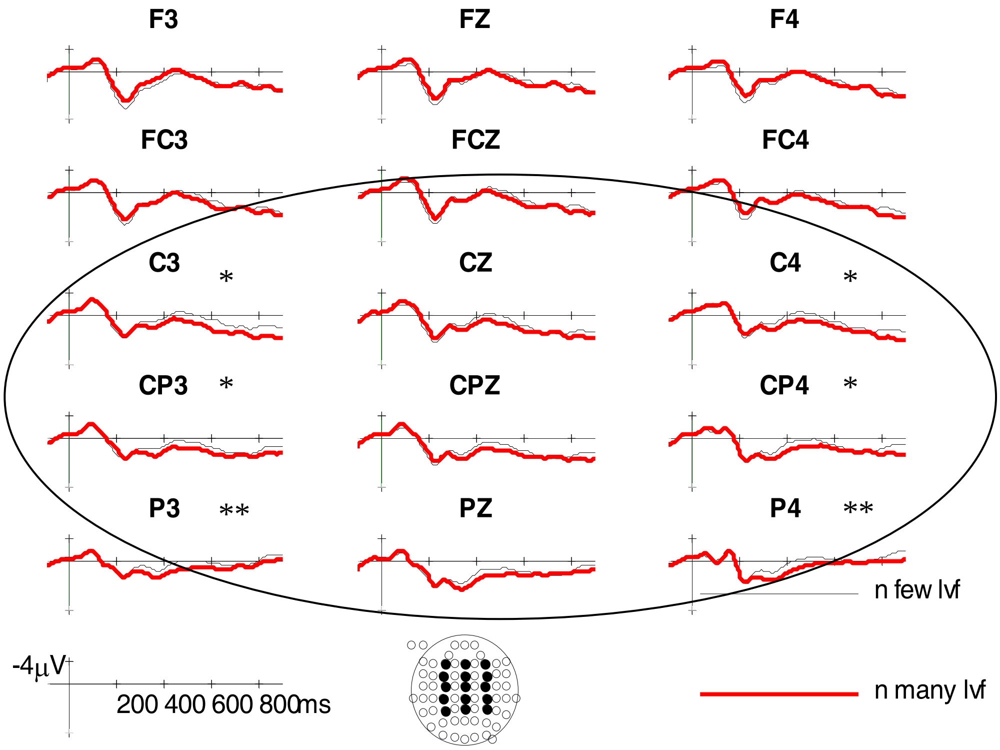
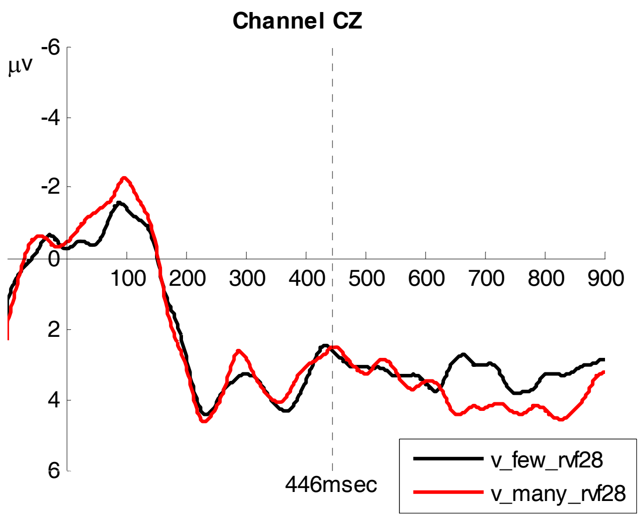


Figure29. Grand average of ERPs elicited by few/many senses of **nouns** in the **LVF**

Verbs

In the midline analysis, there was no significant main effect of senses or interaction. In the lateral analyses, there were significant interactions of visual field × number of senses (F (1, 27) =4.69, p<.05) and visual field × number of senses × electrodes × hemispheres (F (4, 108) = 4.23, p<.01). Planned comparisons of four way interaction showed that when presented to LVF/ RH, few senses were more negative in F3, C3, CP3 and FC4 (p's<.05 to <.01) whereas when presented to the RVF/ LH, there was no difference between few and many senses.



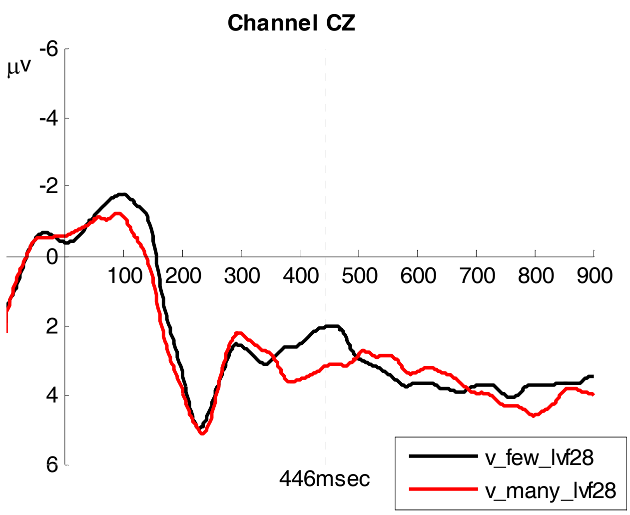


Figure30. N400 at CZ for the RVF (upper) and LVF (lower) presentation in **verbs**

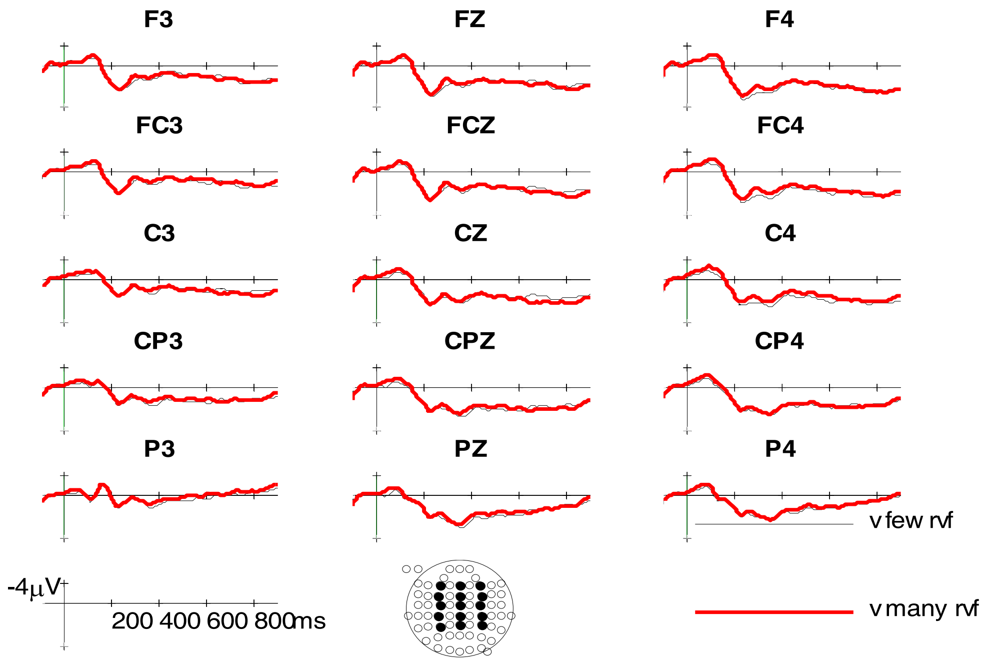


Figure31. Grand average of ERPs elicited by few/many senses of **verbs** in the **RVF**

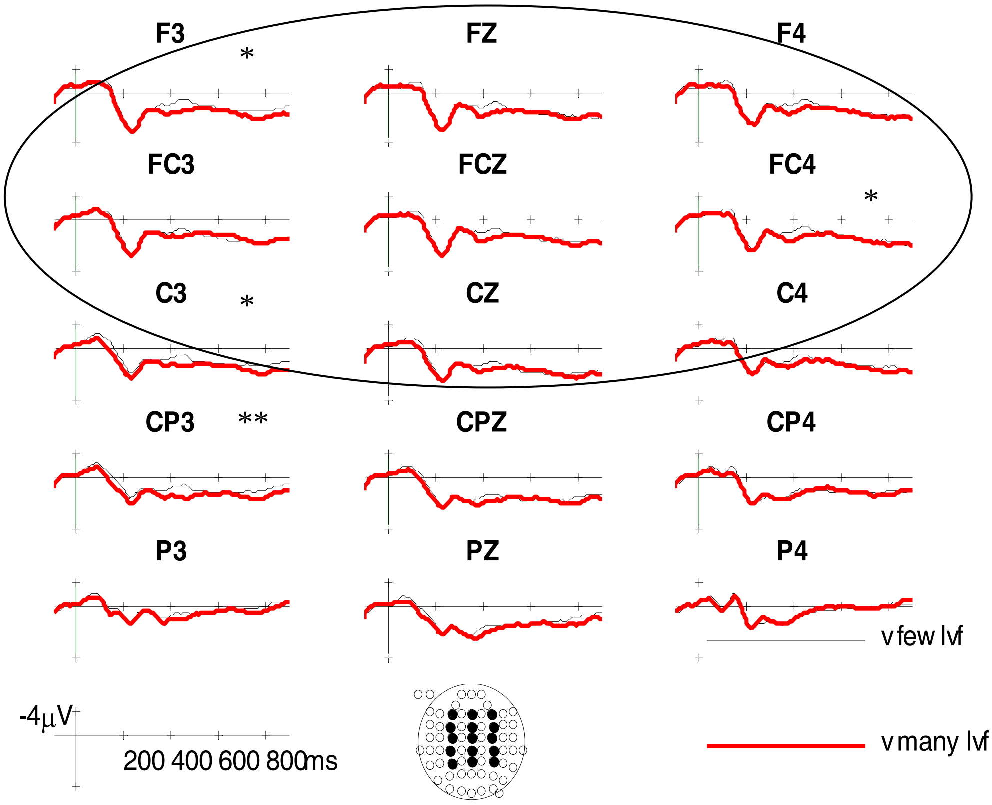


Figure32. Grand average of ERPs elicited by few/many senses of **verbs** in the **LVF**

4.5 Discussion 2

The purpose of additional analyses of sense effects in nouns and verbs was to examine clearer effects of senses without the confounding of the word class factor. The results supported the idea that different parts of speech would have influence on lexical processing. Originally, the overall mean amplitude of ERPs for N400s only reached marginal significance in the midline (visual field × number of senses, p=.06) and in the lateral site (visual field × number of senses, p=.086; visual field × number of senses × electrodes × hemispheres interaction, p=.072). Nevertheless, the additional analyses in nouns and verbs both reached significance in the lateral sites (nouns: three-way interaction of visual field × number of senses × electrodes, p<.05; verbs: two-way interaction of visual field × number of senses, p<.05; four-way interaction of visual field × number of senses × electrodes × hemispheres, p<.01). Furthermore, planned comparison of the senses demonstrated disparate distributions for nouns and verbs respectively. To be more specific, the simple simple-main effects of senses for nouns were located in central-to-parietal areas of brain, whereas these effects for verbs primarily showed up in frontal, central, central-parietal electrodes on the left. The re-analyses of ERP data explained at least two things. First, the differences of distribution from either word category diluted the sense effect observed in the first analysis; therefore, the data was only marginally significant in the original analyses. Secondly, though the current study was not meant to resolve the representations for different word categories, the additional results seemed to support the distinct neural representations for nouns and verbs by chance, since each word class had its distribution for the sense effects. Certainly, further evidence of Chinese word class was required to approve the statement since there was also evidence suggesting distributed network for Chinese lexical processing (e.g. Li et al., 2004).

As for the pattern of the senses discussed in experiment 2, we obtained the sense effects in LVF/ RH in which few senses were more negative than many senses either in nouns or verbs. According to Vitevitch and Luce (1998) and Cheng (2006), different levels of processing in perception of words would lead to opposing results. Suppose the results obtained in experiment 1 was derived from the single entry representation of senses, the sense effect should be observed in the RH in experiment 2 since the depth of the task was changed. Therefore, when subjects were undergoing a deeper level of lexical processing, the relatedness of senses might have been early processed in the LH due to the engagement in fine semantic processing; on the other hand, the sense effect might appear in the RH because its capacity allowed alternate meanings to maintain. Hence, in a deeper level of task, which slowed down the semantic processing, the sense was able to be observed in the LVF/ RH.

Therefore, the results confirmed that the representation for senses had single entry and that the pattern in the RH in experiment 1, 2 should attribute to the hemispheric processing of semantic ambiguity in different levels of semantic processing. In a superficial level of loose decision-making criteria as in experiment 1, the RH allowed for free associations and conceptual selection. So the pattern was like possible sense inhibition resulted from separate entry representation. Nevertheless, in a deeper level of lexical processing, under the assumption of single representation for senses, we had the chance to observe the facilitative sense effects in the LVF/ RH. The disappearance of the sense effects in the RVF/ LH did not mean that there was not any semantic activation; instead, semantic information has been quickly processed due to the efficient nature of the LH. Previous studies on hemispheric asymmetries have suggested that the semantic field was narrower and more focused in the LH. On the other hand, the RH also played an important role in semantic processing in the way that alternate meanings can be maintained (e.g. Beeman & Chiarello, 1998; Burgess & Simpson, 1988). In other words, this could be why there was more possibility to observe the sense effects in the LVF/ RH owing to different efficiency of the cerebral hemispheres, especially when the depth of the task was changed to be deeper.

In the end, the current study used Chinese disyllabic compounds as targets and manipulated the number of senses of the first constituent characters. Nevertheless, different levels of processing mainly referred to the lexical and sublexical levels of monosyllabic words in Vitevitch and Luce’s (1998) and Cheng’s (2006) studies. The study has demonstrated that the number of senses of the first individual characters played a role in Chinese compound processing. Yet the linkage from disyllabic compound to monosyllabic individual character was not as straightforward as previous studies. Therefore, in reading Chinese two-character words, it was suggested that further experimentation was required to look into the representation of Chinese disyllabic compounds.