LANGUAGE PROCESSING IN CHINESE
H.C. Chen and O.J.L. Tzeng (Editors)

Cues as Functional Constraints on Sentence Processing in Chinese

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The language-specific properties of Chinese provide a unique testground for theories in sentence processing. This chapter examines the psycholinguistic mechanisms underlying Chinese sentence comprehension processes with results from two experiments. First, an off-line experiment was designed to investigate how Chinese speakers use word order and animacy cues in processing simple sentences. The results are largely compatible with previous studies in that Chinese speakers rely more on animacy than on word order. Second, an on-line experiment was designed to tap into the role of word order, animacy, the object marker BA, and the passive marker BEI in real-time processing of Chinese sentences. Consistent with the results from the off-line experiment, this experiment shows that different cues play different roles in the interpretation process, but they interact with each other as a function of competition and convergence that correspond to the patterns of cue use in the language. These studies also provide clues to the dynamic properties of sentence processing in general.

Crosslinguistic methods have in recent years become very important in the field of language acquisition and language processing. Because of the diversity of the world's languages with respect to their specific linguistic properties, comparison across languages allows researchers to disentangle variables that are likely to be confounded in a single language. Crosslinguistic comparison also allows investigators to identify the role of specific variables that may not be transparent in a single language. However, most of the languages that have been well examined so far are the Indo-European languages, all of which have, to different degrees, some kinds of grammatical devices that mark number, gender, or case relations between nouns, or nouns and verbs. Chinese, in contrast to these languages, makes virtually no use of such morphological devices. There are no case markings, no agreement markings, and no tense suffixes. The impoverished system of grammatical morphology in Chinese thus provides a good opportunity for the study of language processing from a crosslinguistic perspective.

A large body of recent crosslinguistic studies have been carried out within a research paradigm called the Competition Model (Bates & MacWhinney, 1982, 1989; Bates, McNew, MacWhinney, Devescovi, & Smith, 1982; MacWhinney, 1987). This model is an interactive activation model of language comprehension and language use, in which the cue validity or the information value of linguistic forms in a given language plays a probabilistic role in the process of mapping between surface forms and underlying functions. The surface forms that can be used to assign meaning include grammatical devices and semantic cues. The underlying functions that can be extracted from these surface cues include categories like agent and topic. The strength of the connection between forms and functions vary from language to language. A cue, in this context, is a particular piece of information for the speaker or listener to identify the functions of linguistic forms.

The major predictive construct in the Competition Model is cue validity, which is evaluated as the product of a cue's availability (how often the cue is available) and its reliability (when the cue is available, how often it leads to the right answer) in a given language. Cue validity serves as the primary determinant of cue strength, i.e., the weights that speakers assign to different cues in real-time sentence processing. For example, word order has a higher cue validity in English than animacy or morphology, while the reverse is true in Italian. Thus English speakers rely more on word order while Italian speakers rely more on animacy and morphology in sentence interpretation.

Different cues cooperate and compete with each other in the comprehension process. If two or more cues point to the same interpretation, their strengths are combined, leading to a greater activation of that interpretation than the activation produced by a single cue acting alone. If the cues disagree, the interpretation with the highest activation is chosen.

In contrast to most nativist models of language processing, the Competition Model emphasizes linguistic variation rather than linguistic universals in explaining language behaviors. Because this model was formulated from the beginning as a crosslinguistic model, it has been applied in studies of a wide range of languages, including Dutch, English, French, German, Hebrew, Hindi, Hungarian, Italian, Japanese, Serbo-Croatian, Turkish, and Warlpiri (see MacWhinney & Bates, 1989 for representative works). However, it has not been applied systematically to the study of Chinese, a major Sino-Tibetan language spoken by a fifth of the world's population. The goal of this study is to examine the basic principles of the Competition Model in Chinese. We are interested in the question of how Chinese speakers, in the absence of grammatical morphology, make use of other types of cues, and how these cues interact in determining Chinese speakers' performance in real-time sentence processing.

Most previous studies within this framework have adopted a sentence comprehension task in which native speakers of different languages are presented with simple sentences that contain two nouns and one transitive verb, and are asked to identify the agent of the sentence, i.e., the performer of the action described in the sentence. In these studies, competing and converging combination of surface cues are often incorporated into sentence stimuli. For example, in the English sentence *The cow is hitting the ball*, there are three cues: (1) the pre-verbal position of the first noun (which is usually the agent in English); (2) agreement between the first noun and the main verb in person and number; (3) a contrast in animacy between the first and the second noun (first noun animate, second noun inanimate). All three cues converge to indicate *the cow* as the agent of the sentence. In contrast, in the sentence *The pencils is kissing the elephant*, the word order cue which promotes *the pencils* as the agent competes with the agreement and the animacy cues which promote *the elephant* as the agent. Performance on these sentences with converging and competing cues would provide us with information on the processing strategies that native speakers adopt in sentence interpretation.

There are only a few studies that have adopted this paradigm to investigate some aspects of Chinese sentence processing. Miao (1981) and

Miao, Chen, and Ying (1986) studied the role of word order and animacy in interpreting simple Chinese sentences. In the first study, Miao found that native Chinese speakers relied more on noun animacy than on word order in determining the agent of a sentence. In fact, the main effect of word order did not even reach statistical significance. There was only a slight tendency for subjects to choose the first noun as the agent in NVN (Noun-Verb-Noun) sentences, i.e., to interpret NVN as SVO. This was a surprising finding, since in traditional grammars word order was considered to be almost the only syntactic device in Chinese (cf. Chao, 1968). In the second study, using the same procedure as in the first one, Miao et al. still found that animacy was a stronger cue than word order. However, this time the main effect of word order was significant. For NVN sentences, adult subjects (the study also involved children) chose the first noun as agent 77.5% of the time, as compared with 51.4% for NNV (Noun-Noun--Verb) and 40% for VNN (Verb-Noun-Noun) sentences. They also found that there was an interaction between word order and noun animacy. When these two cues agree with each other, e.g., in AVI sentences (first noun animate, second noun inanimate), interpretation was uniform across subjects (100% first noun choice), and when these two cues conflict, e.g., in IVA sentences (first noun inanimate, second noun animate), subjects depended more on animacy (35.8% first noun choice). These authors claimed that results from the second study should be regarded as more reliable since there were 20 subjects in the second study and only 8 in the first.

In a study of sentence interpretation in Chinese aphasia, Chen, Tzeng, and Bates (1990) looked at both aphasic patients and normal controls. They found that both normal controls and aphasic patients were sensitive to animacy and word order cues in processing simple NNV, NVN, and VNN sentences. Consistent with Miao's studies, their results indicate that the effect of animacy was much stronger than that of word order. There was also a significant interaction between animacy and word order. However, the aphasic patients were not significantly different from the normal controls in their performance on these sentences. The only difference was a small overall tendency for a few aphasic patients to choose the first noun as agent. Their results thus demonstrate that aphasic patients, in spite of focal brain injury, preserve the basic processing strategies of their native language.

So far, these studies have concentrated on two types of cues, word order and animacy, and their conclusions were drawn from results of off-line experiments. Our study reported in this chapter will, in addition to word order and animacy cues, examine a number of other cues. Moreover, we will use both off-line and on-line techniques to tap into issues of real-time sentence processing. We shall see that the on-line method will, on the one hand, complement what has been found in off-line experiments, and on the other, reveal some new dynamic aspects of cues as functional constraints on sentence processing.

Before reporting our experimental results in detail, let us look at some facts about the Chinese language. In particular, we want to examine some of the syntactic and semantic properties of the major cues to Chinese sentence processing.

An Analysis of Four Cues in Chinese

In the absence of inflectional morphology, Chinese makes use of a number of devices in indicating sentence roles between different constituents. These devices include word order, animacy, free-standing morphemes such as the object marker *ba*, the passive marker *bei*, the locative preposition *zai*, the dative marker *gei*, and the aspect marker *-le* (For detailed discussions of some aspects of these morphemes, see Li & Thompson, 1981; Li, 1990). In the following, we will briefly discuss four cues in Chinese that will be examined in our experiments: word order, the object marker *ba*, the passive marker *bei*, and animacy.

According to traditional grammars, word order is the primary syntactic device in Chinese. This is not only true on sentential level, but also true on phrasal level (see Chao, 1968; Tai, 1985; Li, 1989 for discussions of head-modifier relations and the ordering of temporal and locative prepositional phrases). The basic word order in Chinese is SVO (Sun & Givón, 1985).[1] However, there are some word order variations. Three other word orders, OSV, SOV, and OVS are available in the spoken language, although they are marked in a number of ways. The basic SVO sentences are neutral in meaning with respect to the status of both the subject and the object. In contrast, OSV and SOV sentences place special emphasis on the object. In OSV, the object is the topic of the sentence. It is assumed to involve information that is given to both the speaker and the hearer. In SOV, the object is definite and is usually preceded by the object marker *ba*. SOV sentences with *ba* are semantically associated with highly transitive, resultative events (Li, 1990); those without *ba* are pragmatically restricted to situations in which the speaker provides information counter to the expectation of the hearer (Li & Thompson, 1981). This second type of SOV is particularly marked: given a simple NNV string with no *ba* marking, it is more likely to be OSV than SOV in Chinese. Finally, VOS sentences are only possible if S is an afterthought, as in *kan -le nabu dianying, tamen* (see -LE that movie, they) (see Lu, 1980 for a detailed discussion).

To illustrate the word order variations discussed above, let us look at the following examples:

(1) *Zhangsan mai -le yi ben shu.* (SVO)
Zhangsan sold a book.

(2) *Shu Zhangsan mai -le.* (OSV)
Book Zhangsan sold.

(3) *Zhangsan (ba) shu mai -le.* (SOV)
Zhangsan (BA) book sold.

(4) *Mai -le shu, Zhangsan.* (VOS)
Sold book, Zhangsan.

The existence of SOV sentences indicates that the pre-verbal position is not particularly associated with a fixed function in Chinese. It contrasts with the post-verbal position in which only the object of the sentence can occur. Thus, the way in which word order cues are configured in Chinese is almost the opposite of the way they are configured in English. In English, it is pre-verbal positioning which is the single most reliable cue to sentence interpretation (MacWhinney & Bates, 1989). Postverbal positioning is a useful cue to the identification of the object, but not nearly as strong as the pre-verbal cue to the identification of the subject. Furthermore, the subject can often be omitted in Chinese when the context is clear, frequently resulting in simple VO and (less often) OV sequences. Subject omission also reduces the reliability of the pre-verbal position as a cue to the subject in Chinese. Omission is common in Chinese. Not only the subject, but also other constituents of the sentence can frequently be omitted, as long as the context provides clues as to who does what to whom. In general, omission reduces the reliability of word order cues.

As mentioned above, the object marker *ba* is associated with SOV sentences. It cannot be used in the basic SVO sequence. Although the original meaning of *ba* as a verb ('take hold of', 'grasp') is very weak or nonexistent in modern Chinese, its trace can still be seen in that *ba* requires an object that is highly affected by the activity denoted by the verb. Traditional grammars have termed the *ba* construction "the disposal construction" (Wang, 1957), due to this property of the form. Two other features of *ba* have also been widely noted (Chao, 1968). First, the object noun phrase must be definite or specific; that is, indefinite noun phrases cannot normally occur following *ba*. Second, the verb phrase in these constructions must be structurally complex (Ding, 1961; Li, 1990). In particular, causative and resultative verbs (e.g., verb-complement structures like *da-po* ('hit-break')) are required in the *ba* construction. Developmental evidence indicates that children are sensitive to the properties of this morpheme and acquire its use at an early stage (Li, 1990, 1991; Chang, 1986).

The passive marker *bei* is another important device like *ba* in Chinese grammar. Although *bei* does not occur frequently in spoken language, it is extremely reliable as a cue to role assignment in that the noun phrase after it always indicates the agent of the sentence. On the surface, the *bei* construction is structurally similar to the *ba* construction (i.e., both appear in front of the second noun in an NNV string), but their functions in indicating sentence roles are different: *bei* marks an OSV structure while *ba* marks an SOV structure. However, they also share some features in common. For example, the *bei* as well as the *ba* construction requires the verb phrase to be highly transitive or to indicate a causative meaning, and structurally the verb phrase has to be complex, i.e., single monosyllabic verbs cannot occur alone in sentences with *bei* or *ba*.

There are at least two reasons why *bei* does not occur very often. First, Chinese often uses the topicalized object construction (OSV) to express the same meaning for which other languages would use a passive construction, e.g., *douzi xiaohai reng -le* (beans child throw -LE = the beans were thrown away by the child). Second, the *bei* construction in Chinese is traditionally associated with an adverse meaning. It is used when the speaker wants to indicate that something unfortunate or undesired has happened.[2]

Sentence roles are not determined solely by grammatical devices. It can also be influenced by the semantic properties of the noun phrase itself, such as animacy, i.e., whether a noun phrase indicates an animate (including human and animals) or an inanimate object.[3] Comrie (1981) discusses in detail the interrelations of animacy with other syntactic and semantic factors, e.g., number, gender, and case marking, showing that animacy is relevant and important to grammatical distinctions. As Corrigan (1988) has shown, many verbs expect to have an animate agent and an inanimate patient. If there is an animate-inanimate contrast involved in an action, it is usually the case that an animate agent is acting on an inanimate patient. These semantic biases for particular verbs hold across many languages (Gass, 1987) and should be available to Chinese speakers just as they are to speakers of other languages.

We have thus far discussed the importance of word order, animacy, *ba*, and *bei* in Chinese as a function of their validity in natural speech. In order to evaluate these different cues and their interaction patterns in Chinese sentence processing, we have carried out two experiments in which different cues were crossed over in different sentences, so that subjects had to rely on one or more competing or converging cues to identify the agent role. The first experiment was an attempt to replicate previous studies, in particular, Miao (1981) and Miao et al. (1986), using an off-line method (Liu, Bates, & Li, 1991). The second experiment was an attempt to tap into issues of dynamic processes of sentence interpretation, using an on-line technique (Li, MacWhinney, & Bates, 1991). In the second experiment, sentences and pictures were digitized for computer presentation and the subject's task was to press a button when he decided which of the two pictures indicates the agent of the sentence. On the basis of results from these experiments, we hope to be able to disentangle the role of individual cues and their interactions in the processing of Chinese sentences. In the following, we will report the major results from both experiments, first the off-line study, then the on-line study. For technical details of these studies, see Liu, Bates, & Li (1991) and Li, MacWhinney, & Bates (1991).

Experiment One: Off-line Sentence Interpretation

Method

Subjects. Eight native Mandarin Chinese speakers participated in this experiment (6 females and 2 males, age range 28 - 44). Six of these subjects were family dependents of Chinese graduate students who were studying at the University of California, San Diego; the other two were visiting scholars. All of them had been exposed to the English speaking environment for no more than half a year by the time of the beginning of the experiment, and had received little or no formal training in English when they were in mainland China. At the time of testing, all of them reported using Chinese almost all of the time while they were staying in the United States.

Materials. The two variables manipulated in this study were word order sequences (NVN, NNV, and VNN) and noun animacy (AA: both nouns animate; AI: first noun animate and second noun inanimate; IA: first noun inanimate and second noun animate). The crossing of the three levels of word order with the three levels of animacy yielded nine types of sentences: AAV, AIV, IAV, AVA, AVI, IVA, VAA, VAI, VIA. Each test sentence was generated by a random selection of two nouns and a verb from a pool of nouns and verbs (see Appendix 1 for a complete list of the nouns and verbs used in this experiment), appropriate to that particular sentence type. The nouns and verbs used in this and the following experiment are all familiar items to the subjects. There were six individual tokens for each of the nine types, resulting in a total of 54 test sentences. There were three versions of the test sentences. Each subject was randomly assigned one of the three versions for testing. Below are some examples of the test sentences:

AVA: *Xiaoma ti xiaoniu.*
Horse kick cow.

IAV: *Luobo daishu xi.*
Carrot kangaroo wash.

VAI: *Qiao nuhai chuanghu.*
Knock girl window

Procedure. Each subject was tested individually in a quite room. All the instructions and the test sentences were recorded by a native Chinese speaker before the test and then played back on a tape-recorder one sentence after another. There was a pause for subjects to give verbal responses after each sentence had been played. Subjects received the stimuli via an earphone.

The instructions were as follows (translated from Chinese), "In this experiment you will hear a series of short sentences in Chinese. Each sentence describes an action and there will be two objects involved in the action. One of the objects will be the actor of the action. Your task is to determine who is the actor, depending upon your understanding of the sentence. There are no right or wrong answers here, but we need you to listen carefully to each sentence."

Data analysis. In this kind of sentence interpretation experiment, the notion 'percent correct' is not meaningful. Thus we followed the scoring procedure adopted in other studies (see MacWhinney & Bates, 1989), to derive the dependent variable 'percent choice of the first noun as agent'. For each test sentence, subjects were given a score of 1 for choosing the first noun as the agent, a 0 for choosing the second noun. The values were summed for the six individual sentences belonging to the same sentence type and were then entered as the raw data for subsequent statistic analysis. In all text and figures reported below, these results have been converted to percentages. Hence a score close to 100% means that the first noun was reliably chosen as the agent, a score close to 0% means that the second

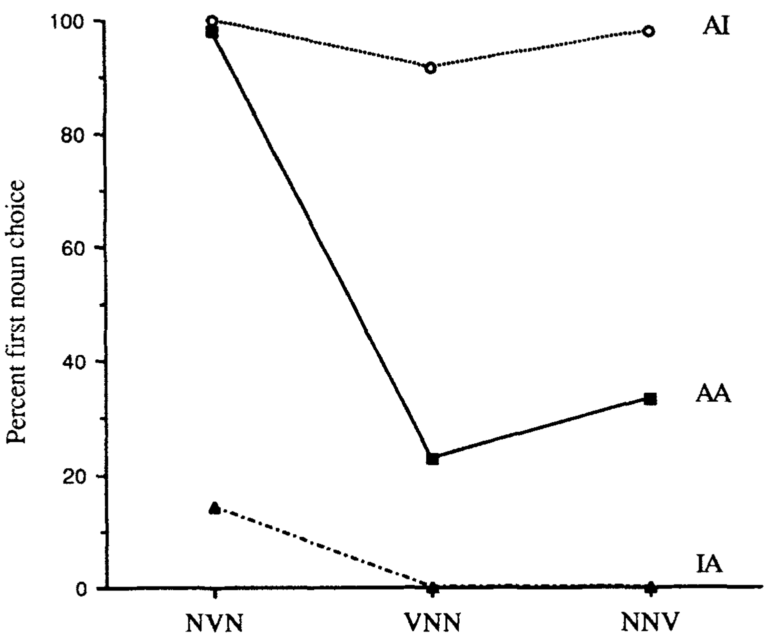

Figure 1. Choice responses in Experiment 1.

noun was reliably chosen as the agent, and scores in the 50% range indicate random performance.

Results

The results from this experiment are summarized in Figure 1. A 3 X 3 within-subject analysis of variance (i.e., with three levels of word order and three levels of animacy) indicates that there were both main effects of word order, $F(2,14) = 91.21$, $p < 0.001$, and animacy, $F(2,14) = 15.68$, $p < 0.001$, and there was also a significant interaction between the two, $F(4,28) = 18.27$, $p < 0.001$.

It should be clear from Figure 1 that these native speakers of Chinese relied primarily on the animacy cue to interpret simple sentences. On the AI and IA items, where there was an animacy contrast, subjects chose almost exclusively in favor of the animate noun (96.5% first noun choice on AI, and 4.9% on IA), irrespective of the order differences. On the AA items, where there was no animacy contrast, subjects showed a strong tendency to choose the first noun in NVN (97.9%, an SVO strategy), and somewhat weaker tendency to choose the second noun in VNN (22.9%, a VOS strategy) and NNV (33.3%, an OSV strategy). These word order strategies are stronger than the ones reported by Miao (1981, 1986) and Chen et al. (1990). In particular, the second noun strategy in the non-canonical word orders NNV and VNN was absent in Miao's and Chen's studies. However, they are consistent with results from our on-line sentence interpretation study (cf. Li et al., 1991). We will return to these similarities and differences later in the discussion.

A direct comparison of the strength of word order vs. animacy can be obtained by looking at the critical "competition cells", i.e. items in which word order and animacy lead to opposite conclusions. For example, in the cell IVA (where animacy must compete with canonical SVO word order), subjects chose the second noun 85% of the time. The same is true for the competition cells VAI and AIV, where animacy competes with the default VOS and OSV word order strategies. Here too, subjects chose in favor of animacy close to 100% of the time. It shows that animacy plays a predominant role as a cue to Chinese speakers' identification of sentence constituents.

Experiment Two: On-line Sentence Interpretation

The experiment discussed above used the traditional configurations of materials and procedures, and subjects' responses were measured in an off-line fashion after initial processing has been completed. The experiment only considered word order and animacy and did not take other important cues into account. To overcome the limit of the off-line experiment, we moved to on-line techniques in the second experiment, in which we could measure not only how often subjects choose a particular noun, but also how fast they do so as a function of cue use. In the following, we will discuss two kinds of results from the on-line experiment, choice responses and reaction times. As will be seen, these results are highly consistent with each other, and with results from the off-line experiment.

Method

Subjects. Twenty native adult Chinese speakers participated in this experiment (11 males and 9 females, age range 22 - 44). These subjects were either college students, visiting scholars, or their family dependents, and had been in the United States for no more than a year by the time of the testing. None of these subjects took part in Experiment One. Two subjects were dropped from the final analysis because their responses contained more than 10% missing values.

Materials. The experimental materials contained three sets of stimulus sentences: simple sentences, *ba* sentences, and *bei* sentences.[4] The simple sentences were structurally identical to the sentences used in the off-line experiment. The *ba* and *bei* sentences had the object marker *ba* and the passive marker *bei* in front of the second noun, respectively. Word order and animacy were also systematically varied in these sentences. Thus, the contribution of *ba* and *bei* as markers of sentence roles can be evaluated by comparing results from *ba* and *bei* sentences with those from simple sentences.

To match the number of sentences tested in the off-line experiment, we used 54 sentences for each of the three types of sentences, which resulted in a total of 162 sentences. Within each type, there were nine sub-types identical to those in the off-line experiment. Each sub-type represents an individual cell in which one level of word order is crossed with one level of animacy. There were six test sentences in each of these sub-types. All sentences were generated randomly by combining two nouns and a verb from a pool of lexical items (for a complete list of these items, see Appendix 2). A sample of the test sentences are presented below:

(1) Simple sentences

AVI: *Xiaomao ti chuanghu.*
Cat kick window.

AIV: *Daishu putao zhai.*
Kangaroo grapes pick.

VIA: *Xi damen nanhai.*
Wash door boy.

(2) *Ba* sentences

A*ba*IV: *Xiaoya ba dashu reng-diao.*
Duckling BA tree throw-away.

AV*ba*I: *Houzi chi-diao ba xiangjiao.*
Monkey eat-up BA banana.

VI*ba*A: *Fang-zou fengzheng ba mianyang.*
let-go kite BA sheep.

(3) *Bei* sentences

I*bei*AV: *Qiqiu bei nuhai reng-diao.*
Balloon BEI girl throw-away.

AV*bei*I: *Xiaozhu yao-lan bei dashu.*
Pig bite-mash BEI tree.

VA*bei*I: *Da-po xiaogou bei pingguo.*
Hit-break dog BEI apple.

The test sentences were first recorded on a high bias audio tape by a native Mandarin speaker and then digitized into the computer. All sentences were read in a smooth and flat intonation. Each sentence was matched with two pictures that represented the objects described in the sentence. Pictures were selected from Abbate and LaChappelle (1978, 1984). The pictures were digitized with an AST Turbo scanner and displayed on a high resolution RGB monitor.

Procedure. During the testing, subjects heard a sentence played back on a speaker, and simultaneously saw a pair of pictures corresponding to the two objects of the sentence on the computer screen. They were instructed to listen to the sentence and look at the pictures at the same time. The task was to determine which of the two objects did the action in each sentence. The subjects were asked to express their choices by pushing one of the two buttons on a button box as soon as possible.

The experiment was conducted in a dimly-lit room so that the subject could concentrate on the computer screen where the pictures were displayed. Each subject was tested individually. The experiment was run on a Macintosh IIsi model. The experimental program was configured so that the onset time of the pictures being displayed on the screen was the same as the onset time of the sentence being played on the speaker. The onset of each sentence started the button box timer for subjects' response times to that sentence. Each time after the subject pressed a button, the current pictures disappeared. There was then a two second silence with a blank screen before the next pair of pictures appeared and the next sentence began to play. Subjects were given a maximum of three seconds to respond after the sentence had been played. This amount of time was sufficient to allow full responses for most subjects under most of the conditions, while still putting some pressure on the response speed. Within each of the four types of sentence, the order of presentation was randomized for each subject. Subjects' responses, i.e., choice responses and reaction times, were recorded automatically by the program for later analyses.

At the beginning of the testing, each subject had a warm-up session in which he or she practised with ten sentences similar to the test sentences. Simple sentences were tested first, and then *ba* sentences, and then *bei* sentences. This was to ensure that performance on sentences with markers would not influence performance on simple sentences without any markers. Subjects were given a five minute break after the testing of each type of sentences.

Results

Simple sentences. Figure 2 presents the choice responses for the simple sentences, averaged across 18 subjects. Analysis of variance on the raw data showed a significant main effect of animacy, $F(2,34) = 75.54$, $p < 0.001$. Collapsed over word order types, subjects chose the animate noun as the agent 85% of the time on AI items and 88% of the time on IA items. This animacy effect accounts for 72% of the experimental variance. There was also a significant main effect of word order, $F(2, 34) = 21.61$, $p < 0.001$. When there was no animacy contrast, i.e., on the AA items, subjects chose the first noun in NVN 87% of the time, 34% in NNV, and 25% in VNN. This reflects a first noun strategy in the canonical order NVN, and a second noun strategy in the non-canonical orders NNV and VNN. However, as compared with the main effect of animacy, the word order effect is smaller, accounting for only 23% of the experimental variance. Finally, the word order by animacy interaction was also strongly significant, $F(4,68) = 11.46$, $p < 0.001$.

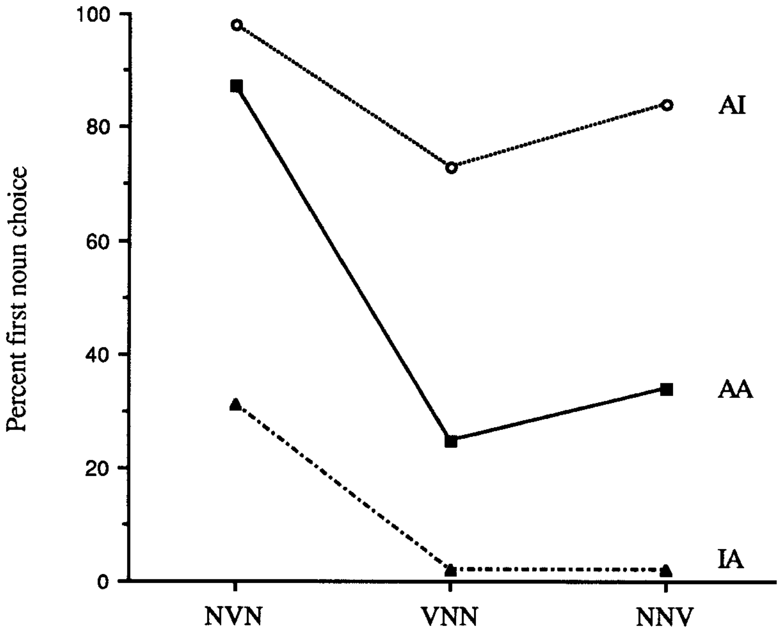

Figure 2. Choice responses for the simple sentences in Experiment 2.

These results are highly compatible with those from the off-line experiment. In both cases, animacy was the dominant cue, and word order interacted with animacy. Comparing Figures 1 and 2, we can see that there was only a slightly stronger word order effect in the on-line experiment. For example, subjects chose the first noun in VAI sentences 91% of the time in Experiment One, but only 73% of the time in this experiment.

The reaction time data, averaged across 18 subjects, are summarized in Figure 3. RTs in this and the remaining graphs represent the response times in milliseconds from the beginning of the sentence to the point where the subject pressed the button for his choice decision.

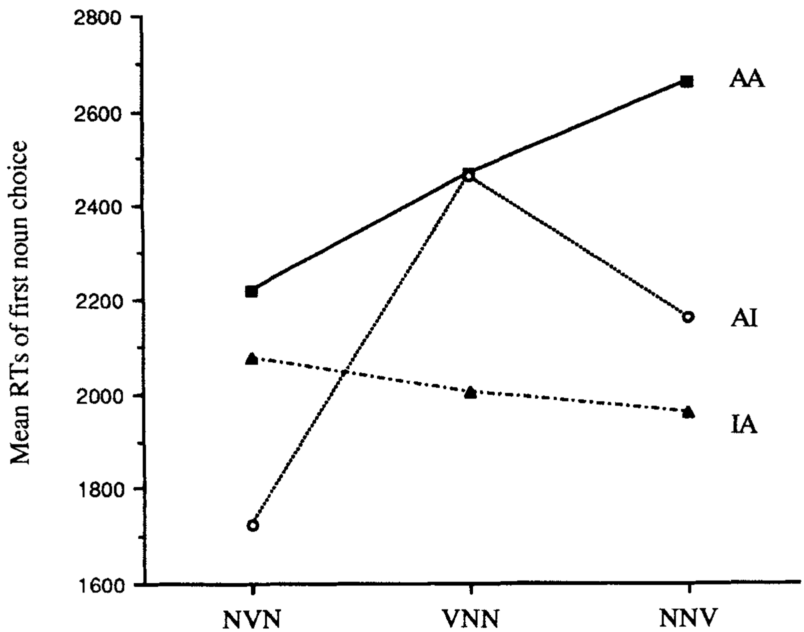

Figure 3. Reaction times for the simple sentences in Experiment 2.

Consistent with the choice response data, the main effects of animacy and word order and the interaction effect between the two all reached significant level ($p < 0.001$). In general, subjects were faster when the animacy cue was present (AI and IA items) than when there was no animacy contrast (AA items). When the animacy cue and the word order cue agree with each other, sentence processing was facilitated and subjects' response speed was faster. For example, the mean reaction time for AVI (mean = 1724 ms) was faster than that for any other type of sentences, because both cues agree with the SVO configuration, thus promoting a first noun choice. In contrast, when the two cues conflict with each other, sentence processing was inhibited and subjects' response speed was slower. The IVA sentences, in which word order promotes first noun while animacy promotes the second noun as agent, produced significant slower reaction times (mean = 2077 ms) as compared with AVI. In the non-canonical order VNN, VIA elicited much faster RTs (mean = 2002 ms) than VAI sentences (mean = 2462 ms). This may reflect the fact that VOS is a possible string in Chinese, while VSO is not: only the object can occur at the post-verbal position. In NNV, subjects were slower with AIV (mean = 2162 ms) than with IAV (mean = 1958 ms), which probably reflects the fact that in adult Chinese OSV is more common than SOV for simple NNV strings.

BA sentences. Turning to the results with the *ba* sentences, we found that in general, the presence of the *ba* marker did not change the underlying pattern that was seen in the simple sentences. In a combined analysis incorporating data from both the simple sentences and the *ba*

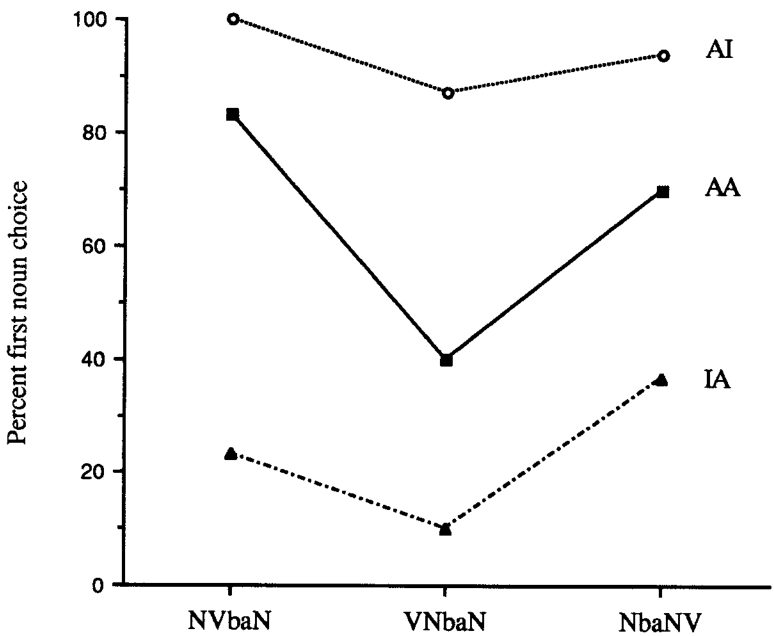

Figure 4. Choice responses for the BA sentences in Experiment 2.

sentences, animacy is still the dominant cue and the shape of its significant main effect ($F(2,34) = 115.75$, $p < 0.001$) is similar across sentences with and without *ba*. The significant interaction between word order and animacy ($F(4,68) = 15.80$, $p < 0.001$) also has the same shape as in the results of the simple sentences without *ba*. Figure 4 illustrates the results from subjects' choice responses to the *ba* sentences.

The contribution of *ba* marking was mainly shown in the non-canonical orders, but not in the canonical order NVN. The presence of *ba* had its effect most clearly on the NNV word order, since this is the only order in which *ba* occurs naturally in the language. In the combined analysis, there was a significant main effect of *ba* marking in that the presence of *ba* tended to lead to a higher level of first noun choice. This effect can be clearly seen by comparing A*ba*AV with AAV sentences. In AAV, subjects chose the first noun only 34% of the time, whereas in A*ba*AV, they chose the first noun 70% of time. This difference accounts for much of the effect of *ba* marking. However, counter to expectation, the presence of *ba* did not elevate the first noun choice to an even higher level. According to traditional grammars, the *ba* construction is exclusively associated with the SOV structure.

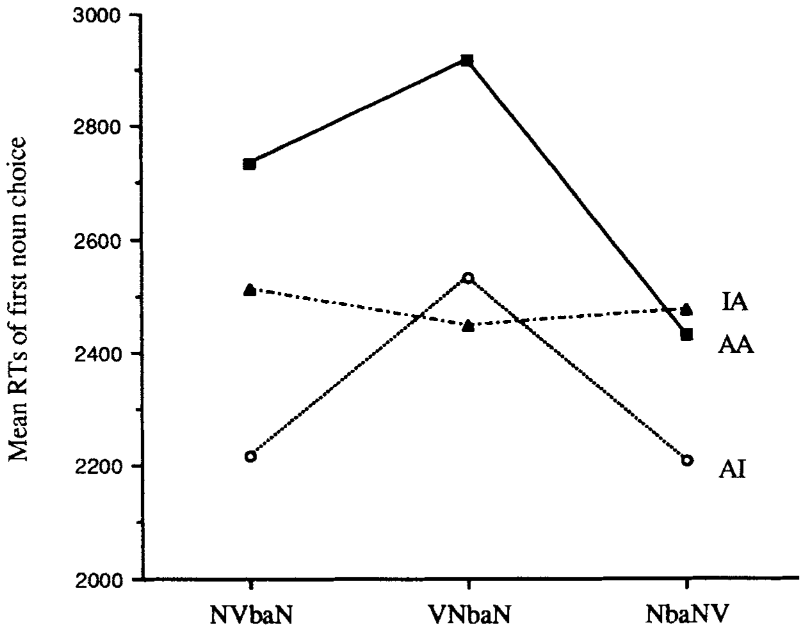

Figure 5. Reaction times for the BA sentences in Experiment 2.

An inspection of the reaction time data for the *ba* sentences shows that subjects' response speed was highly consistent with their choice responses. In addition, these RTs revealed facts about on-line competition and convergence that were not apparent in the choice data. Figure 5 presents the RT results from subjects' performance on the *ba* sentences.

As can be seen from Figure 5, A*ba*IV and AV*ba*I elicited fastest response times of all sentence types (mean = 2209 ms, and mean = 2217 ms, respectively) because both animacy and *ba* marking point to the first noun as agent in these sentences.

A comparison with the results from simple sentences indicates that for NVN sentences, the basic pattern of response speed is the same whether *ba* was present or absent. This similarity is entirely consistent with the choice response data in which the presence or absence of *ba* did not make a difference to subjects' performance on NVN sequences. However, in the non-canonical VNN sentences, the presence of *ba* produced a facilitation of response speed from VA*ba*A (mean = 2915 ms) to VA*ba*I (mean = 2531 ms); the convergence of animacy and *ba* marking was enough to overwhelm the word order cue in VA*ba*I. In contrast, when the *ba* marker was absent (cf. Figure 3), there was no facilitation from VAA (mean = 2470 ms) to

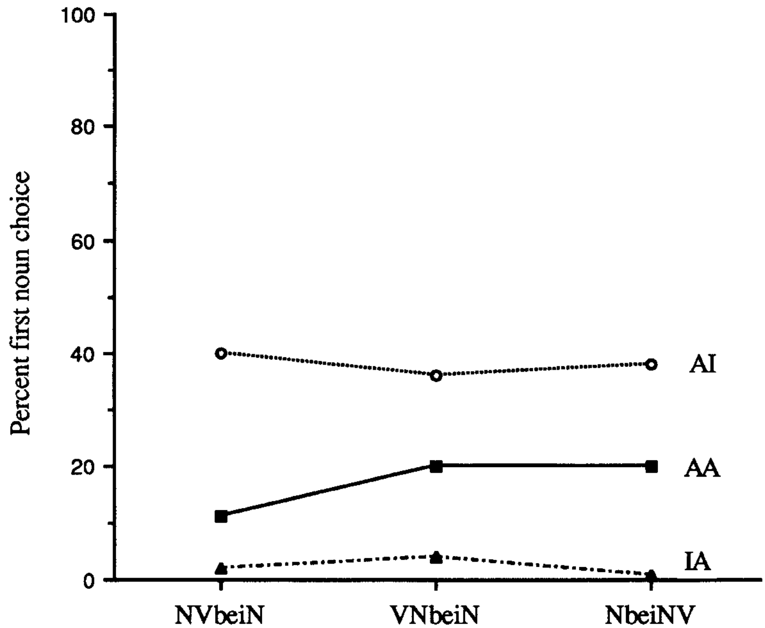

Figure 6. Choice responses for the BEI sentences in Experiment 2.

VAI (mean = 2462 ms), indicating that both kinds of simple VNN strings were equally difficult for subjects to process, given that the animate noun occurs at the post-verbal position.

BEI sentences. The results with the *bei* sentences are summarized in Figure 6. As can be seen, unlike the object marker *ba*, the passive marker *bei* was clearly dominant over all other cues in sentence interpretation. Subjects chose the second noun predominantly for all different conditions of word order and animacy, although animacy still has a strong effect, $F(2,34) = 12.80$, $p < 0.001$. There was no main effect of word order, $F(2,34) = 1.51$, $p > 0.05$. The interaction between word order and animacy was barely significant, $F(4,68) = 2.89$, $p < 0.05$.

These results indicate that native Chinese speakers rely on the passive marker almost exclusively and ignore other cues whenever *bei* is present. In other words, *bei* wins over word order and animacy when these cues are set into competition. However, we can still see a small effect of animacy in these data. On the AI items, first noun choice was pushed to about 40% for different orders.

In the RT data (Figure 7), although there are main effects of both word order, $F(2,34) = 5.87$, $p < 0.01$, and animacy, $F(2,34) = 7.99$,

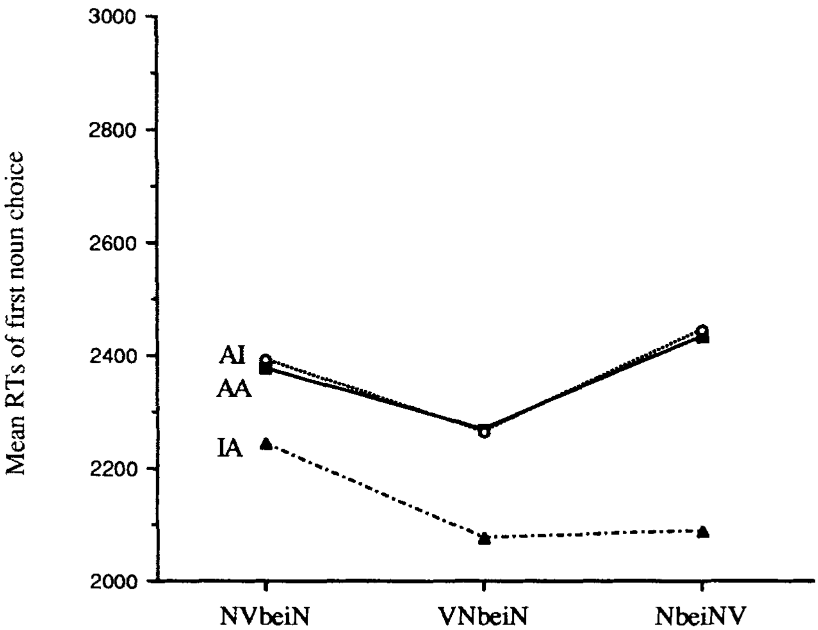

Figure 7. Reaction times for the BEI sentences in Experiment 2.

$p < 0.01$, the differences between different word orders are small (in a given animacy condition, all differences were within 200 milliseconds), and of less interest. The effect of animacy is shown by comparing IA with AA or AI conditions. In the IA condition, response times were faster by about 150 milliseconds for NV*bei*N, 200 ms for VN*bei*N, and 250 ms for N*bei*NV sentences. These facilitations are compatible with the fact that in Chinese *bei* is followed by the agent and preceded by the patient. IA sentences produced the fastest responses among the different animacy conditions because animacy converges with *bei* marking in promoting the second noun as agent in these sentences.

Discussion

The main results from our off-line and on-line experiments on simple sentences are highly consistent with each other. We found a strong main effect of animacy, a reliable word order effect, and an interaction effect between animacy and word order. In both studies, animacy was shown to win over word order when the two were set into competition. These results are also compatible with Miao (1981), Miao et al. (1986), and Chen et al. (1990). Furthermore, it was shown that the passive marker *bei* plays a dominant role in Chinese sentence processing whenever it occurs. The object marker *ba* is less as important as *bei* to the assignment of sentence roles, but its presence also strongly promotes the first noun as agent in sentences with non-canonical word orders, in particular, the NNV sentences. Overall the hierarchy of cue strength we found in these experiments was: passive marker > animacy > word order > object marker. Because the passive marker *bei* is rare in informal speech, overall, it is noun animacy that is the most valid cue in Chinese sentence processing.

As previous crosslinguistic studies of sentence processing have shown, the types and functions of cues vary across different languages and accordingly determine the processing strategies by speakers of different languages. Results from our two experiments further confirm these predictions. Studies in English (Bates & MacWhinney, 1982; Bates et al., 1982) have indicated that word order is the most important cue to English speakers in the assignment of sentence roles. Although our results have also shown that Chinese speakers rely on word order in addition to other cues, the word order pattern is not the same in these two languages. English speakers exclusively depend on word order cues whenever there is a competition between word order and animacy. In contrast, Chinese speakers rely more heavily on animacy than on word order when conflict between the two occurs. Moreover, English speakers tend to rely on the pre-verbal position as a cue to the subject of the sentence (an SV strategy) while Chinese speakers rely on the post-verbal position as a cue to the object of the sentence (a VO strategy), since the post-verbal position in Chinese is a better predictor of the object than the pre-verbal position as a predictor of the subject (see earlier discussion on Chinese).

Although our results are largely compatible with Miao (1981), Miao et al. (1986), and Chen et al. (1990), there are some discrepancies. In particular, subjects in our study showed a second noun strategy in the non-canonical VNN and NNV orders, while this processing strategy was absent in Miao's studies. The reason for this difference is so far unclear. However, we would like to argue that this second noun strategy fits in well with the fact of word order patterns in adult Chinese. The strong post-verbal cue as an indicator of the object clearly promotes a VOS interpretation for VNN strings, while the more frequent use of OSV over the marked SOV in simple sentences (see earlier discussion) tend to lead the subject to interpret the second noun in NNV as the agent.

The role of the *ba* and *bei* markers as functional cues in adult sentence interpretation has not been well examined in previous studies. Although our main results are clear in showing that these cues are important to sentence processing in Chinese, our on-line experiment has revealed a surprising finding which was not expected: contrary to expectation, the object marker *ba* did not serve as a strong cue to the identification of patient, in contrast to the passive marker *bei* which played a predominant role in marking the agent role. The first noun choice in A*ba*AV sentences reached only 70% of the time. However, a detailed analysis of the adult language suggests that this discrepancy may have well stemmed from the differences between *ba* and *bei* with respect to their functions. First, *ba* functions to mark the pre-verbal object in an SOV sentence. Unlike morphological markings of the accusative in inflectional languages, it does not mark the object in post-verbal positions. Second, grammatical analysis has identified the *ba* construction as conveying a highly transitive or causative meaning, due to the original meaning of the verb *ba* (cf. Sun, 1991). Third, *ba* marks a definite rather than an indefinite object. These syntactic, semantic, and pragmatic constraints on *ba* would probably reduce the validity of *ba* as a pure object marker, and accordingly, *ba* is less prominent to speakers as an indicator of sentence roles.

Bei, unlike *ba*, is not particularly associated with definiteness, and thus carries a more uniform function. Furthermore, the fact that simple NNV strings without any marker are more strongly associated with an OSV than with an SOV interpretation could have influenced our results since both *ba* and *bei* appear in NNV strings. *Ba* indicates an SOV structure while *bei* indicates an OSV structure. The higher probability of NNV as OSV rather than SOV shows that there is a conspiracy between the more frequent OSV and the passive marker *bei*, whereas there is a competition between the OSV and the object marker *ba*. Given that word order is an important cue and that the NNV order is more compatible with *bei* than with *ba*, it comes as no surprise that subjects more uniformly chose the second noun in *bei* sentences than they chose the first noun in *ba* sentences.

Conclusion

The experimental results summarized in this chapter have systematically investigated four cues in Mandarin Chinese with respect to their functional roles in sentence processing: word order, animacy, the object marker *ba*, and the passive marker *bei*. Using both on-line and off-line methods, we have attempted to address the question of how sentence processing in Chinese, the language in which there is no explicit inflectional marking, is determined as a function of cue use. Our results are, in general, highly consistent with previous crosslinguistic work that has examined the predictions of the Competition Model. The results clearly argue for an interactive point of view in which cues differentially affect speakers' performance by means of competition and convergence. The results indicate that Chinese speakers, in the absence of inflectional morphology, make use of almost all possible cues and integrate them interactively in identifying the functional roles of different linguistic constituents. In a language like Chinese, speakers cannot rely only on one type of information, either because single pieces of information would not give unique answers to the processing task, or because some of them, such as the passive marker *bei*, although highly reliable, are not always available (*bei* is optional even for a sentence for which other languages would use a passive construction, see earlier discussion on Chinese).

In the discussion above we have pointed out that animacy is overall the most important cue to Chinese sentence processing. This result is consistent with the fact that Chinese is a context-oriented language in which speakers use "supra-syntactic" information, i.e., semantic and pragmatic information to determine who does what to whom. In contrast to many other languages, syntactic information has only a very limited range in Chinese (cf. Chao, 1968) and cannot possibly be the major functional determinant in Chinese sentence processing.

Although we have taken a crosslinguistic perspective in our study, we did not try to directly compare our results with results from other languages. Such comparisons would be most relevant in the context of bilingualism, where it is important to see how different patterns from different languages influence bilingual speakers' performance. In future studies, we plan to use both on-line and off-line techniques to study sentence interpretation and grammaticality judgment in Chinese-English bilingual speakers. Some pilot work is currently underway in our laboratory (Liu, Bates, & Li, 1991).

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Notes

1. In a simple sentence like *the dog chases the cat*, the noun *dog* can be categorized as a subject, an agent, an initiator and so on, in contrast with the noun *cat* which can be viewed as an object, a patient, a theme, etc. As the distinctions between these categories are highly disputable in linguistics, we do not make a particular commitment here and would like to treat the difference between *dog* and *cat* as a contrast along any of these dimensions.

2. Both Wang (1957) and Chao (1968) have noted that in modern Chinese the adverse meaning is becoming weak because of the influence from massive translation works of Western science and literature in which passive constructions in Western languages were simply translated with the *bei* construction.
3. This cut-off is somewhat idealized since noun animacy may be a continuum on the human-animal-inanimate scale rather than a discrete phenomenon. As Comrie (1981) points out, some languages use finer distinctions while others use less fine distinctions.
4. In the original design we had included another set of sentences with the indefinite marker *yi*. Since these sentences constitute a completely separate piece of the design and the effect of the indefinite marker was not clear from the experiment, we will not report the results here. See Li, MacWhinney, and Bates (1991) for discussion of these results.

References

Abbate, M. & LaChappelle, N. (1978). *Pictures, please: a language supplement.* Communication Skill Builders, Inc.

Abbate, M. & LaChappelle, N. (1984). *Pictures, please: an articulation supplement.* Communication Skill Builders, Inc.

Bates, E., & MacWhinney, B. (1989). Functionalism and the competition model. In B. MacWhinney & E. Bates (eds.), *The crosslinguistic study of sentence processing.* Cambridge University Press.

Bates, E., & MacWhinney, B. (1982). Functionalist approaches to grammar. In Wanner, E., & Gleitman, L. (eds.), *Language acquisition: the state of art.* New York: Cambridge University Press.

Bates, E., McNew, S., MacWhinney, B., Devescovi, A., & Smith., S. (1982). Functional constrains on sentence processing: A cross-linguistic study. *Cognition, 11,* 245-299.

Chang, H-W. (1986). Young children's comprehension of the Chinese passives. In H. Gao & R. Hoosain (eds.), *Linguistics, psychology, and the Chinese language.* Center of Asian Studies, University of Hong Kong.

Chao, Y-R. (1968). *A grammar of spoken Chinese.* Berkeley: University of California Press.

Chen, S., Tzeng, O., & Bates, E. (1990). Sentence interpretation in Chinese aphasia. In *Proceedings of the tenth meeting of the second language research forum,* Department of Linguistics, University of Oregon, Eugene, Oregon.

Comrie, B. (1981). *Language universals and linguistic typology: syntax and morphology.* Oxford: Basil Blackwell.

Corrigan, R. (1988) Who dun it? The influence of actor-patient animacy and type of verb in the making of casual attributions. *Journal of Memory and Language, 27,* 447-463.

Ding, S-S. (1961). *Xiandai Hanyu yufa jianghua* (Lectures on Modern Chinese

Grammar). *Yuwen Huibian* (Collections in Linguistics), *17*, Beijing.

Gass, S. (1987). The resolution of conflicts among competing systems: A bidirectional perspective. *Applied Psycholinguistics*, *8*, 329-350.

Li, C., & Thompson, S. (1981). *Mandarin Chinese: A functional reference grammar.* Berkeley: University of California Press.

Li, P. (1991). *"Zai" and "ba" constructions in child Mandarin.* CRL Newsletter, Vol.5, No.5, University of California, San Diego.

Li, P. (1990). *Aspect and aktionsart in child Mandarin.* Ph.D. dissertation, Leiden University, the Netherlands.

Li, P. (1989). *What cues can Chinese speakers use in sentence processing?* Paper presented at the Workshop on Crosslinguistic Study of Sentence Processing, Dept. of Psychology, Carnegie Mellon University, Pittsburgh, July.

Li, P., MacWhinney, B., Bates, E. (1991). *Processing a language without inflections: An on-line study of sentence processing in Chinese.* CRL Technical Report, 9102. Center for Research in Language, University of California, San Diego.

Liu, H., Bates, E., & Li, P. (1991). *Sentence interpretation strategies and grammaticality judgments in bilingual Chinese-English speakers.* Manuscript, University of California, San Diego.

Lu, J-M. (1980). Hanyu kouyu jufa-li -de yiwei xianxiang (On reversed sentence patterns in spoken Chinese), *Zhongguo Yuwen* (The Chinese Language), *1*, 28-41.

MacWhinney, B. (1987). The Competition Model. In B. MacWhinney (ed.), *Mechanisms of language acquisition.* Hillsdale, NJ: Erlbaum.

MacWhinney, B., & Bates, E. (eds.). (1989). *The crosslinguistic study of sentence processing.* Cambridge University Press.

Miao, X-C. (1981). Word order and semantic strategies in Chinese sentence comprehension. *International Journal of Psycholinguistics*, *8*, 109-122.

Miao, X-C., Chen, G., & Ying, H. (1986). Sentence comprehension in Chinese. In M. Zhu (ed.), *Studies in child language development.* Shanghai: East China Normal University Press.

Sun, C-F. (1991). *Transitivity and the "ba" construction.* Paper presented at the 3rd North American Conference on Chinese Linguistics, Cornell University, Ithaca, May.

Sun, C-F., & Givón, T. (1985). On the so-called SOV word order in Mandarin Chinese: a quantified text study and its implications. *Language*, *61*, 329-351.

Tai, J. (1985). Temporal sequence and Chinese word order. In J. Haiman (ed.), *Iconicity in syntax, typological studies in language.* Vol.6. Amsterdam: J. Benjamins.

Wang, L. (1957). *Zhongguo xiandai yufa* (Modern Chinese grammar). Shanghai: Zhonghua Book Co.

Appendix 1

Nouns and Verbs Used in Experiment One.

A. Nouns

1. Animate nouns:

daxiang (elephant), *daishu* (kangaroo), *gongji* (cock), *gouxiong* (bear), *houzi* (monkey), *mama* (mother), *mianyang* (sheep), *nanhai* (boy), *xiaohai* (child), *nuhai* (girl), *xiaogou* (dog), *xiaoma* (horse), *xiaomao* (cat), *xiaoniu* (cow), *xiaotu* (rabbit), *xiaozhu* (pig);

2. Inanimate nouns:

chuanghu (window), *fengzhen* (kite), *luobo* (radish), *pingguo* (apple), *qiqiu* (balloon), *xiangjiao* (banana), *yifu* (clothes), *yizi* (chair).

B. Verbs

chi (eat), *da* (hit), *fang* (let go), *kan* (look), *qiao* (knock), *ti* (kick), *wan* (play), *xi* (wash), *zhai* (pluck), *zhui* (chase).

Appendix 2

Nouns and Verbs Used in Experiment Two.

A. Nouns

1. Animate nouns:

chongzi (insect), *daxiang* (elephant), *daishu* (kangaroo), *gongji* (cock), *gouxiong* (bear), *houzi* (monkey), *hudie* (butterfly), *laoshu* (mouse), *mama* (mother), *mianyang* (sheep), *nanhai* (boy), *nuhai* (girl), *xiaogou* (dog), *xiaoma* (horse), *xiaomao* (cat), *xiaoniao* (bird), *xiaoniu* (cow), *xiaotu* (rabbit), *xiaoya* (duckling), *xiaozhu* (pig);

2. Inanimate nouns:

beizi (cup), *chuanghu* (window), *damen* (door), *dashu* (tree), *fengzhen* (kite), *luobo* (radish), *pingguo* (apple), *putao* (grapes), *qiqiu* (balloon), *qingcai* (vegetable), *shitou* (stone), *xiangjiao* (banana), *yifu* (clothes), *yizi* (chair).

B. Verbs

1. Monosyllabic single verbs:

chi (eat), *da* (hit), *fang* (let go), *gan* (drive), *kan* (look), *qiao* (knock), *ti* (kick), *wan* (play), *xi* (wash), *yao* (bite), *za* (smash), *zhai* (pluck), *zhua* (seize), *zhuang* (bump), *zhui* (chase);

2. Disyllabic complex verbs:

chi-diao (eat-up), *da-bai* (hit-defeat), *da-lan* (hit-mash), *da-po* (hit-break), *fang-zou* (let-go), *gan-pao* (drive-go), *kan-jian* (look-see), *reng-diao* (throw-away), *ti-dao* (kick-down), *tui-kai* (push-open), *yao-lan* (bite-mash), *za-po* (smash-break), *zhua-zhu* (seize-stop).