Research Report

The semantic processing of syntactic structure in sentence comprehension: An ERP study

Zheng Ye[a], *Weidong Zhan*[b], *Xiaolin Zhou*[a,c,*]

[a] *cc 0, ie a ic 0e ie , he c e, d . ide . ii hec ica di*

i de e de f e ica ea i g f hei i e e d .

1. Introduction

The past 15 years witnessed the emergence of a new family of linguistic approaches to the language system, namely constructionist approaches (for short reviews, see Goldberg, 2003; Kako and Wagner, 2001). The constructionist approaches share certain fundamental ideas but contrast sharply, in other ways, with the mainstream generative approaches introduced by Chomsky (e.g., Croft, 2001; Culicover, 1999; Fillmore et al., 1988; Goldberg, 1995; Jackendoff, 2002; Kay and Fillmore, 1999; for constructional approaches to language acquisition, see Tomasello, 2003). The generative approaches adhere to the dichotomy between syntactic structures and semantic functions. Claims relevant to the present study are: (1) syntactic structures are characterized by increasing layers of abstractness without independent meaning; and (2) sentence mean-

and “rules”. Syntactic structures are psychologically real pairings of form and meaning. Syntactic structures (or more

based semantic violations and to distinguish them from those elicited by the usual lexical–semantic violations, the present study took advantage of special characteristics of the Chinese *ba* construction to create construction-based semantic mismatches and draw a contrast between construction-based and lexical-based semantic violations.

In Mandarin Chinese, the phrasal *ba* construction takes the form of "*ba*–Object–VP". Fig. 1a shows the hierarchical structure of *ba* sentences, i.e., sentence with *ba* construction, as compared with the more canonical "Subject–VP–Object (SVO)" sentences (see Fig. 1b). In SVO sentences, verbs should satisfy semantic requirements of both subject and object nouns during the incremental processes of sentence comprehension (Friederici and Frisch, 2000). In *ba* sentences, however, verbs are semantically constrained not only by the co-occurrence of pre-verb nouns (i.e., subjects and objects), but also by the *ba* construction. The word *ba* is a preposition (Chao, 1968/1979; Wang, 1970) but functions as a case marker, which indicates a scrambled object of a transitive relation (Goodall, 1987; Li, 1974, 1990). The preposition *ba* has little lexical meaning and assigns a patient role to the following object noun (for an alternative linguistic interpretation of the word *ba*, see Hashimoto, 1971).

As proposed by Chinese linguists, the *ba* construction has abstract meanings such as "disposal" or "causation" independent of content words inhabiting it. Only transitive verbs that encode such meanings are permitted to appear in it (Chao, 1968/1979; Cui, 1995; Lü, 1984; Wang, 1943). This construction-based semantic constraint cannot be attributed to the word *ba* which lacks semantic content. Thus, a verb which is perfectly acceptable in the SVO structure but does not have the appropriate "disposal" or "causation" meaning would constitute a construction-based semantic violation if (

tional violation conditions, percents of unacceptable sentences were 94% and 87% respectively.

2.2. *ERP data*

effect was limited to the posterior sites, while the lexical–semantic N400 effect was much widely distributed. This topography difference may be due to the fact that the overall constructional N400 effect was small and the potential effect at the anterior sites could not be observed. Thirdly, both N400s peaked around 400 ms post-onset and none of them was followed by a late positive shift. These ERP patterns demonstrate that semantic constraints arising from syntactic structure as well as from preceding nouns have impacts upon the semantic integration of upcoming verbs in *ba* sentences, although the construction-based semantic constraints are weaker than the lexical–semantic constraints.

3.1. *Functional significances of the N400s*

Lexical–semantic violations were reported to elicit the N400 effect in many previous studies using similar stimulus materials in English (e.g., Holcomb and Neville, 1991), Dutch (e.g., Hagoort et al., 2003), and German (e.g., Friederici et al., 1993). Clearly, the lexical–semantic N400 effect observed in the present study was very similar to those observed in other languages. The timing of the present lexical–semantic N400 was compatible to that of other languages as well, but not to that of our previous study (Ye et al., 2006), which employed auditory presentation of Chinese *ba* sentences and found an N400 effect initiating in a very early time window, i.e., 150–200 ms. The difference in onset may be partially due to the different presentation modes used in these two experiments since it has been shown in an earlier study that the N400 in the visual domain starts later than that in the auditory domain (Holcomb et al., 1992). Secondly, it is possible that the two-character, two-syllable verbs used in the present study could not be processed as fast as the one-syllable verbs serving as critical words in our previous study. It may take more time to process two-syllable words than one-syllable words (see Schirmer et al., 2005 for additional evidence of speeded),/F51T20.49

semantic processing of monosyllabic Chinese words in the auditory modality). In any case, the general pattern of the lexical–

N400, in addition to following P600, for gender agreement violations in the sentence-final position (Hagoort, 2003; Osterhout and Holcomb, 1992, 1993), they reported no such N400 effect but only a P600 at mid-sentence words in response to gender disagreements (see Hagoort, 2003 for comparisons between sentence-final and sentence-internal effects; and see Friederici and Weissenborn, in press for alternative interpretations of Hagoort, 2003). In contrast to these studies, the present constructional violation was realized by mid-sentence verbs and it induced an N400 rather than a P600 effect. Thus, the present constructional N400 effect could not be attributed to the impacts of syntactic violations on the semantic integration of sentence meaning.

The absence of the P600 also rules out the possibility that readers could, to some extent, ignore the incompatibility between semantic requirements of the *ba* construction and the verb meaning and combine the lexical items in the most plausible way according to their world knowledge, i.e., in the canonical SVO order (Bever, 1970; Ferreira et al., 2002; Town-

processing, they cannot be completely ignored. The very existence of the constructional N400 effect demonstrates the semantic processing of syntactic structures in sentence comprehension, supporting the constructionist approaches to language which take into account not only meanings of content words but also meanings of the conventionalized syntactic structures.

5. Experimental procedures

5.1. *Participants*

violation sentences, <0.01. For the cloze probability, neither the lexical–semantic, <0.01, nor the constructional violated verbs, <0.01, were as predictable as the correct verbs. The lexical–semantic violated verbs were even less predictable than the constructional violated verbs, <0.01.

For all the non-*ba* SVO sentences (d–f), the repeated measure ANOVA also revealed significant main effects of Condition (correct vs. lexical–semantic vs. constructional). For the acceptability rating, $F(2,58)=477.11$, <0.01, and the cloze probability, $F(2,38)=192.56$, <0.01. For the acceptability rating, pairwise comparisons demonstrated that the SVO counterparts of constructional violation sentences were as acceptable as SVO counterparts of correct sentences, $=0.18$. But the SVO counterparts of lexical–semantic violation sentences were less acceptable than those of correct, <0.01, or constructional violation sentences, <0.01. For the cloze probability, the verbs in SVO counterparts of constructional violation sentences were more predictable than SVO counterparts of correct sentences, <0.05, but verbs in SVO counterparts of lexical–semantic violation sentences were not predictable than those in SVO counterparts of correct, <0.01, or constructional violation sentences, <0.01.

Therefore, both lexical–semantic and constructional violation sentences were not well-formed as compared to correct sentences. However, constructional violations no longer existed when being transformed from the *ba* form to the non-*ba* SVO form, indicating that critical verbs in this condition satisfied semantic requirements of subjects and objects but violated semantic constraints of the *ba* construction. Meanwhile, critical verbs in the lexical–semantic

the two violation conditions on the following factors: Condition (lexical–semantic vs. constructional), Region and Electrode. We focused on two regions of interest (ROIs), with F3, FC3, Fz, FCz, F4, and FC4 electrode representing the anterior region, and CP3, P3, CPz, Pz, CP4, and P4 electrodes representing the posterior region. Further comparisons were planned for each ROI if interactions reached significance. The Greenhouse–Geisser correction was applied when evaluating effects with more than one degree of freedom in the numerator. The partial effect size (Hays, 1973) was provided in addition to the *F*-value and the -value.

Acknowledgments

This study was supported by grants from China National Pandeng Program (95-special-09) and National Science Foundation (30070260, 30470569, 60435010). We thank Drs. Angela D. Friederici, Jerry Packard, Yaxu Zhang, and anonymous reviewers for their comments on an earlier draft of this paper. Electronic mail concerning this paper should be addressed to xz104@pku.edu.cn.

REFERENCES

Ahrens, K., 1995. Verbal integration: the interaction of participant roles and sentential argument structure. J. Psycholinguist. Res. 22, 497–516.

Bever, T.G., 1970. The cognitive basis for linguistic structures. In: Hayes, J.R. (Ed.), Cognition and the Development of Language.

Hays, W.L., 1973. Statistics for the Social Science, 2nd ed. Holt, Rinehart and Winston, New York.
Hoeks, J.C.J., Stowe, L.A., Doedens, G., 2004. Seeing words in