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Processing a Language without Inflections: A Reaction Time Study of Sentence Interpretation in Chinese

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Chinese is well-known for its impoverished system of grammatical morphology. This study examines how, in the absence of inflections, Chinese speakers employ other types of cues in real-time sentence interpretation. A reaction time technique was designed to tap into the role of word order, noun animacy, the object marker *ba*, the passive marker *bei*, and the indefinite marker *yi*. Results show the following hierarchy of cue strengths in Chinese: passive marker *bei* > animacy > word order > object marker *ba* > indefinite marker *yi*. The fact that the semimorphological markers (*ba* and *bei*) are intercepted by semantic (noun animacy) and syntactic (word order) cues in this strength hierarchy shows that cues are not necessarily grouped together by linguistic type (e.g., morphology > order vs order > morphology). Complex interactions among cue types were observed in both the decision and the reaction time data, reflecting principles of competition and convergence. These findings are compatible with interactive activation models of sentence processing (e.g., the Competition Model), while posing problems for models that assume a modular architecture in which morphological, semantic, and syntactic sources of information are insulated from one another at various points in parsing and interpretation. Finally, reaction time data reveal aspects of processing that are often not available in results from choice response measures, attesting to the usefulness of reaction time studies at the sentence level.

Recent years have seen a fast-growing interest in crosslinguistic studies of sentence processing. Building on results from studies of sentence processing in a large number of different languages, Bates and MacWhinney (1982, 1987, 1989) have constructed a model of sentence processing, known as the Competition Model, to emphasize the extent to which languages can vary in the way that cues compete and converge to determine meaning. A cue, in this context, is a particular piece of information that a speaker or listener can use to determine the relationship between meaning and form. A typical finding in research within this paradigm is that the strongest cue in one language can be one of the weakest cues in another. For example, in English, the cue that speakers rely on most to identify the subject of a sentence is word order; in Italian, the strongest cue to the identification of the subject is the morphological marking on the verb (Bates, McNew, MacWhinney,

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Devescovi, & Smith, 1982; Bates, MacWhinney, Caselli, Devescovi, Natale, & Venza, 1984; MacWhinney, Bates and Kliegl, 1984). The same cue that is so strong in Italian is extremely weak in English.

The Competition Model assumes an interactive process in which the mapping between surface forms and underlying meanings is mediated by competitions and collaborations among cues. Cues can be evaluated with respect to their validity, i.e., their information value for the identification of linguistic functions. In any given language, the overall validity of a cue is a joint product of its availability (how often the cue is present when a given interpretation has to be made) and its reliability (when the cue is available, how often it leads to the right answer). 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. Cues compete and converge with each other at different points in time as the sentence unfolds. Sentence processing is facilitated when cues converge and inhibited when cues compete.

Because the Competition Model has been formulated from the beginning as a crosslinguistic model, it has been applied in studies of a wide variety 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, the majority of these studies have so far focused on Indo-European and Ural-Altaic languages. All of the languages studied to date have, to different degrees, some kinds of inflectional devices that indicate number, gender, or case relations between nouns, or nouns and verbs. Among the various languages that have been studied so far, English is the poorest in the amount of inflections it offers, as compared with languages such as Hungarian, Turkish, or German, which have rich inflectional systems. As a Sino-Tibetan language, Chinese provides a particularly interesting test case for theories in this area. Chinese is more extreme than English in that it makes virtually no use of any inflectional devices. There are no case markings, no tense suffixes, no agreement markings, and no plural markings on the verb. A simple Chinese sentence sounds almost telegraphic in a richly inflected language. But how, then, do Chinese listeners succeed in correctly interpreting sentences? If they do not use inflectional markings, what cues are important to them and how do they use those cues in sentence processing? And how do these different cues interact in contributing to real-time sentence processing?

There are two earlier studies of sentence interpretation in Chinese which give us some initial ideas of what to expect. Miao (1981) and Miao, Chen, and Ying (1986) investigated the role of word order and semantic properties of nouns (whether the noun indicates an animate or an inanimate object) in interpreting simple Chinese sentences. They asked subjects to enact sentences that consisted of two nouns and a verb. The two nouns and a verb were combined into three different word orders: NNV (Noun–Noun–Verb), NVN (Noun–Verb–Noun), and VNN (Verb–Noun–Noun). The animacy of the nouns was also systematically varied. The design and procedure for these studies were much like those in other Competition Model studies such as Bates *et al.* (1982) and MacWhinney, Pléh, and Bates (1985).

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 sentences, i.e., to interpret NVN as SVO (Subject–Verb–Object). 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 a second study using the same procedure, 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 and 40% for VNN 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). Miao *et al.* 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 recent study of sentence interpretation in Chinese aphasia, Chen, Tzeng, and Bates (1990) looked at three groups of subjects: Broca's aphasics, Wernicke's aphasics, and normal controls. Using an enactment task similar to the one used by Miao (1981) and Miao *et al.* (1986), 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, despite focal brain injury, preserve the basic processing strategies of their native language.

The studies by Miao and Chen, and colleagues focused on only two types of cues, word order and animacy, and subjects' performance was measured by their choice decisions at the end of each sentence. Our study will examine interactions between these same two cues and a set of three additional sentential cues, to extend our knowledge of sentence processing in Chinese. In addition, we will use a reaction time technique to tap into issues of sentence interpretation in further detail. This new methodology will complement results obtained in earlier studies, but it will also push the Competition Model in some new directions.

Most previous studies within the Competition Model have used choice responses as a primary measurement for sentence interpretation. In these studies, subjects are given simple or complex sentences with at least one transitive action verb and asked to decide which of the nouns in the sentence is the agent (i.e., the "doer of the action"). Interpretations are registered after the sentence is complete, at the subjects' leisure. Although such procedures are important in that they provide us with information about what decision speakers make and how often they make it, they do not provide information about the speed with which listeners arrive at their decisions. Reaction time methods aid us in this regard. The Competition Model yields a number of relatively clear predictions regarding the relationship between cue strength and decision time, some of which have received strong support from empirical studies (e.g., McDonald & MacWhinney, 1990).

(1) There should be a monotonic relationship between cue strength and speed of response (i.e., stronger cues will lead to faster reaction times; weaker cues will be associated with slower reaction times).

(2) Converging cues should facilitate sentence interpretation and thus lead to faster response times.

(3) Competing cues should inhibit immediate interpretation and thus slow reaction times down.

(4) Prediction 1 will interact with predictions 2 and 3, so that a very strong cue may still result in relatively fast reaction times, despite competition from weaker sources of information.

These four predictions for reaction time parallel the predictions that are always made in Competition Model experiments using choice response data (i.e., stronger cues should result in more consistent decisions; decisions should be more uniform under cue convergence and less uniform under cue competition; stronger cues may "win" despite a conspiracy from weaker sources of information). However, as we shall see in the present study, reaction time measurements can also yield new insights into the decision-making process. For example, a cue that is too weak to have a significant impact on the final outcome may still have a detectable effect on speed (i.e., reaction time data may be sensitive to convergence or competition effects that are too weak to detect in the final outcome). It is also possible that reaction time data will be sensitive to processing factors that are independent of cue strength (e.g., early vs late placement of a cue within a sentence type, see MacWhinney & Pléh, 1988). The present study is an attempt to use the reaction time method to examine the consistency of these predictions to a new set of data.

Before describing the experiment in detail, let us give a brief review of the relevant syntactic and semantic characteristics of sentence structure in Chinese.

The Function of Cues in Chinese

Although there are no inflectional markers on nouns and verbs in Chinese, there are a number of devices that serve as cues to the assignment of syntactic roles to nominal phrases. These include word order, semantic features of nouns, and the use of semimorphological devices such as the object marker *ba*, the passive marker *bei*, the dative marker *gei*, and the aspect markers *-le*, *-zhe*, and *zai*[1] (for detailed discussions of syntactic and semantic aspects of these devices, see Li and Thompson, 1981; Li, 1990). In the following, we will briefly discuss the major properties of word order, the indefinite marker, the object marker, the passive marker, and animacy.

Word Order

Traditional Chinese grammars[2] have identified word order as the only important device for grammatical relations (cf. Chao, 1968). However, this view has been challenged in modern Chinese linguistics. Word order seems to be far more variable than has been suggested by traditional grammars, although some of these orders are highly constrained.

The basic word order in Chinese is SVO (Sun & Givón, 1985).[3] Three other word orders, OSV, SOV, and VOS are also found in the spoken language. Unlike the unmarked SVO order, the other three orders are semantically and pragmatically marked in special ways.

(1) SVO sentences are neutral in meaning with respect to the status of both the subject and the object.

(2) OSV sentences emphasize the topic-

[1] We call these "semimorphological" devices because unlike morphological markers in Indo-European languages, these markers do not form an organic part of the words with which they occur (for example, they are not bound to the words they modify and do not undergo phonological assimilations to the words), but they are functionally equivalent to the morphological devices in Indo-European languages.

[2] By traditional Chinese grammars we are referring to the grammatical frameworks of Wang (1957) and Lü (1947), whose various grammar books have been very influential in Chinese linguistics. Chao's (1968) work is a further step in this tradition.

[3] 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 Chinese linguistics (see Ding, 1961; Zhu, 1982, for discussion), we do not make a particular commitment here and would like to treat the difference between *dog* and *cat* as a contrast along any or all of these dimensions.

hood of the sentence object. The object in OSV involves information that is given to both the speaker and the listener.

(3) SOV sentences are marked in two different ways, depending on whether or not the object is preceded by the object marker *ba*. SOV sentences with *ba* are semantically associated with highly transitive, resultative events (Li, 1990; Sun, 1991); those without *ba* are pragmatically restricted to situations in which the speaker provides information counter to the expectation of the listener (Li & Thompson, 1981). This second type of SOV usage is particularly marked. Given a simple NNV string with no *ba* marking, it is more likely to be OSV than SOV in Chinese.

(4) VOS sentences are restricted to a particular usage. They are only possible if S is an afterthought, as in *kan -le na-bu dianying, tamen* (see -LE that-CL[4] movie, they; for a detailed discussion, see Lu, 1980).

The existence of SVO, OSV, and SOV sentences means that the preverbal position is not associated with a fixed function in Chinese. On the other hand, OVS and VSO orders do not exist in Chinese, which means that a noun phrase in postverbal position must take the object role. 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 the preverbal positioning which is the single most reliable cue in sentence interpretation (MacWhinney & Bates, 1989). In Chinese, it is the postverbal cue to the identification of the object that is stronger. However, the object does not have to immediately follow the verb since the OV order is possible. Thus there seems to be no single positional cue that is strongly identified with the subject role in Chinese.

Subject omission in Chinese also reduces the reliability of the preverbal position as a cue to the subject. When the context is clear, the subject can often be omitted, resulting in simple VO sequences. Omission is common in Chinese. Not only the subject, but also other constituents of the sentence are frequently omitted, as long as the context provides clues as to who does what to whom. A Chinese sentence in informal speech often consists of a single noun or a single verb. In general, omission reduces the reliability of word order cues.

Indefiniteness and YI

In Chinese, there are no definite or indefinite articles. A noun can in principle be either definite or indefinite, depending on the context. However, the positioning of a noun vis-à-vis the verb can influence the way in which definiteness is assigned. Nouns that occur in the preverbal position are more likely to be interpreted as definite, whereas nouns that occur in the postverbal position are more likely to be interpreted as indefinite (cf. Li & Thompson, 1981). Definiteness is also associated with sentence roles in Chinese. Since the subject occurs preverbally and the object postverbally in canonical word order, the subject is more likely to be definite and the object more likely to be indefinite. Thus, definiteness is associated with both the preverbal position and the subject role, whereas indefiniteness is associated with postverbal position and the object role. However, because the object can also occur preverbally in noncanonical word orders, i.e., OSV and SOV, the above association is not absolute. The object in these constructions is necessarily definite, either because it is the topic of the sentence (topic by definition is definite) or because it is usually marked with *ba* which requires a definite object.

There are also ways of marking indefiniteness explicitly, for example, by adding the marker *yi* (literally "one") plus a classifier such as *zhi* to the front of a noun phrase. Because of the above associations between (in)definiteness, position, and sentence roles, the addition of *yi* (with a clas-

[4] Capitals in the translation represent function words in Chinese, for example, -LE is an aspect marker, CL stands for classifier.

sifier) to a preverbal noun is likely to reduce its subjecthood, while its addition to a postverbal noun is likely to increase its objecthood. The use of *yi* in marking indefiniteness is now so common that Li and Thompson (1981) say that the unstressed *yi* is beginning to function like an English indefinite article. Note that the use of *yi* in an NNV construction (SOV or OSV) is quite unlikely on pragmatic grounds: it could not refer to the object (which must be definite in these constructions) and therefore must refer to the subject, but indefinite subjects are just as unlikely in Chinese as they are in other languages. Hence the most natural context for a *yi* marker would be a canonical SVO construction with an indefinite object.

The Object Marker BA

As mentioned earlier, the object marker *ba* is particularly associated with SOV sentences. Unlike morphological markings of the accusative in inflectional languages, *ba* does not mark the object in postverbal positions. This marker is derived from the verb *ba* (meaning "take hold of," "grasp") in ancient Chinese. Although its original verbal meaning is very weak or nonexistent in modern Chinese, its trace can still be seen in that *ba* normally requires an object that is highly affected by the activity denoted by the verb (causative and resultative verbs are typically required in the *ba* construction). Traditional grammars have termed the *ba* construction "the disposal construction" (Wang, 1957), due to this property of the form.

Several features of the *ba* construction should be noted here. First, only definite or specific noun phrases may occur as the object marked by *ba*. In other words, *ba* marks a definite rather than an indefinite object. Second, the verb phrase in the *ba* construction must be structurally complex, i.e., single monosyllabic verbs cannot occur alone with *ba* (Ding, 1961; Li, 1990). Third, in some cases, the noun phrase immediately following *ba* may not be the semantic patient of the action in the sentence. For example, in a subjectless sentence such as *ba wo e hua -le* (BA I hungry bad -LE = it made me very hungry), the noun after *ba* is the experiencer of the activity. In fact, the class of nouns that can occur after *ba* may be very heterogeneous (cf. Chao, 1968). Finally, *ba* is partially homophonous with a few other markers (e.g., the question marker *ba* and the hesitation marker *ba*, although these markers carry a neutral tone while the object marker *ba* has a dipping tone). The syntactic, semantic, and phonological constraints on *ba* would seem to reduce its validity as a pure object marker. However, developmental evidence indicates that children are sensitive to the properties of the marker and acquire its use at an early stage (Li, 1990, 1991; Chang, 1986).

The Passive Marker BEI

The passive marker *bei* is another important device like *ba* in Chinese grammar. This marker is used to indicate that it is the second and not the first noun that is the agent of an N*bei*NV sentence. *Ba* and *bei* share some semantic and structural features in common. For example, the *bei* as well as the *ba* constructions require the verb phrase to be highly transitive or to indicate a causative meaning, and structurally the verb phrase also has to be complex. However, their functions in indicating sentence roles are very different: *bei* indicates an OSV structure while *ba* indicates an SOV structure. Although *bei* occurs only rarely in the 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 action. Unlike *ba*, whose status as a pure object marker is unclear, the function of *bei* is quite uniform in marking the agent of the sentence.

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 (i.e., to indicate that something unfortunate or undesired has happened, cf. Li & Thompson, 1981), although this association is becoming weak in modern Chinese (cf. Wang, 1957; Chao, 1968).

Animacy

Role assignment to a noun phrase is not determined solely by grammatical devices. It can be influenced by the semantic properties of the noun phrase itself, such as animacy. 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 many 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 also be available to Chinese speakers.

In order to evaluate the ways in which the different cues discussed above interact during real-time sentence processing, we designed the following experiment in which each of the cues is systematically varied. The task selected for this experiment is a picture choice task. Sentences and pictures are digitized for computer presentation and the subject is asked to press a button when he knows which of two pictures indicates the actor of the sentence. On the basis of results from this experiment, we hope to be able to disentangle the role of individual cues and their interactions in sentence processing in Chinese.

METHOD

Subjects

Twenty native adult Mandarin Chinese speakers from mainland China participated in this experiment (11 males and 9 females, age range 22–44, mean age = 29.7). These subjects were college students, visiting scholars, or their family dependents who were studying or working at the University of California, San Diego during the time of our experiment. In order to minimize the influence of English on the subjects' performance in Chinese, we recruited only subjects who had been in the United States for no more than a year by the time of the beginning of the experiment.[5]

Materials

Four different types of sentences were tested in this experiment. Each of the test sentences contains two nouns and a verb. The specific nouns and verbs used in the experiment are listed in the Appendix. Our computer program generated random combinations of nouns and verbs for the 198 test sentences required by the experimental design. Within each of the four types of sentences, the total number of syllables in each sentence was held constant. We used only disyllabic nouns for all sentences. We used monosyllabic verbs for sets A and B and disyllabic verbs for sets C and D because the latter two types require complex verbs. The four types of sentences are:

A. *Simple transitive sentences with no markers*. These sentences contain two nouns that indicate either an animate or an inanimate object (e.g., *xiaogou* "dog" or *yizi* "chair"), and a verb that represents

[5] In a study of sentence interpretation by bilingual Chinese–English speakers (Liu, Bates, & Li, in press), we found significant differences in the patterns of performance between native Chinese subjects who had different degrees of proficiency in English (from true monolinguals to true bilinguals); those patterns confirm that the subjects in our study perform like true monolingual speakers (i.e., they were not influenced by English processing strategies).

transitivity relations between the two objects (e.g., *ti* "kick"). The constituents were ordered into three sequences: NNV, NVN, and VNN. The three animacy configurations were AA (both nouns animate), AI (first noun animate and second noun inanimate), and IA (first noun inanimate and second noun animate). The crossing of the three levels of word order with the three levels of animacy yielded these sentence types: AAV, AIV, IAV, AVA, AVI, IVA, VAA, VAI, VIA. There were six test sentences for each of the nine types, resulting in a total of 54 simple transitive sentences for testing. Here are some examples.

AVI: *Xiaomao ti chuanghu.* (cat kick window)

AIV: *Daishu putao zhai.* (kangaroo grapes pick)

VIA: *Xi damen nanhai.* (wash door boy)

B. Sentences with marking for indefiniteness. If indefinite nouns are associated with postverbal position and postverbal position is in turn associated with the object of a sentence, then when a sentence contains only two nouns, indefiniteness information will contribute to identifying the noun that is not marked as subject or agent. In order to test this, we constructed 36 sentences in which the indefinite marker *yi* plus the classifier *zhi* (a generic classifier for animals) were placed in front of the noun phrases. The configurations used were the AAV, AVA, and VAA sequences. Since we did not assume that indefiniteness would interact strongly with noun animacy, we did not include an animacy factor in the indefinite sentences. Thus, all items were semantically reversible in these sentences, with two animate nouns. Indefiniteness was marked on either the first or the second noun. This resulted in six types of sentences: *yi-zhi*AAV, A*yi-zhi*AV, *yi-zhi*AVA, AV*yi-zhi*A, V*yi-zhi*AA, and VA*yi-zhi*A. Some examples are given below.

AV*yi-zhi*A: *Xiaogou yao yi-zhi xiaoma.* (dog bite one-CL horse)

*yi-zhi*AAV: *Yi-zhi xiaotu gongji zhui.* (one-CL rabbit cock chase)

VA*yi-zhi*A: *Chi gongji yi-zhi daxiang.* (eat cock one-CL elephant)

The contribution of *yi-zhi* to the interpretation of reversible sentences can be evaluated through comparison with the simple reversible items in Set A.

C. Sentences with the object marker "ba." These sentences are an expansion of the Set A sentences. For each of the nine types of simple sentences, we inserted *ba* in front of the second noun phrase.[6] This makes 54 *ba* sentences in which both word order and noun animacy are varied, in parallel to the simple sentences. The contribution of *ba* as a cue to sentence processing can thus be evaluated by comparing results from *ba* sentences with those from simple 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)

D. Sentences with the passive marker "bei." These sentences were constructed similarly to the *ba* sentences. *Bei* was also inserted in front of the second noun phrase for each of the nine types of simple sentences, resulting in a total of 54 *bei* sentences. Below are some examples.

I*bei*AV: *Qiqiu bei nühai reng-diao.* (balloon BEI girl throw-away)

AV*bei*I: *Xiaozhu yao-lan bei dashu.* (pig bite-mash BEI tree)

[6] A complete diagonal design in which *ba* is put in front of both the first noun and the second noun would be more desirable. However, since this would increase the number of test sentences radically to the already large enough set of sentences (as would also happen for the passive marker *bei*, see below), we did not test *ba* in front of the first noun phrase. Placement of *ba* in front of the second rather than the first noun would probably allow us to see its effects more clearly because *ba* is used to mark the second noun in the adult language.

VAbeiI: *Da-po xiaogou bei pingguo.* (hit-break dog BEI apple)[7]

There were also sets of pictorial materials for this experiment. Each sentence was matched with a pair of pictures that correspond to the objects denoted by the two nouns. These pictures were selected from Abbate and LaChappelle's (1978, 1984) *Pictures, please.* A total of 34 individual pictures were used for this experiment.

Task

Subjects heard a sentence played back on a speaker and simultaneously saw on the computer screen a pair of pictures that corresponded to the two objects described in the sentence. Their task was to determine which of the two objects in the pictures was the actor or doer of the action in the sentence. They indicated this choice by pressing one of the two buttons on a button box.

Experimental Apparatus

The stimulus sentences were first recorded on a high-bias audio tape by a native Mandarin speaker who was unaware of the experimental purpose. The stimuli were read in a smooth and flat intonation in the same way across different types of sentences. They were digitized into the computer, using the analog-to-digital functions of the AudioMedia 16-bit card, sampling at 22 kHz. During playback, the digital-to-analog functions of the AudioMedia converted the sound materials into signals which were sent to an amplified speaker.

The CMU button box is a device that registers responses and reaction times for pushing built-in buttons or for other external inputs. It utilizes a crystal oscillator producing time measurements accurate to 1 ms. It has three buttons mounted in a row on a sloped-front box and connects to the modem port of the MacIntosh machine. The present experiment used only the left and right buttons for registering responses and response times. The middle button was used by subjects to rest their index finger before and after each response.

The experiment was run on a MacIntosh IIsi model. Pictures were digitized with an AST Turbo scanner and displayed on a high-resolution RGB monitor. Each picture was displayed in a 7 × 11-cm frame.

Procedure

The experiment was conducted in a dimly lit room so that the subject could concentrate on the computer screen where the pictures were displayed. Before the experiment began, the experimenter explained the task to the subject in Chinese, in some cases asking him or her to read the written instructions (in Chinese) to make sure that he or she understood the task. Subjects were also told that in some cases the sentence might sound a little odd, but that they still need to select one of the two objects as the actor. It was made clear that there was no right or wrong answer, and the subject only needed to pay attention to the sentence and make decisions.

After the subject was seated in front of the testing computer screen, the experimenter asked him to practice making button presses. The subject was instructed to rest the index finger of one hand (depending on handedness of the subject) on the middle button of the button box, press the right button if the picture of the agent appears on the right side of the screen, press the left button if the picture of the agent appears on the left side of the screen. Each time after pressing a button, the subject needed to move the finger back to the middle button. This was to ensure that the subject start each button press from the same position, for every trial, with equal distance to both buttons.

The experimental program was config-

[7] Note that sentence types A, C, and D constitute three major cells in a complex crossed design. The design is a 3 × 3 × 3 × 6 with three levels of word order, three levels of animacy, three levels of marking (none, *ba*, and *bei*), and six replicates in each cell. Type B sentences constitute a completely separate piece of the design. The four types of sentences were administered in separate blocks.

ured 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 2-s 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 3 s 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 response speed. Within each of the four sets of sentence, the order of presentation was randomized for each subject. Subjects' responses, i.e., choice decisions 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 practiced with 10 sentences similar to the test sentences. The experimenter made sure that the subject fully understood the task and performed the button press in the required pattern (starting from and resting the index finger on the middle button). During this time, the experimenter stayed with the subject. After the practice trials, the subject was left alone in the testing room for the experiment. All subjects were tested individually.

The experiment was divided into two sessions with each set of sentences tested separately. In the first session, simple sentences and *yi* sentences were tested. In the second session, *ba* and *bei* sentences were tested. This order of testing was to ensure that the more complex sentences of *ba* and *bei* would not interfere with the processing of simple sentences. Each session took about 20 min. A blocked design was adopted for the experiment for three reasons. First, it would allow the current results to be directly comparable with results from previous studies that tested only the simple sentences (Miao, 1981; Miao *et al.*, 1986; Chen *et al.*, 1990), while at the same time revealing aspects of processing with a new set of cues (i.e., *yi*, *ba*, and *bei*). Second, it would ensure that results from the simple and *yi* sentences are statistically usable in case there would be subject loss for the second session (there was approximately a 1-week interval between the two sessions so that the interference between sentence types was minimal). Third, we presented *ba* and *bei* items in separate blocks within session two, because pilot testing with a mixed design showed that a random mixture of *ba* and *bei* sentences was very confusing for Chinese subjects. Pragmatically these two morphemes require listeners to interpret sentences from a highly marked perspective. The constant perspective shifting involved in a random presentation of *ba* and *bei* appears to be extremely difficult for Chinese speakers.

In order to make sure that subjects were not satiated with the test sentences, they were given a 5-min break in the middle of each session. During the break in the first session, the subject was asked to fill in a language history questionnaire. During the break in the second session, the subject was asked to read some text in a novel.

Results and Analysis

In this section, we will report our experimental results for each set of sentences separately. Two kinds of results will be presented within each section: choice responses and reaction times. For each set of sentences, we will first analyze choice responses and then reaction times. We later integrate the results in a general discussion. The dependent variable for the choice responses in our experiment was whether the subject chose the first or the second noun as the agent of the sentence. Each subject's response was given a score of 1 if he chose the first noun and 0 if he chose the second noun. Missing responses were scored as 0.5. A summary score was calculated for the six individual sentences in a type and these numbers were entered in the analysis of variance (ANOVA). Note that the percentage of first-noun choice is inversely related to the percentage of second-noun choice. Thus, a score close to 100% means that the first noun was reliably chosen as agent, while a score close to 0% means that the second noun was reliably chosen. Two subjects were dropped from the statistical analysis because their responses contained more than 10% missing values in both test sessions. The overall rate of missing values for the remaining subjects is less than 1%.

Simple Sentences

The two cues that were tested in the simple sentences (Set A) were noun animacy and word order, identical to those tested in Miao (1981), Miao *et al.* (1986), and Chen *et al.* (1990). The results with these sentences are presented in Fig. 1, expressed as percentages of first-noun choice across the 18 subjects.

ANOVA on these data shows a significant main effect of animacy ($F_1(2,34) = 75.54$, $p < .001$; $F_2(2,45) = 287.48$, $p < .001$). Collapsed over word order types, subjects chose the first noun 85% of the time when the first noun is animate (AI), 12% of the time when the second noun is animate (IA), and 48% of the time on the semantically reversible items. This is a very large effect, accounting for 72% of the experimental variance (i.e., of the variance accounted for by the two main effects plus the interaction, based on the F_1 analysis).

There was also a significant main effect of word order ($F_1(2,34) = 21.61$, $p < .001$; $F_2(2,45) = 89.53$, $p < .001$). Collapsed over animacy conditions, subjects chose the first noun 72% of the time for NVN, 40% for NNV, and 33% for VNN. In contrast with the main effect for animacy, however, this word order effect is smaller, accounting for only 23% of the experimental variance (based on F_1 analysis). This effect is due primarily to the contrast between canonical NVN and the other two word orders. Individual comparisons indicate that the two noncanonical orders NNV and VNN were not significantly different from one another ($F_1(1,17) = 3.15$, $p > .05$; $F_2(1,10) = 1.46$, $p > .05$).

The interaction between animacy and word order was also strongly reliable ($F_1(4,68) = 11.46$, $p < .001$; $F_2(4,45) = 9.96$, $p < .001$). As illustrated in Fig. 1, variation in first-noun choice is a function of both animacy and word order, reflecting competition and convergence effects between these two cues. On NVN strings, the most consistent response occurred on the convergent AVI items (98% first-noun choice), and the least consistent response occurred on the IVA competition items (31% first-noun choice). On VNN strings, we also see clear-cut convergence and competition effects. Recall that VOS is the only legal interpretation of VNN strings (although VOS constructions are rare). This means that VIA items represent a convergence between animacy and word order—and, indeed, the first noun was chosen on these items only 2% of the time (i.e., 98% second-noun choice). In contrast, VAI items represent a competition between animacy and the VOS cue. Animacy did win this competition (73% first-noun choice), but the conflicting information clearly had

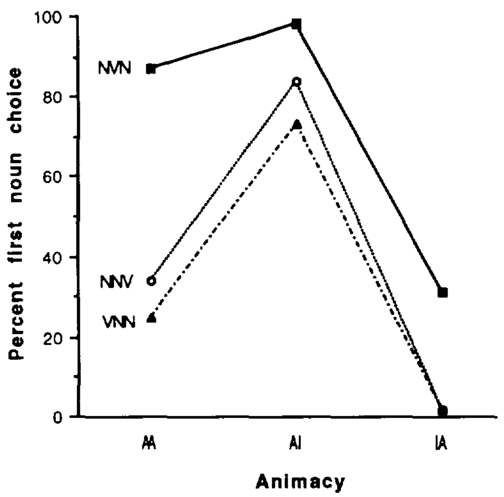

FIG. 1. Choice responses for the simple sentences.

an effect. For NNV strings, the competition/convergence situation is much more complex. Recall that SOV and OSV are both legitimate word order types in Chinese, in contrast with the situation for NVN (which can only be SVO) and VNN (which can only be VOS). Hence the convergence between animacy and SOV word order in AIV items is countered by competition from the OSV option. In the same vein, the convergence between animacy and OSV in IAV items is countered by a competition from SOV. However, OSV sentences are far more frequent in Chinese than SOV, so that the competition against IAV should be weaker than the competition against AIV. In fact, that is exactly what we see in the choice data: IAV items resulted in decisions close to ceiling (2% first-noun choice, 98% second-noun choice), but AIV items were less consistent (84% first-noun choice, 16% second-noun choice). In short, the interaction between animacy and word order in these simple sentence types correspond exactly to the convergence and competition predictions of the Competition Model.

Figure 2 summarizes the results from subjects' decision times under each condition. The numbers represent mean reaction times (RTs) in milliseconds for the decision

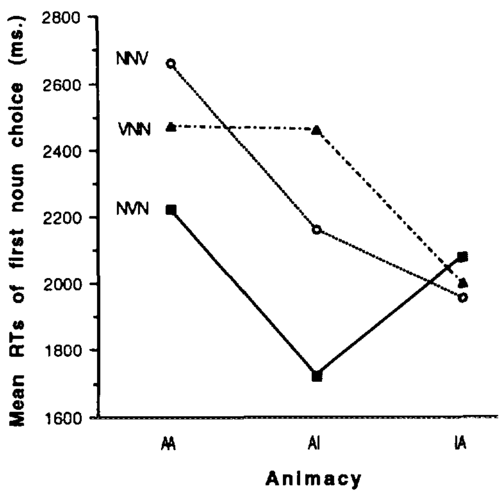

FIG. 2. Reaction times for the simple sentences.

to press a button to indicate first-noun choice. All reaction times were calculated from the beginning of the sentence.

The reaction time results are highly consistent with the results from the analysis of the choice data, providing further support for effects of competition and convergence. First, there was a significant main effect of animacy ($F_1(2,34) = 16.97$, $p < .001$; $F_2(2,45) = 36.94$, $p < .001$). Overall, subjects were faster when there was an animacy cue (AI and IA) than when no animacy cue was available (AA). Second, there was also a significant mean effect of word order ($F_1(2,34) = 12.59$, $p < .001$; $F_2(2,45) = 18.71$, $p < .001$). Overall, subjects were faster with the canonical NVN order (2007 ms) than they were with the noncanonical orders, VNN (2312 ms) and NNV (2260 ms). Finally, the interaction of animacy with word order was also significant ($F_1(4,68) = 13.49$, $p < .001$; $F_2(4,45) = 12.96$, $p < .001$).

Exploration of this interaction indicates that in general, when the two cues agree with each other, they facilitate interpretation and the reaction times are faster; when they conflict with each other, they inhibit immediate interpretation and the reaction times are slower. We can identify the locus of this interaction by comparing AI and IA configurations in the various word orders.

In the canonical order NVN, subjects were much faster in interpreting AVI strings than any other item type (1724 ms), because in AVI strings word order is canonical and animacy agrees with an SVO interpretation, so that both cues strongly promote first-noun choice. In contrast, IVA strings produced significantly slower response times (2077 ms; $F_1(1,17) = 10.31$, $p < .01$; $F_2(1,10) = 17.55$, $p < .01$) because the postverbal animate noun conflicts with the SVO interpretation.

In the noncanonical order VNN, VOS is the only legal word order option. Hence VIA items represent cue convergence while VAI involves cue competition. In fact, reaction times were significantly faster on

VIA convergence items (2002 ms), compared with VAI competition items (2462 ms; $F_1(1,17) = 16.60, p < .001$; $F_2(1,10) = 14.56, p < .01$). However, there was almost no difference between the VAI competition items and the semantically reversible VAA items (2470 ms), reflecting the greater absolute strength of animacy compared with the rare VOS construction (i.e., availability of the strong animacy cue speeds overall reaction time, even in a competition cell, in line with prediction 4 in the Introduction).

The most complex effects are those involving NNV strings. These sentences can be legally interpreted as either SOV or OSV, although OSV is more frequent. As noted above, this means that there is no such thing as a pure convergence between animacy and word order in the NNV items. IAV cells represent a convergence between animacy and the higher-frequency OSV interpretation, with competition from SOV; AIV cells represent a convergence between animacy and the lower-frequency SOV interpretation, with competition from OSV. These facts are reflected in the reaction time data for NNV items. In general, interpretations were faster in the presence of an animacy contrast (regardless of its direction), compared with the reversible AAV strings (2220 ms). However, in the presence of an animacy contrast, IAV strings elicited significantly faster response times (1958 ms) than AIV (2162 ms; $F_1(1,17) = 8.31, p < .05$; $F_2(1,10) = 7.88, p < .05$), which shows that NNV strings are more easily and rapidly interpreted as OSV than as SOV.

Finally, an interesting result emerges when we restrict our attention to reversible items only, comparing word order types. The fastest results were obtained with canonical AVA (2220 ms), as we might expect. Of the two noncanonical word order types, VAA items elicited faster decision times (2470 ms) than AAV items (2662 ms). Presumably, this difference reflects the fact that VOS is the only plausible interpretation for VAA items, while SOV and OSV both compete to determine the interpretation of AAV items. In other words, competition effects on reaction time can be observed even within a single word order type, in the absence of conflicting information from any other source (i.e., semantics or morphology).

To summarize the results with the simple sentences, we have found a very significant effect of animacy, a weaker but significant effect of word order, and a significant effect of interaction between animacy and word order, in both subjects' choice responses and reaction times. The choice response data and the reaction time data are consistent in that convergence between cues leads to higher performance scores and faster reaction times, whereas competition between cues leads to lower performance scores and slower reaction times. Furthermore, the absolute strength of a cue affects the absolute size and speed of its "victory" in competition cells, and it affects the speed with which decisions are reached when a single cue acts alone. In short, all four reaction time predictions outlined in the Introduction are confirmed in this set of simple sentence types.

Indefinite Sentences

We now turn to results for Set B, in which reversible sentences (AA) in three different word orders (NVN, VNN, NNV) were marked for indefiniteness on either the first or the second noun. In this data set, results were strikingly uniform. Word order was by far the strongest cue; effects of indefiniteness were subtle and relatively weak.

In the analysis of choice responses, we found a large main effect of word order ($F_1(2,34) = 114.71, p < .001$; $F_2(2,30) = 342.55, p < .001$), but no main effect of the indefiniteness marker *yi* (i.e., no difference between items with *yi* marking the first noun and items with *yi* marking the second noun, $F_1(1,17) = 2.64, p > .05$; $F_2(1,30) = .64, p > .05$) and no interaction between the position of *yi* and word order ($F_1(2,34) =$

0.01, $p > .05$; $F_2(2,30) = .01$, $p > .05$). The magnitude and consistency of the word order effect was quite striking: 93% first-noun choice on NVN items compared with 14% on NNV and 13% on VNN.

In fact, the word order effects in this analysis appear to be somewhat larger (although they are identical in shape and direction) than the word order effects obtained with reversible (AA) items in the previous analysis. Figure 3 compares the word order effects observed in Set B with the same word order effects for simple reversible sentences without *yi* in Set A. To verify the impression that word order effects are different in the two sets, we compared them directly in a 3 × 3 analysis of variance (i.e., three levels of word order: NVN, NNV, VNN; and three levels of indefiniteness: simple AA items without *yi*, items with *yi* in first position, items with *yi* in second position). The interaction in this analysis reached significance ($F_1(4,68) = 6.84$, $p < .001$; $F_2(4,45) = 3.58$, $p < .05$), confirming the inference that word order effects are "sharper" in Set B and/or "flatter" in Set A (see Fig. 3). How should we interpret this difference? Recall that the simple reversible items in Set A were administered in the context of other, nonreversible items with an animacy contrast.

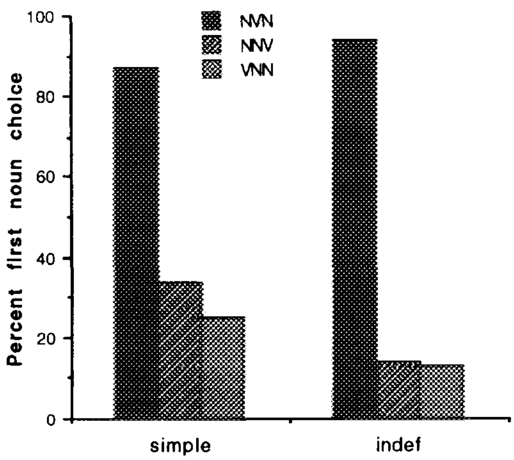

FIG. 3. Word order effects in simple vs indefinite sentences.

Because animacy is a very strong cue in Chinese, it may be that short-term experience with sentences that involved an animacy contrast resulted in an increased inhibition of the weaker word order cue, even when the subject was presented with reversible items. In other words, subjects "trusted" the word order cue much less than usual when they were actively making use of semantic information. In contrast, all the items in Set B were semantically reversible, varying only with respect to the position of an indefiniteness marker. In this analysis, there may be some short-term enhancement of word order cues (or, conversely, no short-term inhibition). The main point here is that the *absolute* effects of cue strength can vary with context, even though the *relative* effects of those cues remain constant.

Turning now to the results for reaction time with Set B, we found a significant main effect of word order ($F_1(2,34) = 27.15$, $p < .001$; $F_2(2,30) = 39.4$, $p < .001$), but no main effect of the position of *yi* ($F_1(1,17) = .33$, $p > .05$; $F_2(1,30) = .4$, $p > .05$). Overall, the slowest reaction times were obtained on NNV strings. This is compatible with results obtained in the Set A analysis and probably reflects the fact that NNV items are ambiguous between OSV and SOV, while there is only one legal interpretation for NVN (SVO) or VNN (VOS).

In contrast with the analysis of choice data, the reaction time analysis did yield a significant interaction between word order and *yi* ($F_1(2,34) = 7.16$, $p < .01$; $F_2(2,30) = 5.59$, $p < .01$), illustrated in Fig. 4.

To understand the interaction between word order and indefiniteness marking in the reaction time data, let us return to our earlier predictions regarding the effects of indefiniteness on role assignment. We have argued that indefiniteness should increase the objecthood (and decrease the subjecthood) of a candidate noun phrase. Furthermore, this effect should be enhanced if the indefinite noun phrase occupies a position that is usually associated with the object

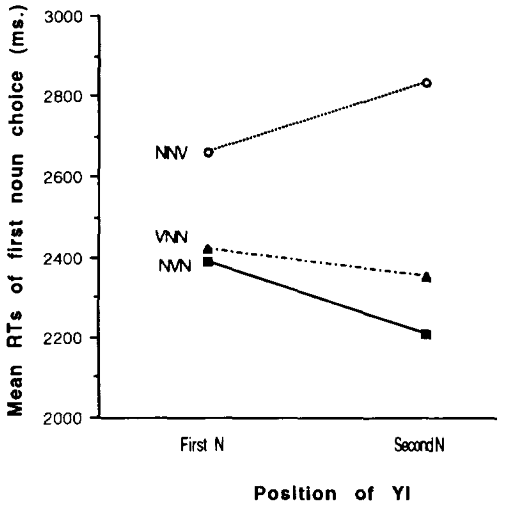

FIG. 4. Reaction times for the indefinite sentences.

role. To test these predictions explicitly, we explored the significant interaction through a series of planned comparisons within each word order type. On NVN items, which are normally interpreted as SVO, decisions should be faster if the *yi* marker falls on the second noun phrase, compared with items where *yi* is on the first noun phrase. This prediction was confirmed (2207 ms with *yi* on the second noun vs 2390 ms with *yi* on the first noun, $F_1(1,17) = 11.38, p < .01; F_2(1,10) = 7.09, p < .05$). On VNN items, which are normally interpreted as VOS, we would expect faster and more consistent decisions for items with *yi* on the first-noun phrase. This prediction was not borne out since there was no significant difference between VNN items with *yi* on the first-noun phrase vs *yi* on the second-noun phrase (2419 ms vs 2350 ms, $F_1(1,17) = .76, p > .05; F_2(1,10) = .87, p > .05$). Finally, on NNV items, which were more often interpreted as OSV (and less often as SOV), reaction times should be faster with *yi* on the first-noun phrase than with *yi* on the second-noun phrase. This comparison was in the predicted direction, but it just missed significance (2664 ms with *yi* on the first noun vs 2833 ms with *yi* on the second noun, $F_1(1,17) = 4.17, p = .06; F_2(1,10) = 4.01, p = .07$).

The fact that indefiniteness marking affected NVN sentences but did not have an equivalent impact on noncanonical strings may reflect the fact that VNN and NNV structures are already highly marked constructions. In fact, the OSV, SOV, and VOS interpretations usually presuppose that the object is given, and in most of these cases the object is also the focal point of the sentence. Hence indefiniteness marking may not promote objecthood within the context of a noncanonical word order. If this is correct, then our earlier predictions about the relationship between indefiniteness and objecthood have to be constrained. Indefiniteness marking may belong to a larger class of cues that have no "absolute" effect; cues within this class can only be used with reference to the word order type in which they occur. An interpretation of this kind has been offered to account for the effect of contrastive stress and/or pronominal clitics in languages like Italian, Spanish, and French (Kail, 1989; Bates and MacWhinney, 1989; MacWhinney *et al.*, 1984).

To summarize the results with the indefinite sentences, word order contrasts were overwhelmingly stronger than the indefiniteness marker *yi* in this set of comparisons. Indeed, word order effects were stronger in Set B than they were in Set A, suggesting that the absolute strength of word order cues can vary with context (although the shape and direction of the word order effects were the same in both sets of items). However, indefiniteness did have a significant effect on reaction times. In the absence of semantic cues, the fastest reaction times were observed with NVN items with *yi* in second position—a convergence situation in which canonical word order and indefiniteness marking both promote assignment of the object role to the second noun. This provides at least one example of a cue convergence that can only be detected within the reaction time data.

BA Sentences

In the third group of sentences (Set C) we examined the impact of the object marker *ba* on role assignment. Subjects' choice responses to the sentences with the *ba* marker are presented in Fig. 5.

Comparing these results with results from the simple sentences, we find that the presence of the *ba* marking before the second noun made an important contribution to the noncanonical word orders VNN and NNV, but not to the canonical order NVN. We conducted a 3 × 3 × 2 ANOVA incorporating data from both the simple and the *ba* sentences, with word order, animacy, and the presence or absence of *ba* as the three independent variables. The results indicate that there were significant main effects of word order, animacy, and the presence of *ba*, and there were significant interactions between word order and animacy and between word order and *ba*. However, the presence of *ba* did not change the underlying pattern that was observed in the simple sentences. Animacy was still the dominant cue and the shape of its significant main effect ($F_1(2,34) = 115.75$, $p < .001$; $F_2(2,90) = 381.55$, $p < .001$) was similar across sentences with and without *ba*. The significant interaction between word order and animacy ($F_1(4,68) = 15.80$, $p < .001$; $F_2(4,90) = 9.5$, $p < .001$) also had the same shape as in the results of the simple sentences without *ba*.

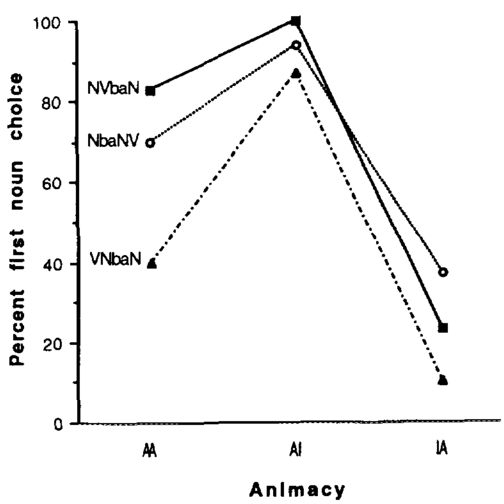

FIG. 5. Choice responses for the BA sentences.

The main effect of *ba* was significant ($F_1(1,17) = 15.75$, $p < .001$; $F_2(1,90) = 31.39$, $p < .001$) in that its presence tended to lead to a higher level of first-noun choice. The main effect of word order in the combined analysis was also highly significant ($F_1(2,34) = 27.49$, $p < .001$; $F_2(2,90) = 69.79$, $p < .001$). In order to understand these two main effects, we need to look at the significant interaction between word order and the *ba* marking ($F_1(2,34) = 6.19$, $p < .01$; $F_2(2,90) = 16.8$, $p < .001$). There is a much elevated choice of the first noun as agent in the A*ba*AV sentences compared to simple AAV sentences. It is this effect that accounts for much of the interaction between word order and the *ba* marking. 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 simple sentences without *ba*, subjects chose the second noun more often when there was no animacy cue (only 34% first-noun choice with AAV sentences), whereas in *ba* sentences, they chose the first noun more often (70% first-noun choice with A*ba*AV). This difference is statistically significant ($F_1(1,17) = 13.18$, $p < .01$; $F_2(1,10) = 11.64$, $p < .01$). It is surprising, however, that the first-noun choice in the *ba* sentences did not reach an even higher level, since traditional grammars dictate that the *ba* construction is exclusively associated with the SOV structure.

The effect of *ba* on NNV strings can also be observed when the animacy cue is present. In A*ba*IV strings, subjects chose the first noun 94% of the time, in contrast to 84% of the time when there was no *ba*, although this difference is not statistically significant ($F_1(1,17) = 1.40$, $p > .05$; $F_2(1,10) = 4.27$, $p > .05$). In I*ba*AV strings, subjects chose the first noun 37% of the time, in contrast to only 2% when there was no *ba*, and this difference is statistically significant ($F_1(1,17) = 14.54, p < .01; F_2(1,10) = 64.46, p < .001$), providing further evidence for the contrasting effects of competition and convergence.

Next, we examine the reaction time for the *ba* sentences. Analysis of the results in Fig. 6 indicates that the word order in which *ba* naturally occurs, N*ba*NV, elicited the fastest responses under both A*ba*AV and A*ba*IV conditions, since these two patterns agree with an SOV interpretation. A*ba*IV has the fastest response times of all (2209 ms) because both animacy and the *ba* marking converge in this configuration for first-noun choice. AV*ba*I also yielded very fast responses (2217 ms). Although *ba* is almost a nuisance in this string, the convergence of animacy and word order in NVN is strong enough to give preference to a first-noun choice, and the presence of *ba* before the final noun can easily be interpreted as a further marking of its object status. Note that under the IA condition, there was almost no difference between the different types of sentences. The effect of word order has been cancelled out by the competition between animacy and the *ba* marking in all cases.

It can be seen by a comparison between the *ba* sentences and the simple sentences (cf. Fig. 2) that for the canonical word order

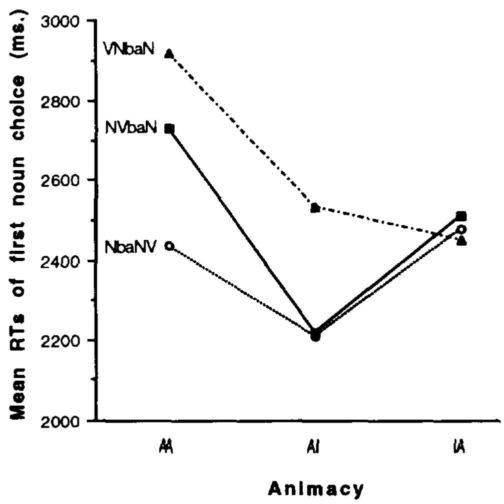

FIG. 6. Reaction times for the BA sentences.

NVN, the basic pattern of response speed is the same regardless of the presence or absence of *ba*. 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 strings.

In contrast, for the noncanonical order VNN there was a difference between the simple sentences and the *ba* sentences in their reaction times. The preference for selecting the animate noun in the simple VAI sentences is in direct competition with a preference for the VOS interpretation, thus yielding no facilitation of response times compared with the VAA sentences in which no animacy cue was present. In VA*ba*I sentences, however, the convergence of the *ba* marking and the animacy cue overwhelmed the word order cue, yielding an enhanced response speed compared with VA*ba*A. The VA*ba*A sentence without the animacy cue was the slowest of all, due to the competition between *ba* and word order. Placement of a noun after the verb is a strong cue for it to be the object in Chinese, while *ba* marks the second noun as the object in VA*ba*A. This direct competition between the two grammatical cues in the context of a pattern that is already extremely rare in the language led to very slow reaction times.

To summarize the results with the *ba* sentences, the presence of the object marker *ba* contributed to the identification of sentence roles in both the choice response data and the reaction time data. Its effect was most clearly reflected in the NNV word order, the order in which *ba* naturally occurs in the language. The interaction between *ba*, animacy, and word order cues further strengthens our hypothesis about the role of cue competition and convergence in sentence processing. However, the effect of the *ba* marking was not overwhelmingly strong in that the basic response patterns were similar across the sentences with and without *ba* (i.e., *ba* sentences vs simple sentences). The relative weakness of *ba* may be due to the plurifunctionality of the marker itself (e.g., *ba* marks definiteness and is homophonous with a number of other markers; in other words, it does not serve as a pure object marker for Chinese speakers).

BEI Sentences

Finally, we come to the results from sentences with the passive marker *bei* (Set D). The results observed with these sentences were extremely uniform, particularly in the choice analysis. As illustrated in Fig. 7, the passive marker was dominant over all other cues in the analysis of choice behavior. Subjects chose the second noun predominantly for all different conditions. Although animacy still had a significant effect ($F_1(2,34) = 12.80$, $p < .001$; $F_2(2,45) = 72.08$, $p < .001$), there was no main effect of word order ($F_1(2,34) = 1.51$, $p > .05$; $F_2(2,45) = .4$, $p > .05$). The interaction between word order and animacy was barely significant in the subject-based analysis ($F_1(4,68) = 2.89$, $p < .05$), and nonsignificant in the item-based analysis ($F_2(4,45) = 1.12$, $p > .05$).

These results indicate that whenever the passive marker occurs in a sentence, speakers rely almost exclusively on it to determine who does the action. Even though the competition between animacy and *bei* pushed first-noun choice to 40% under AI conditions, *bei* still won over animacy numerically. Although *bei* sentences were structurally similar to the *ba* sentences, i.e., *bei* appears as a preposed marker before the second noun, the processing results showed different patterns for sentences with these two markers. Comparing these sentences with the simple sentences, we found that the presence or absence of *ba* did not change the overall picture of the results even though it was an important cue that was involved in some higher-order interactions in the NNV sentences. In contrast, the presence or absence of *bei* made a striking difference. We will return to the processing discrepancies between the two markers later under Discussion.

The reaction time results with *bei* sentences, as shown in Fig. 8, are again different from all others that we have seen so far. Although there were main effects of both word order ($F_1(2,34) = 5.87$, $p < .01$; $F_2(2,45) = 4.95$, $p < .05$) and animacy ($F_1(2,34) = 7.99$, $p < .01$; $F_2(2,45) = 16.02$, $p < .001$), it can be seen that the differences between different word orders were small (under a given animacy condition, all differences were within 200 ms) and of less interest. The effect of animacy can be shown by

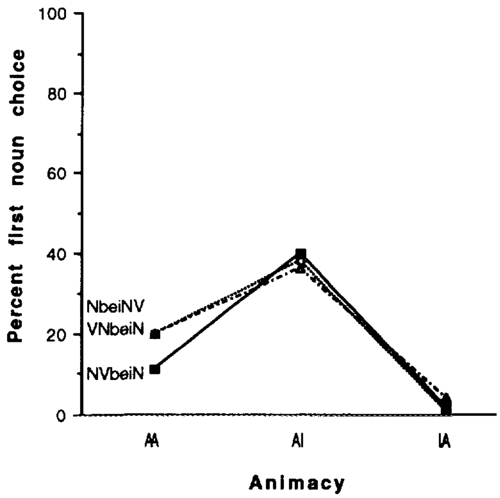

FIG. 7. Choice responses for the BEI sentences.

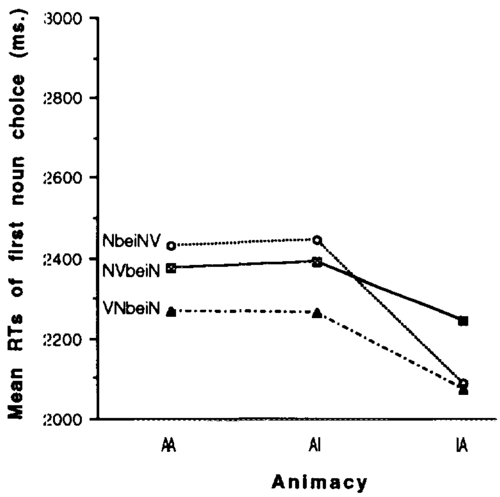

FIG. 8. Reaction times for the BEI sentences.

comparing IA with AA or AI strings. Under the IA condition, response times were faster by about 150 ms for NV*bei*N, 200 ms for VN*bei*N, and 250 ms for N*bei*NV sentences. These facilitation effects may be due to the convergence between the *bei* marking and the animacy cue. N*bei*NV received the largest facilitation because this is the order in which *bei* is naturally used in the language. NV*bei*N received the smallest facilitation because *bei* occurred postverbally in this case, which is unnatural in the language (item analysis also reveals that the reaction times are unstable across different tokens of the NV*bei*N sentence type).

To summarize the results with the *bei* sentences, we see that unlike the object marker *ba*, the passive marker *bei* is a powerful cue to sentence interpretation in Chinese. Subjects relied overwhelmingly on *bei* in choosing the second noun as the agent. *Bei* won over any other cue in cases of competition, although there was still an important effect of animacy. The greater cue strength of the *bei* marker may be due to its unifunctionality as a passive marker in the language, in contrast to the multifunctionality of the *ba* marker.

Discussion

The results of our study are highly consistent with previous work that has examined the predictions of the Competition Model. As in previous crosslinguistic studies of sentence processing (Bavin & Shopen, 1989; Miao, 1981; Miao *et al.*, 1986; Pléh, 1989, to name just a few), this study has shown that the exact configurations of cue types vary radically across languages, and accordingly, they determine the processing strategies by speakers of different languages. In addition, our study provides new information about issues of sentence processing and about the processing of Chinese, a language that offers very different structural properties from all other languages that have been examined so far.

What cues do speakers use and how do they use them in the processing of Chinese, a language in which there is little to rely on in terms of inflectional morphology? Earlier, Miao (1981) suggested that Chinese listeners rely exclusively on semantic information to determine sentence roles. In the revised study by Miao *et al.* (1986), they suggest that word order is also important. Our results indicate that Chinese listeners, in the absence of inflectional morphology, make use of all possible cues to some degree. In addition to the important semantic (i.e., animacy) and syntactic (i.e., word order) cues that have also been investigated in other studies, our study indicates that semimorphological cues, i.e., the passive marker *bei*, and to a lesser extent, the object marker *ba*, are also significant to Chinese speakers.

Previous studies in Indo-European languages have indicated that there is usually one primary type of cues that speakers rely on during sentence processing (morphological, syntactic, or semantic). For example, Hungarian speakers rely primarily on inflectional markers (Pléh, 1989), while English speakers depend almost exclusively on word order. However, the pattern of cue use in Chinese is more subtle than we have found in other languages. Chinese speakers make use of a mixed set of cues, each of which combines to form a complex interactive configuration. Semantic, syntactic, and semimorphological cues all play their roles and interact with each other at different levels.

Our results are largely compatible with those from Miao *et al.* (1986) and Chen *et al.* (1990) in that the animacy cue was found to be dominant over word order cues. However, we have also found a significant word order effect, which was absent in Miao (1981) and Chen *et al.* (1990) (note that Miao *et al.*, 1986 found a weaker word order effect, but no second-noun strategy as found in this study). We think that word order is an unusual and somewhat volatile piece of information in Chinese, compared with word order in other languages. It is neither as strong as suggested by analysis in traditional grammars (i.e., the view that word order is the only syntactic device and must be important, see earlier discussion), nor as weak as suggested by Miao *et al.* or Chen *et al.* The strength of word order as a cue to sentence processing can be either reduced by other more important cues (e.g., animacy and the passive marker) or magnified when no other important information is available (see Results with Indefinite Sentences). The fact that the absolute effects of the strength of a particular cue may vary with context is not contradictory to the predictive value of cue validity; rather, it illustrates that the validity of certain types of cues (e.g., word order) may be realized differently in sentence processing, depending on the context, and its final strength is a product of its dynamic interaction with other cues.

Moreover, the way in which word order affects processing in Chinese is different from the effects observed in English. English speakers rely mainly on the preverbal position as a cue to the subject of the sentence (an SV strategy), while Chinese speakers rely on the postverbal position as a cue to the object of the sentence (a VO strategy). The strong postverbal cue in Chinese can be seen in the difference between VNN and NNV orders in both simple and indefinite sentences: VNN elicited faster responses than NNV when animacy is neutral, presumably because VNN is strongly associated with a VOS interpretation for Chinese speakers, while NNV is associated with both OSV and SOV interpretations. In other words, in Chinese, the strength of the postverbal position as a predictor of objecthood is greater than that of the preverbal position as a predictor of subjecthood, while the reverse is true in English. This result indicates that a particular cue, in this case word order, may not function in the same way across languages.

Neither Miao *et al.* nor Chen *et al.* tested the role of the indefiniteness cue in Chinese sentence interpretation. In our study, indefiniteness seemed to have little influence on subjects' choice responses, although the reaction time data showed a difference within the canonical word order NVN. One reason for the relative nonsignificance of the indefiniteness cue may be that definiteness and indefiniteness are pragmatic and context dependent, and hence they are not easily subject to experimental manipulation. In the present study, the subjects had to decide who is the agent of the sentence by picking out one of the two nouns. Both of these nouns were depicted in pictures and presented to the subject on the computer screen. The presentation of these pictures already in some way made both nouns equally definite in the context of the experiment, therefore blurring the contrastiveness of definite vs indefinite information in the test sentences. Another reason might be that contrary to beliefs of traditional grammars, indefiniteness is not particularly associated with the postverbal position and is thus not a good predictor of objecthood. Sun and Givón (1985) found that only 30% of the postverbal noun phrases are indefinite in their study of both written and spoken texts. Nevertheless, reaction time results for canonical NVN strings were significant, in the predicted direction, while those for the noncanonical strings were not. We suggested earlier that this may reflect yet another kind of context dependence: because noncanonical word orders are highly marked in Chinese, presupposing (in most cases) elements that are already established in discourse, indefiniteness marking may work differently in noncanonical strings than it does in canonical strings. Like contrastive stress and/or clitic pronouns in Italian, Spanish, and French, Chinese indefiniteness marking may not have a direct and absolute effect on semantic role assignment; instead, such cues must be interpreted with reference to the word order frame in which they occur (Kail, 1989; Bates & MacWhinney, 1989).

Our results with the object marker *ba* and the passive marker *bei* show that there is a difference in terms of cue strength between these two markers. Although *ba* is similar to *bei* in many respects (e.g., both are markers of sentence roles, both occur preverbally before the second noun), *ba* was not a very strong cue to object marking in our data. The percentage of first-noun choice with the semantically neutral A*ba*AV strings reached only 70%. In contrast, *bei* played a dominant role in subjects' identification of the agent role. Subjects overwhelmingly chose the second noun (marked by *bei*) as the agent regardless of the word order cue, and to a lesser extent, the animacy cue. To explain the relatively low cue strength of *ba*, we need to look at the patterns of *ba* and *bei* in the language. There are several properties discussed earlier that would disqualify *ba* as a pure object marker in Chinese. First, *ba* is associated with a definite rather than an indefinite object. That is, at the same time *ba* marks the object, it also marks definiteness. Second, the noun phrase after *ba* is not necessarily the semantic patient of the sentence; for example, it can be the experiencer of the activity. Third, unlike morphological markings of the accusative in inflectional languages, *ba* is restricted to mark the preverbal object. Finally, there are a few other markers that may be partial homophones of the object marker *ba*, e.g., the question marker and the hesitation marker. Taken together, these semantic, syntactic, and phonological constraints on *ba* would reduce its validity as a pure object marker and, accordingly, reduce its influence on our processing results.

In contrast to *ba*, the *bei* marker is not particularly associated with definiteness and marks only the agent of the sentence, thus carrying a more uniform function. Although the use of *bei* as a pure passive marker is a recent event in modern Chinese, its unifunctionality has been strengthened by the massive translation works of Western science and literature in which passive constructions in Western languages are simply rendered with the *bei* marking (cf. Wang, 1957; Chao, 1968). Earlier, we showed that simple NNV strings without any marker are more easily interpreted as OSV than SOV. This fact could also have influenced the results with both *ba* and *bei* sentences since *ba* indicates an SOV structure and *bei* an OSV structure. The higher probability of unmarked NNV as OSV than SOV indicates that there is a conspiracy between OSV and the passive marker *bei*, whereas there is a competition between OSV and the object marker *ba*. Given that the function of *bei* is more uniform than that of *ba*, and that the NNV order is more compatible with *bei* than with *ba*, it comes as no surprise that subjects rely more strongly on the *bei* marker than on the *ba* marker in determining sentence roles.

It may still be surprising that the passive marker *bei* is so strong for Chinese listeners, since they have so few opportunities to rely on a morphological cue to sentence meaning. Although there is much evidence in this study and elsewhere that semantic information is probably the most important cue overall to Chinese speakers, the fact that speakers rely overwhelmingly on *bei*, a marker that is nevertheless infrequent in the language, shows that Chinese, although short of morphological devices, may still make important use of semimorphological markers when they are available. Two conclusions are supported by this finding. First, it is clear that rare cues can gain considerable power if they are high in what McDonald (1989) called "conflict validity" (i.e., they are low in availability, but they invariably win when they are involved in a competition). Second, it shows that languages do not necessarily evolve to prefer cues of a given type, e.g., to uniformly seek or reject morphological cues or to uniformly seek or reject word order cues. This brings us to the next point.

The overall hierarchy of cue strength we have found in this study is passive marker *bei* > animacy > word order > object marker *ba* > indefiniteness marker *yi*. Note that in this hierarchy, the semimorphological cues, i.e., *bei* and *ba*, are intercepted by semantic and syntactic cues, i.e., animacy and word order. In other words, cues do not fall into clusters of linguistic types within the hierarchy of cue importance to sentence meaning (i.e., all word order cues before all morphological cues, or vice versa). Although results of this kind could be handled within a modular processor (by postulating a high degree of parallel processing), they are easier to explain within interactive models of language processing, in which different information types (i.e., semantic, syntactic, and morphological) are handled together, on equal footing. Our reaction time results offer still more support for the interactive view, since a cue that speeds up processing in one context can slow down processing in another. Such results would be difficult to obtain in a modular system in which each cue type is handled by a separate processor, operating on a fixed internal schedule (Fodor, 1983).

Our results may be ruled irrelevant to the modularity issue, if one concludes that these interactions take place at some "postmodular" point in processing. To our knowledge, however, there are still no grounds for determining the temporal boundary that separates "premodular" and "postmodular" effects at the sentence level. Until a more principled account of timing in modular systems is available, we think that it is more parsimonious to ascribe these interactions to a model that is interactive at its core.

CONCLUSION

As a first systematic investigation of sentence processing in Chinese, this study has attempted to address the question of how Chinese speakers utilize different cues in the process of sentence interpretation. In general, our results argue in favor of an interactive model in which cues compete and converge to determine the timing and the outcome of processing at the sentence level. Although some cues are more important than others (i.e., animacy and the passive marker *bei*), semantic, syntactic, and semimorphological cues all work together, in a complex system of mutual constraints.

Our study also indicates that reaction time techniques are useful methods for the study of sentence interpretation and that they are a useful adjunct to sentence-level theories like the Competition Model. While largely consistent with results from measures of choice responses, reaction time data can reveal aspects of processing that are not readily available in choice results. The final choice decision for two different sentences may be the same, but the amount of time it takes to reach the same decision can be very different, showing more clearly effects of competition and convergence in the interpretation process. However, the reaction time procedure adopted here does not tell us when an interpretation is reached. As the sentence unfolds, different cues come in at different points in time. It would be very useful to determine exactly when and how this unfolding information is used. In our laboratories we are currently conducting a set of "sentence-gating" experiments, in which interpretations are evaluated at separate points across the course of a sentence (i.e., asking the subject to guess "who did it" on the basis of a sentence fragment). Combined with reaction time studies of the sort presented here, these techniques should increase our understanding of the time course of sentence processing in Chinese, English, and many other languages.

APPENDIX: NOUNS AND VERBS USED IN THE TEST SENTENCES

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," *nühai* "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," *fengzheng* "kite," *luobo* "radish," *pingguo* "apple," *putao* "grapes," *qiqiu* "balloon," *qingcai* "vegetable," *shitou* "stone," *xiangjiao* "banana," *yifu* "clothes," *yizi* "chair."

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."

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