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Sentence interpretation in bilingual speakers of English and Chinese

HUA LIU, ELIZABETH BATES, and PING LI
University of California, San Diego

ADDRESS FOR CORRESPONDENCE
Hua Liu, Department of Cognitive Science, University of California–San Diego, La Jolla, CA 92093

ABSTRACT
This study examines patterns of transfer in the sentence processing strategies displayed by Chinese–English and English–Chinese bilinguals. Our results indicate that late bilinguals display strong evidence for forward transfer: late Chinese–English bilinguals transfer animacy-based strategies to English sentences; late English–Chinese bilinguals transfer English-like word order strategies to Chinese. Early bilinguals display a variety of transfer patterns, including differentiation (use of animacy strategies in Chinese and word order strategies in English) and backward transfer (use of L2 processing strategies in L1, a possible symptom of language loss). These unusual transfer patterns reflect a complex interaction of variables, including age of exposure to L2 and patterns of daily language use. Implications of these findings for the critical period hypothesis are discussed, together with some new hypotheses concerning the interaction between acquisition of L2 and maintenance of L1.

In the process of sentence interpretation, listeners can rely on a set of probabilistic cues in their language that permit the assignment of surface devices to some underlying set of meanings or functions. The surface forms that can be used to assign meaning include grammatical devices (e.g., morphological markers, word order), phonological markers (e.g., emphatic stress), and semantic cues (e.g., animacy). The functions that can be extracted from these surface cues include major categories like agent and topic – categories that are often associated with more abstract grammatical roles like the sentence subject (Bates, McNew, MacWhinney, Devescovi, & Smith, 1982). A large body of comparative evidence is now available (summarized in Bates & MacWhinney, 1989), showing how cross-linguistic differences in the nature of these form–function mappings affect sentence interpretation by monolingual adults and the development of sentence interpretation by monolingual children. These studies demonstrate dramatic differences in the way that individual listeners are "calibrated" to deal with the peculiarities of their native language, leading to some strong and interesting predictions with regard to the nature of sentence processing in bilingual individuals who speak two or more languages of markedly different language types.

A first round of bilingual studies along these lines was published in *Applied Psycholinguistics* (Harrington, 1987; Kilborn & Cooreman, 1987; MacWhinney, 1987; McDonald, 1987a), providing clear evidence for interlanguage transfer of strategies for sentence interpretation (in particular, evidence for transfer from L1 to L2; see also Bates & MacWhinney, 1981; Kilborn, 1987; Kilborn & Ito, 1989). In the present study, the same methodology has been extended to the study of Chinese–English and English–Chinese bilinguals. We will provide further evidence for interlanguage transfer, including some forms of transfer that have not been discussed in the literature to date (e.g., effects of L2 on L1). In addition, we will show how these patterns relate to conditions of language learning and use. Results are relevant not only to the much studied issue of second language acquisition, but also to the much neglected issue of first language maintenance. In particular, these results will point us toward a dynamic view of first and second language abilities in bilingual individuals. Languages should not be viewed as objects that are "acquired" and "stored," but rather as skills that can wax and wane to varying degrees depending on when they are acquired and how they are used.

CROSS-LINGUISTIC RESEARCH AND THE COMPETITION MODEL

Cross-linguistic comparisons are an important part of psycholinguistic research because they allow investigators to disentangle variables that are likely to be confounded in a single language (Bates & MacWhinney, 1989; Slobin, 1985). The Competition Model is a model of linguistic performance that has been recently proposed by Bates, MacWhinney, and their colleagues to account for cross-linguistic variations in sentence processing by children and adults (Bates & MacWhinney, 1982, 1989; MacWhinney, 1987, 1989). This model belongs to a large family of so-called interactive activation theories, offering a probabilistic account of real-time processing at several levels of discourse. It states the relationship between linguistic forms and underlying functions in quantitative, rather than qualitative, terms.

According to the Competition Model, the mappings between linguistic forms and functions are determined by the "validity" of cues, in other words, the information value of particular information sources in a language (e.g., word order and morphology). Cue validity serves as the primary determinant for the identification of the functions of different linguistic forms. For example, word order and animacy cues are both available in English and Italian, but their cue validities are different. Word order is a very reliable cue to sentence roles in English; it is a much less reliable cue in Italian, a language that permits a great deal of word order variation for stylistic purposes. As a result of this difference, English listeners rely heavily on word order cues in the process of sentence interpretation, while Italian listeners make greater use of other kinds of information (e.g., semantic and morphological contrasts).

In the Competition Model, these differences in behavior are captured by postulating a representational system comprising weighted mappings between forms and functions. Each individual cue is assigned a "weight" that corresponds to the validity or information value of that cue in informal speech. If two or more cues point to the same interpretation (i.e., convergence), their strengths are combined (McDonald, 1986a), leading to a greater activation of that interpretation than the activation produced by a single cue acting alone. If two cues disagree (i.e., competition), the interpretation with the highest activation is chosen. However, the strongest cue can be defeated (or its victory can be diminished) by competition from two or more weaker cues whose strengths combine to support an opposing interpretation (i.e., conspiracy). In this way, different cues cooperate and compete in the comprehension process – hence the term competition.

The Competition Model has been tested and revised in a series of cross-linguistic experimental studies of sentence interpretation in children and adults, in languages including English, Italian, German, Spanish, French, Hungarian, Serbo-Croatian, Dutch, Hebrew, Warlpiri, Japanese, and Chinese (Bates et al., 1982; Bates, MacWhinney, Caselli, Devescovi, Natale, & Venza, 1984; Bavin & Shopen, 1989; Kail, 1989; Kilborn & Cooreman, 1987; Kilborn & Ito, 1989; McDonald, 1989; Miao, Chen, & Ying, 1986; Smith & Mimica, 1984; Sokolov, 1989). The experimental paradigm adopted in most of these studies is a sentence comprehension task in which native speakers of different languages are presented with simple sentences in their own languages (containing two nouns and one transitive verb) and are asked to identify the agent (actor) of the sentence, namely, who performed the action described in the sentence.

In this paradigm, sentence stimuli involve orthogonal combinations of cue types, permitting a systematic test of the notions of competition, convergence, and conspiracy. In most (though not all) of the languages in which this paradigm has been used, this orthogonal design results in a combination of grammatical and ungrammatical sentence types. For example, in the English sentence "The cow is hitting the ball," there are three cues: (a) the preverbal position of the first noun (which is usually the agent in English), (b) agreement between first noun and main verb in person and number, and (c) a contrast in animacy between the first and second noun. All three converge to indicate "the cow" as the agent of the sentence. In the ungrammatical sentence "The pencils is kissing the elephant," the word order cue promotes "the pencils" as the agent, pitted against the agreement and animacy cues, which conspire to promote "the elephant" as the agent. Results to date demonstrate that such ungrammatical sentences yield very systematic information about the sources of information that listeners prefer to use in their language. Thus, at an abstract level, the use of ungrammatical forms is analogous to the use of illusions in research on visual or auditory perception.

In studies of this type, native English speakers rely primarily on word order cues to assign sentence meaning. For example, on an item like "The pencils is kissing the elephant," English-speaking adults most often choose "the pencils" as the subject of the sentence, despite competition from both animacy and agreement. This English reliance on word order also extends to performance on the noncanonical word order types NNV (most often interpreted as OSV) and VNN (most often interpreted as VOS). Interestingly, these noncanonical word order strategies are so strong that they also defeat animacy and agreement in competition items (e.g., given a sentence like "Are kissing the cows the rock," English-speaking subjects are more likely to choose "the rock" as subject). Hence the order of importance of cues in English can be summarized as follows:

SVO > [OSV, VOS] > [Animacy, Agreement]

This order-dominant behavior contrasts markedly with the preferences displayed by Italian listeners confronted with equivalent sentence materials in their language. For example, given the Italian equivalent of an item like "The rock is kissing the elephant," these subjects overwhelmingly prefer "the elephant" as subject, favoring animacy over word order.[1] Moreover, when word order, animacy, or both are pitted against subject–verb agreement (as in "The elephants is kissing the rock"), agreement proves to be the strongest cue of all. For sentences with no animacy or agreement contrasts, there is a clear bias in favor of SVO, but performance on NNV and VNN strings is close to random. Hence, we can summarize the order of performance of cues in Italian as follows:

Agreement > Animacy > SVO > [VOS, VSO, SOV, OSV, OVS]

Results from these and other studies reveal that strategies for sentence comprehension can vary dramatically among monolingual speakers of different language types (Bates & MacWhinney, 1989), in accord with predictions based on cue validity. Other studies have shown that these hierarchies of cue validity also have a strong influence on the order of acquisition of sentence interpretation strategies by monolingual children (although cue validity must interact with developmental constraints on information processing; see Bates & MacWhinney, 1989, for a detailed discussion).

SENTENCE PROCESSING AND BILINGUALISM

The finding that processing strategies differ markedly across language types opens up a series of questions concerning the performance of bilingual individuals in each of their languages. In principle, there are four logically possible outcomes that we might expect to find in adult bilinguals:

1. *differentiation:* a clear separation in the strategies used for each language, equivalent to the performance of monolingual listeners in each language type;
2. *forward transfer:* transfer of first language strategies (L1) in the interpretation of sentences into the second language (L2);

3. *backward transfer:* a process whereby strategies that are appropriate for L2 feed back on L1, effectively supplanting the listener's initial approach to sentence processing; or
4. *amalgamation:* the development of a single set of strategies for use in both languages, reflecting a merger of cue hierarchies across the two language types.

Most theories of bilingualism only offer predictions about forward transfer. For example, biologically based critical period accounts of second language learning predict that L2 learning will be more successful if it begins relatively early. Hence, there should be more forward transfer in late bilinguals. These models have nothing to say about backward transfer (i.e., loss of or interference with L1 as a function of L2 learning) or about the probability of differentiation versus amalgamation in "successful" early bilinguals. By contrast, interactive activation theories like the Competition Model are neutral with respect to the direction of effects, and they provide the kinds of quantitative mechanisms that we need to explain different degrees of transfer and interpenetration between language types.

The first test of these four options came from a pilot study by Bates and MacWhinney (1981), who examined the English sentence interpretation strategies of bilinguals who were native speakers of German or Italian. Only one of the German–English bilinguals in their study showed processing strategies in English parallel to those used by monolingual English speakers; all the other Italian–English and German–English bilinguals tended to apply their first language strategies to English, despite extensive exposure to their second language environment (up to 30 years of immersion, in the case of one prominent German–English psycholinguist).

Subsequent research applying the Competition Model to bilingual listeners has confirmed these effects, with evidence for strong and persistent forward transfer of sentence processing strategies (Gass, 1987; Kilborn, 1987, 1989; Kilborn & Ito, 1989; McDonald, 1986a, 1986b, 1987a, 1987b, 1989; Wulfeck, Juraez, Bates, & Kilborn, 1986). However, two studies have also documented a high prevalence of amalgamation. These include a study of Spanish–English bilinguals by Wulfeck et al. (1986). Half the subjects in that study demonstrated the usual profile of forward transfer by applying Spanish strategies to sentence interpretation in English; the other half showed a mixture of strategies that was applied equally in both languages, reflecting the following merged hierarchy of cue strengths:

SVO > Agreement > Animacy > [OSV, SOV, VSO, VOS]

A replication and extension of these results can be found in a recent report by Vaid and Pandit (1991; see also Vaid & Chengappa, 1988) in a study of 48 Hindi–English bilinguals in a southern Indian city. Although all these subjects lived in a similar environment, using English at school and Hindi in the home, there was considerable variability in the strategies they used across the two language tests. Of the subjects, 7 were Hindi-dominant in both language tests (i.e., full forward transfer); 19 were Hindi-dominant in Hindi, but showed a mixture of Hindi and English in the English test (i.e., partial forward transfer); and 17 displayed a mixture of strategies in both languages (i.e., amalgamation). There were only 5 subjects (less than 11% of the sample) who displayed a clear-cut differentiation between Hindi and English, behaving like Hindi monolinguals in Hindi and like English monolinguals in English. In this sample, there were no cases in which English strategies were applied equally to both the languages tested (i.e., no clear-cut cases of backward transfer).

To summarize, research to date provides ample evidence for outcomes 2 and 4 (forward transfer and amalgamation, respectively). By contrast, outcomes 1 and 3 (differentiation and backward transfer) appear to be fairly rare in the language pairs studied to date, being restricted to a few individual cases. With a few exceptions, most of these studies have focused on acquisition of English as a second language, while employing a variety of different first language sources (German–English, Dutch–English, Italian–English, Spanish–English, Japanese–English, Hindi–English, and Chinese–English). This also means that, except for the Chinese–English bilinguals, the subjects' first language has a much richer system of inflectional morphology than their second. These linguistic contrasts may have some influence on the direction and strength of transfer, as well as on the kind of transfer and/or amalgamation that has been observed to date.

The present study will examine sentence comprehension strategies in both Chinese–English and English–Chinese bilinguals with different degrees of experience in their second language. This will permit us to examine some of the factors that influence the process by which one language invades another. One obvious candidate is the critical period hypothesis (i.e., the hypothesis that proficiency in a second language is a function of the age at which that language is acquired). Newport and her colleagues (Johnson & Newport, 1989) reported a negative linear relationship between onset of second language learning and the final level of proficiency reached by a second language learner. However, this linear relationship only applies up to 15 years. For second language learners who began their learning after 15 years of age, age of onset bears no discernible relationship to ultimate mastery of the language. In this study, we will examine the relationship between age of exposure to English and degree of forward transfer from Chinese to English in our sentence interpretation task. At the same time, we can examine some effects that have drawn less attention in the second language literature, most notably the effect of L2 on the maintenance of processing strategies in L1.

Before we proceed, it will be useful to review some of the relevant structural differences between Chinese and English and to consider the results to date on sentence processing in Chinese.

STUDIES OF SENTENCE PROCESSING STRATEGIES IN CHINESE

Chinese is known for its impoverished system of grammatical morphology (Chao, 1968; Chen, Tzeng, & Bates, 1990; Li, 1989). Verb conjugations and noun declension paradigms that are common in many Indo-European languages are absent in Chinese. Due to its lack of inflections, a given Chinese word has only a single form that does not change according to properties such as person, number, gender, tense, or case. Given that Chinese speakers cannot make use of morphological cues to assign sentence roles, Li (1989) argued that other cues to the subject role must be important in Chinese, including word order, animacy, and definiteness. The language-specific properties of Chinese thus provide a unique case for the study of sentence processing in terms of cues and cue validity.

In the past, only a few studies have tapped into the problem of sentence processing in Chinese. Miao (1981) and Miao et al. (1986) studied the relative role of two cues, word order and semantic features, in the processing of Chinese sentences by native Chinese speakers and by native English speakers who had several years of Chinese speaking experience. Their sentences were sequences of two nouns and a transitive verb, presented in three possible orders (NVN, VNN, and NNV). Nouns indicated either animate (A) or inanimate (I) referents, and the two nouns in a sentence were either AA, AI, or IA. The subjects' task was to act out with toys "who did what to whom" after listening to the test sentences. Results from their studies showed that Chinese subjects relied more on animacy than on word order in interpreting Chinese sentences. That is, they selected the animate noun as the agent more often than the preverbal noun in NVN strings or the second noun in NNV or VNN strings. In contrast, English–Chinese bilinguals relied on a combination of word order and semantics.

There is a discrepancy between Miao's 1981 and 1986 studies. In his 1981 study, the word order contrast was not significant, whereas the 1986 study indicated that both word order and semantic cues play significant roles in Chinese sentence processing, although the semantic cue is significantly stronger than word order in both studies. A recent study by Chen et al. (1990), conducted in Taiwan, obtained results roughly similar to those of Miao in his first study.

In a recent on-line study of Chinese sentence interpretation in our laboratories, Li, MacWhinney, and Bates (1991) examined the interaction of word order cues and animacy cues. In contrast with the "off-line" methods used by Miao and by Chen et al., this experiment used both visual stimuli (pictures of the animate and inanimate nouns mentioned in each sentence, which were presented on a computer screen) and auditory stimuli (auditory recordings of the sentence items). Subjects were native speakers of Mandarin Chinese; although all subjects had recently moved to the United States, their mastery of English was still minimal (e.g., spouses of Chinese graduate students, with no formal or informal training in English prior to their arrival in the United States a few months earlier). Results showed that the animacy cue is indeed stronger than word order cues in Chinese. For semantically reversible sentences, the default or "unmarked" word order preferences appear to be SVO (for NVN items), OSV (for NNV items), and VOS (for VNN items) – the same order displayed by English-speaking subjects in both reversible and nonreversible sentence types.

Even though they deal with only two cue types (word order and animacy), these studies suggest a surprising amount of variability among native speakers of Chinese, particularly when these Chinese speakers have come into contact with English. In the present study, we looked at sentence processing in English, as well as Chinese, in bilingual speakers with different degrees of exposure to their second language. We also varied the direction of language learning, testing English–Chinese, as well as Chinese–English, bilinguals. This was intended to permit us to capture any asymmetries in direction of transfer that might exist between these two language types.

SUBJECTS

In this experiment, we tested 50 subjects (28 males, 22 females; age range 19–44). These subjects were college students, university clerks, or their family dependents who were studying or working at the University of California, San Diego, at the time of testing. They were divided into three groups: monolingual controls, late second language speakers, and early second language speakers. The latter group was further divided into three subgroups, based on age of exposure to the second language. Since these groupings constitute the primary independent variable in this study, we need to describe them in considerable detail before proceeding to the rest of the methodology.

Monolingual controls

Eight native Chinese speakers (two males, six females) and eight native English speakers (five males, three females) participated in one session for the sentence interpretation task in their native language only. None of the native English speakers could speak Chinese. All of the native Chinese speakers had been exposed to an English-speaking environment for no more than half a year and had received little or no formal training in English when they were in China. At the time of testing, all reported using Chinese almost all of the time while staying in the United States. The two monolingual groups represented the standard against which we compared performance by bilingual subjects on the language processing task.

Late bilinguals

Seventeen subjects were assigned to one of two late bilingual subgroups: a native Chinese group ($N = 9$; seven males, two females) and a native English group ($N = 8$; six males, two females). In both these subgroups, subjects were first exposed to the second language speaking environment after 20 years of age. However, they clearly differed in the nature of their second language experience. The late Chinese–English bilinguals were then immersed in a second language environment and chose to learn English for a variety of professional and personal reasons, while the later English–Chinese bilinguals obtained most of their Chinese exposure through formal study in the United States and presumably undertook the learning of Chinese because of a predilection for, or unusual interest in, second language learning. Any contrasts that emerge in the performance of late Chinese-English versus late English–Chinese subjects must be interpreted in this light.

Early bilinguals

Seventeen subjects were assigned to one of three early bilingual subgroups. All these subjects stated that Chinese was their first language (though not necessarily their best), and all were exposed to an English-speaking environment before 16 years of age. However, there was a broad range in age of second language exposure within this group (from 0–16 years). We used this variation as the basis for a further division into three subgroups. The first subgroup consisted of American-born Chinese who were introduced to both languages between 0–4 years of age (N = 6; two males, four females); all these subjects reported that English had become their best language, and a few had actually enrolled in college courses to improve their Chinese. The second subgroup of early Chinese–English bilinguals arrived in the United States between 6–10 years of age (N = 6; three males, three females), and the third subgroup arrived between 12–16 years of age (N = 5; three males, two females). Subjects in these last two subgroups all lived in Chinese-speaking countries before they arrived in the United States.

To refer to these classifications, we use the following abbreviations:

CM	monolingual native speakers of Chinese (N = 8);
EM	monolingual native speakers of English (N = 8);
LateCE	native Chinese speakers who were exposed to English after age 20 (N = 9);
LateEC	native English speakers who were exposed to Chinese after age 20 (N = 8);
CEInfant	native Chinese speakers who were exposed to English before age 4 (N = 6);
CEChild	native Chinese speakers who were exposed to English between ages 6–10 (N = 6); and
CETeen	native Chinese speakers who were exposed to English between ages 12–16 (N = 5).

Later on in the article, these classifications, which are based on age of exposure to the second language environment, will be validated against other fluency measures on a language history questionnaire and against actual performance in the language-processing tasks.

LANGUAGE HISTORY QUESTIONNAIRE

Prior to their participation in this experiment, all bilingual subjects received a language history questionnaire asking about experience and proficiency in each of the subject's two languages (Kilborn, 1987). This included questions about age of first exposure, amount of formal training, years of experience, self-rating of proficiency, and patterns of usage in the first and second language (e.g., with family members, household pets, teachers, friends, and peers). There was also a set of language usage questions focused on use with oneself (in dreams, in mathematical calculations, etc.). A copy of the questionnaire is included in Appendix 1.

The three variables manipulated in the sentence interpretation study were language (whether a sentence was presented in Chinese or in English), word order sequences (NVN: noun-verb-noun; VNN: verb-noun-noun; NNV: noun-noun-verb), and animacy (AA: animate first noun with animate second noun; AI: animate first noun with inanimate second noun; IA: inanimate first noun with animate second noun). For each language, the crossing of the three levels of word order with the three levels of animacy yielded nine types of sentences: AVA, AVI, IVA, VAA, VAI, VIA, AAV, AIV, IAV. There were six individual tokens for each of the nine types, resulting in a total of 54 test sentences. Each test sentence was generated by a random selection from a pool of animate (animals) and inanimate (common objects) nouns and transitive action verbs (see Appendix 2, for a complete list of the nouns and verbs used in this experiment), appropriate to that particular sentence type (i.e., two animate nouns and a verb for AA sentences; one animate and one inanimate noun and a verb for AI or IA sentences).

The following three sentences provide examples of the three levels of word order. For clarity of illustration, the animacy cue is neutralized here.

Structure	*Chinese*	*English*
NVN, AA	Xiaoma ti xiaoniu.	The horse is kicking the cow.
VNN, AA	Ti xiaoma xiaoniu.	Is kicking the horse the cow.
NNV, AA	Xiaoma xiaoniu ti.	The horse the cow is kicking.

The next three sentences illustrate the composition of three levels of animacy and the canonical word order NVN (noncanonical word orders are not listed here for clarity of illustration).

Structure	*Chinese*	*English*
AA, NVN	Xiaoma ti xiaoniu.	The horse is kicking the cow.
AI, NVN	Xiaoma ti luobo.	The horse is kicking the carrot.
IA, NVN	Luobo ti xiaoma.	The carrot is kicking the horse.

PROCEDURE

Each subject was tested individually in two sessions, with one for each language. The exceptions were those monolingual subjects who were tested in one session in their native language only because they were, by definition, unable to use another language. Bilingual subjects were randomly assigned to one of the two test orders (independent of fluency), so that half performed the task in Chinese first and half in English first. The two sessions were separated by two weeks. Because there are so few subjects in each Group × Test Order cell, we could not include test order as a factor in the analyses of variance.[2]

All the instructions and the test sentences were recorded by native speakers and then played back on a tape recorder, one sentence at a time, in the test session. The experiment was conducted in a quiet room. Subjects received the stimuli via earphones and responded by telling the experimenter their choices (e.g., saying "horse"). During a session, only the test language was spoken by the experimenter and the subject. The instructions were as follows:

> In this experiment you will hear a series of short sentences. In each sentence, there will be two objects and one action between the two objects. Your task is to determine which object does the action in the sentence. For example, if you hear "The cow is smelling the pencil," you would answer either "Cow" or "Pencil," depending on which object you think does the action of smelling. Sometimes there will be no right or wrong answers. Just make a choice and don't worry about the sentence not sounding right.

DATA ANALYSIS

In this kind of sentence interpretation experiment, the concept of "percent correct" has no meaning. Hence, we followed the scoring procedure adopted in other studies (see Bates & MacWhinney, 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 and 0 for choosing the second noun. In those rare instances in which there was no response, a score of 0.5 was assigned. 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 statistical analysis. In all text and figures reported here, 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 noun was reliably chosen as the agent, and scores in the 50% range indicate random performance.

RESULTS AND DISCUSSION

Results for the sentence interpretation experiments are organized as follows:

Monolinguals. This section will include two within-group analyses of variance for groups CM and EM only. These serve to determine typical performance profiles for monolingual Chinese and monolingual English speakers, respectively.

Late bilinguals. This section will include four between-group analyses, comparing each of the two late bilingual groups (LateCE and LateEC) to performance by monolinguals, to look for evidence of forward transfer (LateCE in English vs. EM; LateEC in Chinese vs. CM) and backward transfer (LateCE in Chinese vs. CM; LateEC in English vs. EM). It will also include two within-group comparisons looking at degree of differentiation between Chinese and English within each late bilingual group (e.g., Chinese vs. English in LateCE; Chinese vs. English in LateEC).

Age-of-exposure analyses. In this section, we will conduct a series of comparisons of each Chinese–English group (CEInfant, CEChild, CETeen, and LateCE) with monolingual controls to uncover patterns of forward transfer (each group in English compared with EM) and backward transfer (each group in Chinese compared with CM). In addition, we will conduct a series of analyses within each group comparing L1 and L2 to evaluate the degree of differentiation in processing strategies displayed by that group.

After these experimental results, we will proceed to a series of exploratory analyses examining the contribution of factors other than age of exposure to a second language. These will include the following sections:

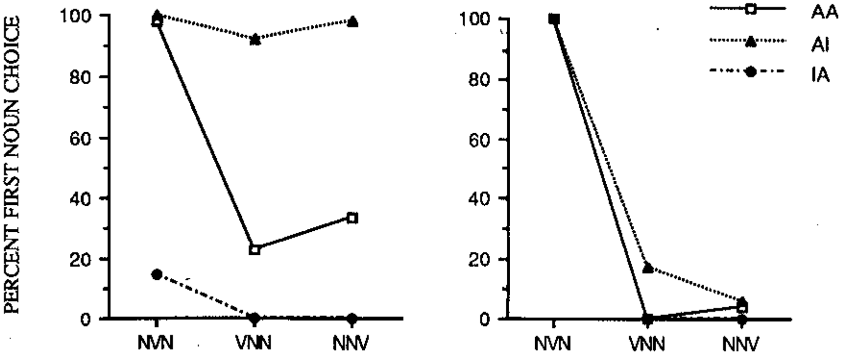
Transfer scores. These scores consist of derivation and analysis of three single numbers that represent amounts of forward transfer, backward transfer, and differentiation, respectively.

Language history questionnaire. This analysis involves correlations between the three transfer scores and aspects of language history and language use from the language history questionnaire.

Experimental results for monolingual controls

Results for the two monolingual control groups were extremely clear and can be summarized briefly as follows:

Chinese monolinguals. These subjects show animacy dominance, with significant, but weaker, effects of word order in the same directions reported in earlier studies (i.e., biases toward SVO, OSV, and VOS). The significant main effect of animacy was very strong, $F(2, 14) = 91.21$, $p < 0.001$, accounting for 78% of the experimental variance (i.e., 78% of the variance jointly accounted for by word order, animacy, and their interaction). The word order effect was smaller, $F(2, 14) = 15.68$, $p < 0.001$, accounting for only 11% of the experimental variance. There was also a significant interaction between animacy and word order, $F(4, 28) = 18.27$, $p < 0.001$, illustrated in Figure 1a. For comparison with our bilingual subgroups later on, note in particular that animacy wins overwhelmingly on items in which word order and animacy compete (e.g., IVA, AIV, and VAI). For example, in the critical cell IVA, where animacy must compete with canonical SVO word order, monolingual Chinese subjects choose in favor of the animate noun (14.6% first noun choice). The same is true for



(a) Chinese controls

(b) English controls

Figure 1. Choice responses of monolingual group ([a] $N = 8$; [b] $N = 8$).

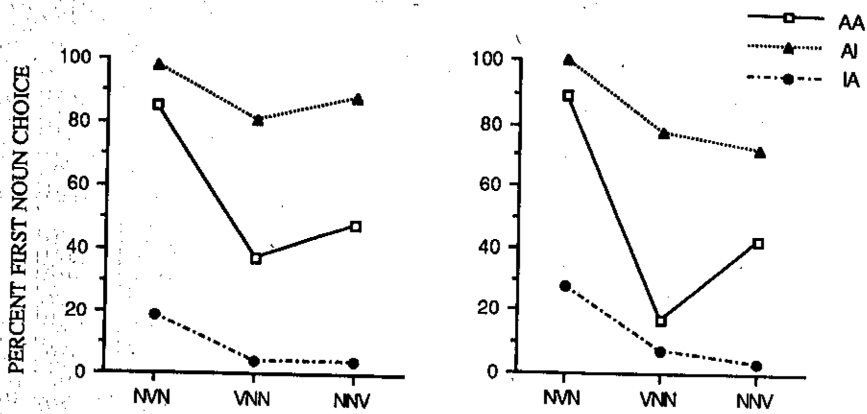
the competition cells VAI and AIV, where animacy competes with the default VOS and OSV word order strategies. Here, too, Chinese native speakers choose in favor of animacy close to 100% of the time (91.2% VAI, 97.9% AIV).

English monolinguals. These subjects show the same clear pattern of word order dominance that has been reported in earlier studies of English using this paradigm. The main effect of word order was extremely strong, $F(2, 14) = 1042$, $p < 0.001$, accounting for 99% of the experimental variance. The animacy strategy was statistically reliable, $F(2, 14) = 5.96$, $p < 0.05$, but much weaker, accounting for only 0.5% of the experimental variance. There was also a significant interaction between word order and animacy, $F(4, 28) = 4.53$, $p < 0.01$, illustrated in Figure 1b. When word order cues compete with animacy, these subjects choose in favor of word order on all the three competition cells (100% IVA, 16.7% VAI, 6.3% AIV).

We will not report results from a between-group analysis comparing monolingual Chinese with monolingual English subjects, because the effects are so strong that they violate homogeneity of variance assumptions. With the monolingual control patterns in Figure 1a and 1b as background, let us now turn to results for our first two bilingual groups.

Experimental results for late bilinguals

In this section, we will begin with four separate between-group comparisons to determine the extent to which these bilingual subjects performed like monolingual native speakers in each of their two languages. Then we will present two separate within-group comparisons to examine the degree to which these late bilingual subjects differentiated between their two languages.



(a) Chinese test

(b) English test

Figure 2. Choice responses of LateCE group ($N = 9$).

LateCE compared with EM in English. (Compare Figures 2b and 1b.) A 2 × 3 × 3 (Group × Word Order × Animacy) ANOVA compared the LateCE group in English with the EM group. This analysis yielded a strongly significant main effect of group, $F(1, 15) = 19.0, p < 0.001$, and two-way interactions of Group × Word Order, $F(2, 30) = 19.9$, $p < 0.001$, and Group × Animacy, $F(2, 30) = 17.6$, $p < 0.001$, as well as a three-way interaction of Group × Word Order × Animacy, $F(4, 60) = 5.6$, $p < 0.001$. This means that LateCE subjects are strikingly different from monolingual English subjects when they interpret English sentences. In the competition cell IVA, for example, the first noun was chosen only 27.8% of the time (an animacy strategy) in the LateCE group, compared with 100% (a word order strategy) in the EM group. This constitutes a clear example of forward transfer, namely, transfer of sentence interpretation strategies from the bilinguals' first language (Chinese) to their second language (English). We will try to quantify the amount of forward transfer later on in this article.

LateCE compared with CM in Chinese. Results of the ANOVA comparing the LateCE group to CM (Chinese controls) yielded no significant main effect of group and no significant two-way interaction of Group × Word Order or Group × Animacy. However, there was a small, but reliable, three-way interaction of Group × Word Order × Animacy, $F(4, 60) = 2.8$, $p < 0.05$. As we can see by comparing Figures 2a and 1a, the response pattern that LateCE subjects displayed in the Chinese test is highly compatible with the pattern displayed by CM controls. In IVA, for example, the first noun was chosen 18.5% of the time in the LateCE group compared with 14.6% in the CM group. Both groups relied overwhelmingly on animacy strategies to interpret sentences in Chinese, suggesting that there has

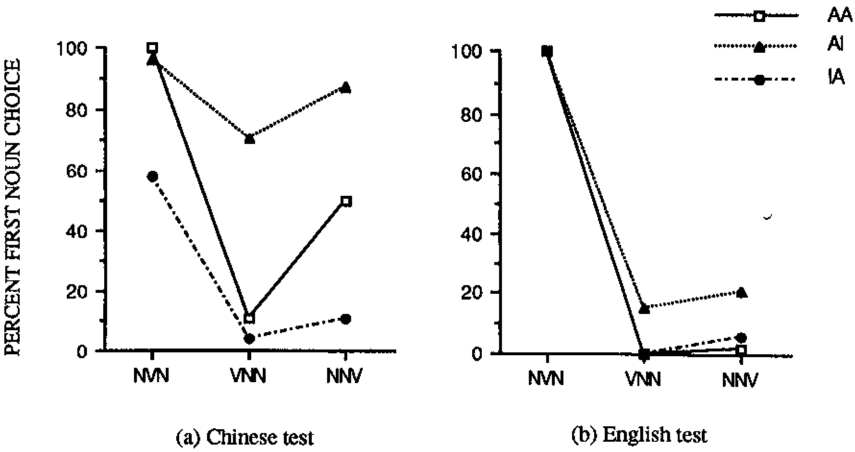


Figure 3. Choice responses of LateEC group ($N = 8$).

been little or no backward transfer from English (L2) to Chinese (L1) in these subjects. The weak three-way interaction appears to reflect a slight flattening in the LateCE group of the SVO/VOS/OSV strategies that Chinese subjects apply to sentences without an animacy contrast. Because the English and Chinese strategies point in similar directions on semantically reversible sentence types, this small effect cannot be considered backward transfer in the sense defined here. However, it might reflect a slight loosening of native language intuitions in late bilinguals who are immersed in a second language setting.

Within-group comparisons of LateCE in Chinese versus English. (Compare Figures 2a and 2b.) Besides forward and backward transfer, another logically possible outcome is differentiation, namely, bilingual speakers who perform like monolinguals in each of their two languages. This outcome can be examined by directly comparing performance on L1 and L2 within individual subjects. A Test Language × Word Order × Animacy ANOVA on LateCE subjects indicated no significant main effect of test language, no two-way interaction of Language × Word Order or Language × Animacy, and no three-way interaction of Language × Word Order × Animacy. In other words, LateCE subjects adopted the same strategies when they interpreted Chinese and English sentences. Taking the strong competition item IVA as an example again, subjects chose the first noun 18.5% of the time in the Chinese test and 27.8% in the English test, both in favor of the animate noun. Hence, there is no statistically reliable differentiation in the late Chinese–English group.

LateEC compared with CM in Chinese. (See Figures 3a and 1a.) Once again, forward transfer can be evaluated by a 2 × 3 × 3 (Group × Word Order

× Animacy) ANOVA comparing the LateEC group in Chinese to the monolingual Chinese group (CM). Most of the effects in this analysis failed to reach significance, including the main effect of group, the two-way interaction of Group × Word Order, and the three way interaction of Group × Word Order × Animacy. However, there was a significant two-way interaction of Group × Animacy, $F(2, 28) = 19.3, p < 0.05$. This can be viewed as evidence for partial forward transfer in late English–Chinese bilinguals from their first language (English) to their second language (Chinese). In particular, LateEC subjects chose the first noun more than 50% of the time in IVA (an English strategy; see Figure 3a); by contrast, the choice response on IVA by Chinese controls was much less (14.6%; see Figure 1a). However, this forward transfer did not show up at all data points. For example, the choice responses of VAI or AIV in Figures 3a and 1a were both more than 50%, indicating animacy strategies in both groups.

LateEC compared with EM in English. (See Figures 3b and 1b.) To evaluate evidence for backward transfer in this group, we conducted another 2 × 3 × 3 ANOVA (Group × Word Order × Animacy) comparing LateEC subjects with monolingual English controls. This analysis indicated no significant effects of group (i.e., no main effect, no two-way interactions, and no three-way interaction). Hence, we may conclude that there is no statistically reliable evidence for backward transfer in this late English–Chinese group (i.e., no detectable effect of experience in Chinese on the processing of English sentences).

Within-group comparisons of LateEC in Chinese versus English. These analyses comparing late English–Chinese subjects with monolingual controls suggest that these bilinguals do show partial differentiation between L1 and L2. This impression was confirmed by a within-group analysis of variance, which yielded a significant main effect of test language, $F(1, 7) = 15.2$, $p < 0.01$, two-way interactions of Language × Word Order, $F(2, 14) = 24.4$, $p < 0.001$, and Language × Animacy, $F(2, 14) = 22.0$, $p < 0.001$, as well as a three-way interaction of Language × Word Order × Animacy, $F(4, 28) = 3.3, p < 0.05$.

To summarize so far, we have found evidence for complete or partial forward transfer from L1 to L2 in both these late bilingual groups. No significant evidence of backward transfer was found in either late bilingual group. On the other hand, comparisons between the late Chinese–English group (LateCE) and the late English–Chinese group (LateEC) suggest that there is more forward transfer and less differentiation in LateCE than in LateEC. This might mean that the transfer of strategies from Chinese to English is easier or faster than transfer from English to Chinese. Such a result would support Gass's (1987) hypothesis that animacy strategies are easier to adopt than syntactic strategies in second language acquisition. An alternative interpretation is that our LateEC subjects were a highly selective sample; in other words, they had better than normal language learning skills and/or an unusual interest in second language learning. These factors

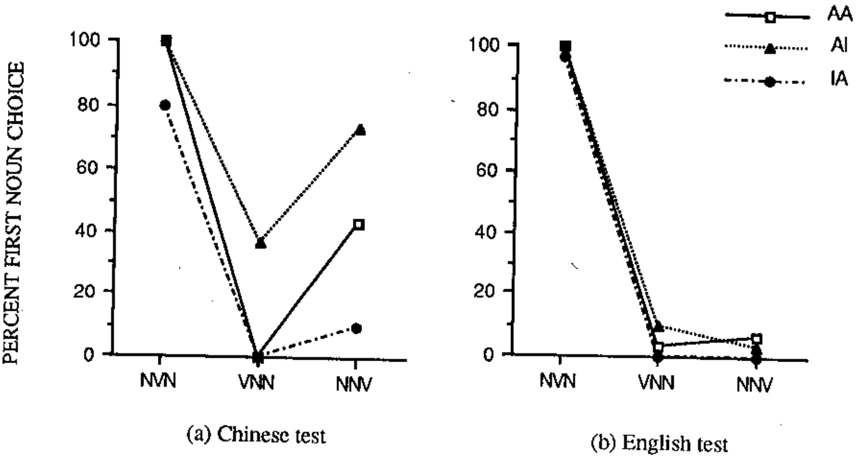


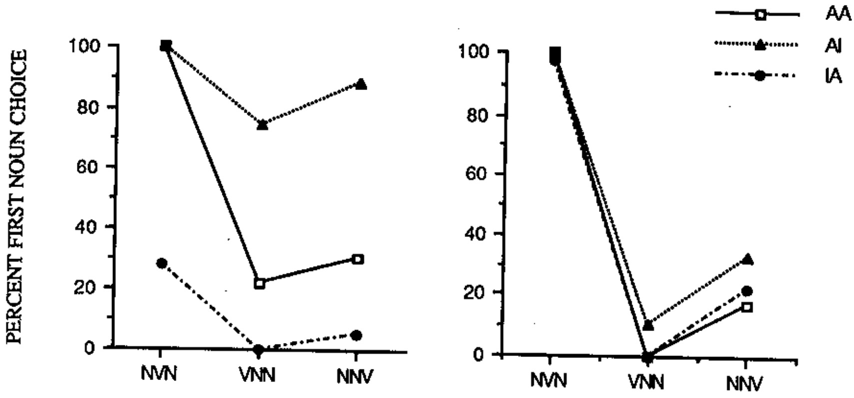
Figure 4. Choice responses of CETeen group ($N = 5$).

might permit the LateEC subjects to overcome forward transfer more rapidly than the LateCE comparison group. We will have to leave this as a question for future research, as we turn to analyses involving the early Chinese–English groups.

Age of exposure analyses in Chinese–English bilinguals

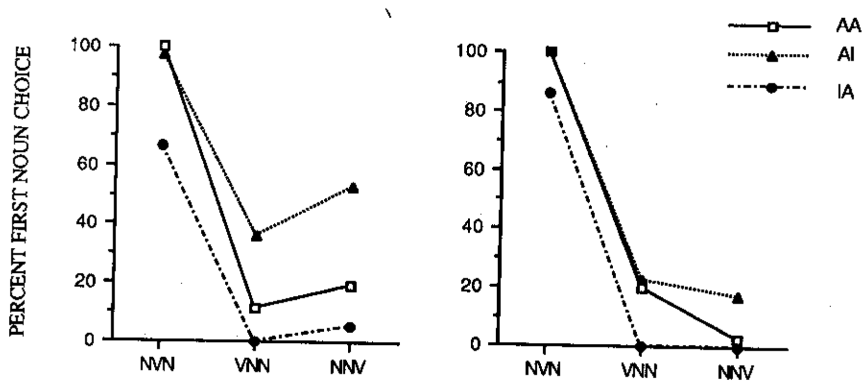
As mentioned earlier, the 34 native speakers of Chinese in our study represented a large range in age of first exposure to their second language (English): from birth to after 20 years of age. In view of claims in the literature regarding "critical period effects" on L2 acquisition, it should be interesting to compare the similarities and differences of transfer styles across all native Chinese speaker groups, ordered from those who we would expect to look "most Chinese" to those who have had the most experience with English (CM, LateCE, CETeen, CEChild, and CEInfant). These analyses will also permit us to study age-of-exposure effects on maintenance of a first language and on forms of interference between L1 and L2. Since results from CM and LateCE groups have already been discussed in detail, in this section we will concentrate here on the early groups: CETeen (see Figure 4), CEChild (see Figure 5), and CEInfant (see Figure 6).

Early bilinguals compared with EM. First, we examined performance by the three early Chinese–English bilingual groups (see Figures 4b, 5b, and 6b) in their second language (English) in search of evidence for forward transfer. Three separate 2 × 3 × 3 (Group × Word Order × Animacy) ANOVAs were conducted to determine whether each of the three early groups (CETeen, CEChild, and CEInfant) performed like monolingual English controls in English (Figure 1b). Briefly summarized, none of these analyses



(a) Chinese test (b) English test

Figure 5. Choice responses of CEChild group ($N = 6$).



(a) Chinese test (b) English test

Figure 6. Choice responses of CEInfant group ($N = 6$).

yielded significant effects of group – either as a main effect, as a significant two-way interaction with word order or animacy, or as a significant three-way interaction of Group × Animacy × Word Order. Hence, these early Chinese–English bilinguals are statistically indistinguishable from monolingual English controls on the English test. We conclude that there is essentially no evidence for forward transfer on this task in any of the early Chinese–English bilingual groups. Forward transfer appears to be restricted to the LateCE group (i.e., bilinguals who were exposed to English after 20 years of age).

Early bilinguals compared with CM. Next we looked for evidence of backward transfer among these Chinese groups by comparing their performance in Chinese (see Figures 4a, 5a, and 6a) with that of Chinese controls (Figure 1a). In contrast with their performance in English, the different early bilingual subgroups each made different choice response patterns on the Chinese test.

As we have already shown, there was no backward transfer in the LateCE group. By contrast, the CETeen subjects (exposure age 12–16) and the CEInfant subjects (American-born Chinese exposed to English from 0–4) made some use of English strategies on the Chinese task. This was especially evident in the crucial competition cell IVA (80% first noun choice within CETeen and 66.7% in CEInfant, both SVO strategies). These patterns are clearly very different from those of monolingual Chinese controls (14.6% first noun choice in IVA, an animacy strategy).

This impression of backward transfer can be demonstrated statistically by looking at the ANOVA results comparing each subgroup with monolingual controls. In CETeen, there were significant two-way interactions of Group × Word Order, $F(2, 22) = 6.5$, $p < 0.01$, and Group × Animacy, $F(2, 22) = 7.7$, $p < 0.01$, as well as a significant three-way interaction of Group × Word Order × Animacy, $F(4, 44) = 3.1$, $p < 0.05$. In CEInfant, there were also significant two-way interactions of Group × Word Order, $F(2, 24) = 4.8$, $p < 0.05$, and Group × Animacy, $F(2, 24) = 6.9$, $p < 0.01$, although the three-way interaction was not reliable. We should point out that these two groups did not show completely different strategies from Chinese controls at all data points. As we will see later, this implies a certain degree of differentiation. Nevertheless, it is clear that sentence interpretation in Chinese has been affected by exposure to English in these two early Chinese–English bilingual subgroups.

In contrast with subjects who were exposed to English before age 4 or after 12, subjects in the CEChild group (exposure age, 6–10) were almost identical to monolingual Chinese subjects in interpreting Chinese sentences. For example, they used a Chinese (animacy) strategy in IVA sentences (27.8% first noun choice). The between-group ANOVA also indicated no significant main effect of group, no two-way interaction of Group × Word Order or Group × Animacy, and no three-way interaction of Group × Word Order × Animacy. Hence, there appears to be no backward transfer in bilinguals who were exposed to English from 6–10 years of age.

To summarize so far, there is no evidence for backward transfer in late bilinguals or in bilinguals exposed to their second language between 6 and 10 years of age. The other two Chinese–English groups did show some forms of backward transfer, including bilinguals who arrived in the United States between 12–16 years of age, and bilinguals who were exposed to English before the age of 4. It appears, then, that these subjects are experiencing difficulty in the maintenance of L1 processing strategies, a symptom that may reflect some degree of language loss.

Within-group analyses for early bilinguals. Finally, a series of 2 × 3 × 3 (Test Language × Word Order × Animacy) ANOVAs were conducted *within* each early bilingual group, to determine whether the strategies used by these subjects were the same or different in their two test languages (i.e., a statistical test of differentiation). Like the evaluation of backward transfer, these analyses suggest a very complex relationship between age of exposure and transfer type.

We have already demonstrated that the LateCE group used animacy strategies in both the Chinese and English tests (Figure 2). Hence, there appears to be no evidence of differentiation in this group. By contrast, the CETeen group (Figure 4) does show modest evidence for differentiation. There was a reliable main effect of test language, $F(1, 4) = 8.9, p < 0.05$, and a two-way interaction of Language × Word Order, $F(2, 8) = 5.3$, $p < 0.05$. However, the two-way interaction of Language × Animacy and the three-way interaction of Language × Word Order × Animacy failed to reach significance. As shown in Figure 4, this group showed English strategies only on canonical NVN sentences. On noncanonical sentences, they showed more differentiation between English and Chinese.

In CEChild (Figure 5), there were significant two-way interactions of Test Language × Word Order, $F(2, 10) = 6.9, p < 0.05$, and Language × Animacy, $F(2, 10) = 17.9, p < 0.001$, and a significant three-way interaction of Language × Word Order × Animacy, $F(4, 20) = 4.0, p < 0.05$. Only the main effect of test language failed to reach significance, $F(1, 5) = 5.5, p = 0.067$. Hence, as we have already inferred from earlier analyses of forward and backward transfer, native speakers of Chinese who were exposed to English between 6–10 years of age show a highly differentiated pattern of performance in their two languages.

Finally, we turn to the CEInfant group, American-born Chinese who were exposed to English before 4 years of age. If differentiation were a simple product of amount of experience in each target language, then we might expect to find the highest degree of differentiation in this bilingual group. Instead, these individuals showed very little evidence for differentiation. None of the effects of test language reached significance in this within-group analysis (i.e., no significant main effect, no two-way interactions with word order or animacy, and no three-way interaction). As can be seen from Figure 6, these American-born Chinese subjects used English strategies in both their languages, to a statistically equivalent degree.

A summary of transfer patterns in all four of the Chinese–English bilingual groups is shown in Figure 7, using the competition item IVA as an example. Among all Chinese subjects, only those in the LateCE group (exposure age > 20) showed forward transfer. Backward transfer was found in the CETeen group (exposure age, 12–16) and in the CEInfant group (American-born Chinese, exposure to English from 0–4). The most differentiated subjects are those in CEChild group (exposure to English from 6–10). In conclusion, different transfer patterns are found at different stages in language acquisition. Although there appears to be a monotonic effect of exposure age on forward transfer, there is a nonlinear and nonmonotonic effect of exposure age on backward transfer and on differentiation.

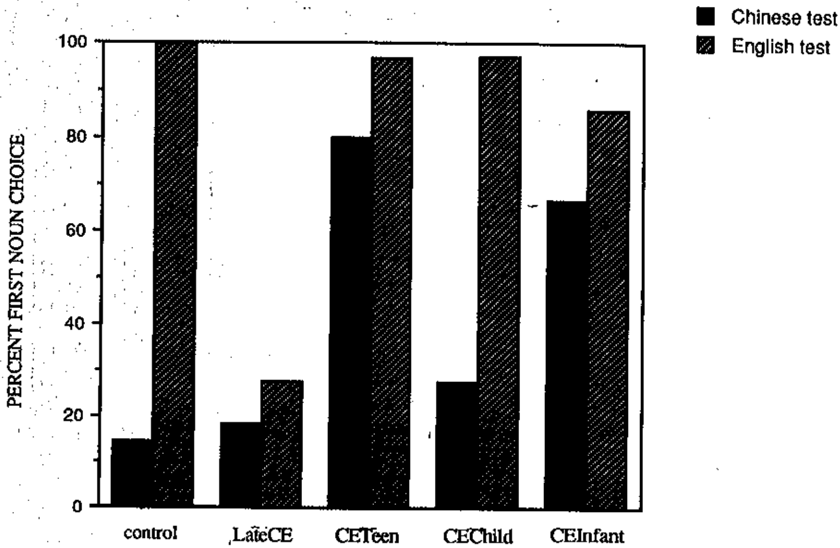


Figure 7. Choice responses of all Chinese group in IVA item.

Derivation of language transfer scores

The goal of these analyses is to obtain a set of individual scores that represent amounts of forward transfer, backward transfer, and differentiation. These summary variables will provide greater economy and flexibility in the exploratory analyses that follow. For the sake of simplicity, we will only consider results for Chinese–English bilinguals.

To derive the transfer scores, we began by conducting two analyses of variance for each individual bilingual subject, one for each of their two languages. Each of these individual analyses was conducted over items in a 3 × 3 design with three levels of word order and three levels of animacy. Following each analysis, an "animacy statistic" was derived by dividing the sums of squares for the main effect of animacy by the total sums of squares for all experimental effects (i.e., the main effect of Animacy + the main effect of Word Order + the effect of Word Order × Animacy interaction). This number (an eta coefficient) represents the relative "strength" of animacy for that individual subject in that particular language. A separate animacy dominance score was derived for each language, referred to as AC for Chinese and AE for English. (Because there are only two linguistic factors in this design, word order and animacy, the size of the animacy statistic can be viewed as the inverse of the size of the word order effect for that subject.) These coefficients were used to derive three distinct transfer scores.

Forward transfer score. Forward transfer (FT) is defined here as the application of sentence interpretation strategies from the bilinguals' first language to the interpretation of sentences in their second language. In the paradigm adopted in this study, forward transfer can be quantified as the difference between the size of the animacy statistic for an individual Chinese subject on the English test and the size of the animacy statistic for the monolingual English group as a whole, using the formula

$$FT = [AE - AE0]$$

where AE refers to the eta coefficient for animacy for an individual subject, and AE0 refers to the eta coefficient for animacy for the English control group (which was 0.005 in this study). The larger the FT, the more forward transfer displayed by that subject. If FT = 0, then no forward transfer has occurred (i.e., the subject's performance was indistinguishable from monolingual English controls).

Using FT as the dependent variable, a series of simple one-way ANOVAs were conducted comparing the various Chinese–English bilingual groups. The grand mean of FTs within the LateCE group (0.61) was much larger than those within any other group (CETeen = 0.00, CEChild = 0.01, and CEInfant = 0.12). In each pairwise comparison of an early bilingual group with the late bilinguals, the analysis was significant at $p < .01$. However, there were no significant differences among any of the early bilingual groups. This mirrors the conclusion that we reached from the full analyses of variance described earlier: that is, forward transfer is observed only in late bilingual subjects who were exposed to their second language after age 20.

Backward transfer score. Backward transfer (BT) is defined as the extent to which a given bilingual subject's performance in his first language deviates from the performance of monolingual controls in a direction that suggests an effect of L2 on L1. We operationalized this concept using the eta coefficients for animacy in Chinese (AC), according to the following formula

$$BT = [AC - AC0]$$

where AC refers to the animacy coefficient in Chinese for an individual subject, and AC0 refers to the animacy coefficient for the Chinese monolingual control group as a whole (which was 0.784 in this experiment). Once again, a large BT score means that the individual shows a large deviation from monolingual Chinese performance. A BT of 0 would mean that the subject performed exactly like monolingual controls.

A series of simple one-way analyses of variance were conducted between each bilingual group. The grand means of BTs within each group were as follows: 0.53 (CETeen), 0.49 (CEInfant), 0.16 (CEChild), and 0.02 (LateCE). Significant group differences were found between LateCE and CETeen, $F(1, 12) = 7.3$, $p < 0.05$, and between LateCE and CEInfant, $F(1, 13) = 5.6$, $p < 0.05$. As noted earlier, these findings suggest that there is a nonmonotonic relationship between age of exposure to L2 and vulnerability to backward transfer.

Differentiation score. The difference (DF) between AC and AE for each subject was used to represent his amount of differentiation by the formula

$$DF = |AC - AE|$$

The larger the DF score, the more differentiation a given subject displayed between the two language tests. The grand means of DFs were as follows: 0.61 (CEChild), 0.25 (CETeen), 0.18 (CEInfant), and 0.16 (LateCE). Between-group comparisons reached significance only for the contrast between CEChild and LateCE, $F(1, 13) = 12.3, p < 0.01$.

These transfer scores provide a convenient way of summarizing the complex group differences reported in the last section. It shows once again that there were different transfer patterns for each group. In particular, the LateCE group displayed much more forward transfer than other groups. The CETeen and CEInfant groups showed stronger backward transfer than the late bilinguals or CEChild. The most differentiated group was CEChild (Chinese-born bilinguals who moved to the United States between 6–10 years of age). These summary scores can now be used in ancillary analyses, examining the relationship between transfer patterns on the sentence interpretation task and patterns of language use reported on the language history questionnaire.

Transfer and language history: Correlational analyses

Assignment to bilingual groups for the analyses reported so far was based exclusively on one criterion: age of exposure to a second language environment. Although there are sound theoretical reasons for choosing this criterion (e.g., critical period findings by Newport and colleagues; see Johnson & Newport, 1989), we are now in a position to validate this index against other measures of relative proficiency and patterns of language use. In these analyses, we will restrict our attention to Chinese–English bilingual subjects because we can assume some parallels in the linguistic and cultural history of these individuals.

In addition to the age-of-exposure measure, items from the language history questionnaire include the number of years the subject has lived in an English environment, the estimated age at which English was acquired, and number of years of formal study in English. For the analyses reported here, self-ratings of speech, reading, writing, and comprehension abilities in each language were summed to produce one measure of "Chinese skill' and another of "English skill." The various items asking about frequency of usage with parents and siblings were collapsed into two "family usage" scores (for Chinese and English, respectively). Items asking about usage with other people (including teachers, friends, peers, etc.) were combined into two "other usage" scores, one for Chinese and one for English. Finally,

Table 1. *Correlations between transfer scores and patterns of language use on the language history questionnaire*

Questionnaire items	FT	BT	DF
Age of first exposure to an English environment	+.63***	−.40*	−.20
Age when English was acquired (estimate)	+.43*	−.26	−.15
Years of formal study in English	−.31†	+.02	+.31†
Years of living in an English environment	−.36*	+.22	+.12
Chinese skill	+.41*	−.01	−.42*
English skill	−.23	+.13	+.09
Use of Chinese with family	+.18	+.07	−.28†
Use of English with family	−.48**	−.03	+.55**
Use of Chinese with others outside the family	+.37*	−.26	−.09
Use of English with others outside the family	−.31†	+.16	+.13
Chinese with self	+.50**	−.26	+.22

†$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

there was a series of forced-choice items asking which language the subject prefers to use for arithmetic calculations, for dreaming, for swearing, and so forth. These items were collapsed into a single score reflecting "Chinese with self" (the inverse of "English with self"). All these language history measures, including age of first exposure to an English environment, were entered into correlational analyses with the three transfer scores (FT, BT, and DF). Table 1 summarizes results from these correlational analyses.

As we might expect from the group results described here, exposure age to the second language environment was significantly correlated with both forward transfer ($r = 0.63$, $p < 0.001$) and backward transfer ($r = 0.40$, $p < 0.05$). In fact, this was the only index on the language history questionnaire that correlated reliably with *both* transfer patterns. This finding justifies our choice of exposure age as a grouping variable in the analyses reported here. However, there was no significant correlation between exposure age and differentiation, and the significant correlation with backward transfer is relatively small, accounting for less than 16% of the variance. These low correlations are what we might expect, given the nonmonotonic group effects reported earlier (e.g., highest differentiation in CEChild, and higher backward transfer in CEInfant and CETeen). We hoped that correlational analyses with the other fluency and language use variables might yield additional clues to the factors that influence backward transfer and differentiation – information that might help to explain these puzzling nonmonotonic effects.

Results in Table 1 show that forward transfer correlates positively with estimated age of English acquisition (+.43, $p < .05$), reported skill in

Chinese (+.41, $p < .05$), use of Chinese with people outside the family (+.37, $p < .05$), and use of Chinese with self (+.50, $p < .01$). It is negatively correlated with frequency of English usage inside the family (−.48, $p < .01$) and with number of years living in an English environment (−.36, $p < .05$). By contrast, backward transfer correlates with none of the items in Table 1 except for age of exposure to an English environment. Differentiation correlates negatively with self-ratings of skill in Chinese (−.42, $p < .05$). This is presumably an indirect reflection of age of arrival in the United States. Differentiation also correlates positively with frequency of English usage inside the family (+.55, $p < .01$).

Because age of exposure to English appears to bear a nonmonotonic relationship to both backward transfer and differentiation, we were alerted to the possibility that other nonlinear relations might be hidden in the correlation patterns reported in Table 1. One approach to this problem might be regression analysis, entering predictors into the formula one at a time in order to identify "suppressor effects." The suppressor effect refers to a situation in which two predictor variables make linear contributions to a target variable, but in opposite directions, so that the two predictors essentially cancel each other out in the raw correlations. To uncover such effects, we carried out a series of regression analyses on the three transfer scores, examining the variance contributed by patterns of family language use after age of exposure has been entered into the formula, and vice versa. Results of these analyses are summarized in Table 2.

Results for the forward transfer measure were quite straightforward, in line with the linear relations that we have seen so far. When age of exposure is entered into the formula on step 1, no significant variance is contributed on step 2 by family usage of either Chinese or English. When these analyses are conducted in the opposite order (entering family usage patterns on step 1), age of exposure continues to add substantial new variance on step 2.

A different and surprising pattern emerged when we conducted these step-by-step analyses on backward transfer. The raw correlations in Table 1 suggest that there is no linear relationship between backward transfer and family usage of either English or Chinese. However, results of our regression analyses suggest that family usage patterns and age of exposure are involved in mutual suppressor effects, canceling each other out in the raw correlations but showing significant contributions to backward transfer when the suppressing factor is controlled. For example, when age of exposure is controlled (entered into the formula on step 1), family usage of English contributes an additional 32% to the variance accounted for in backward transfer ($p < .01$). Moreover, when family use of English goes into the formula first, exposure age now contributes an additional 47% ($p < .0001$). Similarly, when age of exposure is controlled on step 1, family use of Chinese adds an additional 15% ($p < .05$), and when the regression is carried out in the reverse order, age of exposure adds an additional 30% ($p < .01$).

Regressions on the differentiation scores also suggest the existence of suppressor effects, but this time the effects only involve family usage of

Table 2. *Regression analyses on transfer scores*

Regression	Raw correlation on step 1	Variance when added on step 1	Variance when added on step 2	Total variance accounted for by both predictors
Forward transfer				
1.				
Exposure age	+.63***	.39***	.16*	.39**
English in family	−.48*	.23*	<.01	.39**
2.				
Exposure age	+.63***	.39***	.42***	.45***
Chinese in family	+.18	.03	.06	.45***
Backward transfer				
1.				
Exposure age	−.40*	.16*	.47***	.475*
English in family	−.03	<.01	.32**	.475*
2.				
Exposure age	−.40*	.16*	.30**	.31*
Chinese in family	+.07	<.01	.15*	.31*
Differentiation				
1.				
Exposure age	−.20	.04	.16*	.46***
English in family	+.55**	.31**	.42***	.46***
2.				
Exposure age	.20	.04	<.01	.08
Chinese in family	−.28	.08	.04	.08

*$p < .05$; **$p < .01$; ***$p < .001$.

English (and not family usage of Chinese). When age of exposure to English is controlled, family usage of English contributes an additional 42% to the variance accounted for in the differentiation scores ($p < .001$). This contribution is larger than we should expect from the smaller raw correlation with differentiation in Table 1. When this regression is carried out in the reverse order (family use of English on step 1, age of exposure on step 2), exposure age contributes a significant 15% additional variance ($p < .05$) which we might not have predicted from its nonsignificant raw correlation with differentiation in Table 1. However, in contrast with the analyses on backward transfer, family usage of Chinese does not make a significant contribution to differentiation in either of the regression analyses (i.e., no significant contribution on step 1 or step 2).

It appears that transfer processes are affected by a number of different factors, including patterns of daily language usage as well as age of acquisition. Furthermore, these variables interact in some surprising ways. We offer a possible account for these interactions in the General Discussion section.

GENERAL DISCUSSION AND CONCLUSION

Because the sample sizes that we were able to obtain in this study are still quite small, all of our conclusions should be regarded as tentative. Nevertheless, a number of generalizations and working hypotheses can be drawn from this study, suggesting some new lines of research on bilingualism and second language learning.

First, we have found evidence for a transfer of sentence processing strategies in early and late second language acquisition. Several different forms of transfer were found, differences that were related (albeit in rather complex ways) to the age at which these learners were first exposed to a second language environment. Late bilinguals (both Chinese–English and English–Chinese) displayed robust evidence for forward transfer, in line with many other studies of bilingualism using this experimental design. Early bilinguals, who were exposed to English between 6–10 years of age, showed a robust pattern of differentiation, performing very much like monolinguals in each of their two language types. A clear pattern of backward transfer appeared in American-born Chinese exposed to English before age 4. As a group, these subjects appear to use purely English strategies in both English and Chinese. Backward transfer was also clearly present in early Chinese-English bilinguals who came to the United States between 12–16 years of age. It appears, then, that these two Chinese–English groups are experiencing some difficulty maintaining and/or activating the strategies associated with "optimal" processing of Chinese by monolingual native speakers of that language.[3]

Second, several findings reported in earlier Competition Model studies of bilinguals did not appear in our study. For example, studies in Hindi–English bilinguals (Vaid & Pandit, 1991) and Spanish–English bilinguals (Wulfeck et al., 1986) reveal a high prevalence of "amalgamation," an individual mix of strategies from both languages. One can speculate that this occurs more often when early bilinguals continue to use both their languages to a high degree, over a range of environments, including code-switching back and forth in a single conversation. Few of our Chinese–English bilinguals fit this pattern of daily language use. However, degree and type of daily language use did interact with age of exposure to English in this study, affecting the probability of backward transfer or differentiation.

Another contrast with previous studies revolves around the evanescence of forward transfer in Chinese–English and English–Chinese bilinguals. Many previous studies have reported severe and protracted forward transfer, lasting up to 30 years in many cases, even in bilinguals who are immersed in a second language environment. However, all these studies involved a contrast between English (a language with little inflectional morphology) and languages with a much richer morphological system (e.g., German, Italian, Spanish, Japanese, Hindi, and Dutch). By contrast, many of our Chinese–English bilinguals have made a rapid transition into the use of English order-based sentence interpretation strategies. Conversely, our small group of English–Chinese bilinguals seems to have moved with surprising speed in the direction of Chinese animacy-based strategies (at least for the two noncanonical word order types). These findings suggest that English and Chinese may be remarkably "interpenetrable," in other words, that they are "closer" along some strategy dimension even though they are very different in other ways (phonology, writing, etc.).

There are two possible reasons for this apparent interpenetrability. First, although word order is considerably weaker in Chinese than it is in English, the basic word order types that are used by these two languages appear to be the same (SVO, OSV, VOS). Second, English and Chinese both have weak systems of inflectional morphology. It may be much more difficult to move into (or out of) a language that relies heavily on morphological marking. Although these ideas are speculative, they could be tested through systematic variations in the nature of the "source" and "target" languages spoken by bilingual subjects.

Finally, our study has yielded some puzzling, but potentially important, findings regarding the factors that facilitate language loss as well as language learning. The term "language acquisition" implies some strong implications about the nature of first and second language learning and use. Above all, it suggests that languages are possessions, something that we can own and store away and that we cannot lose simply through disuse or contact with another language. There has always been a great deal of interest within our field in the critical period hypothesis, namely, the idea that acquisition is "easier" (and, presumably, more complete) if it occurs early in life. Our results are compatible with the idea that the timing of second language acquisition does indeed matter. However, the effects of timing can cut in more than one direction. Early acquisition may facilitate entry in L2, but it can also (in combination with other factors) result in loss of sensitivity to aspects of L1. Furthermore, the effects of exposure age are not always linear, or even monotonic.

Wong-Fillmore (1991) pointed out that U.S. educational policy may be leading to loss of L1 for many immigrant children. This danger of language loss is due, she argued, to two factors. First, it is due to premature immersion in an L2 environment (e.g., through English-only Headstart classes that begin well before age 6). Second, it is also due to the unhappy fact that multilingualism is not valued in U.S. society – a fact that is not lost on immigrant children who are struggling to "fit in." As a result of these converging forces, many immigrant children lose the ability to communicate fluently with their parents, a result that seriously undermines the role of the family in child and adolescent development. Ideally, we would like to foster a situation that permits true differentiation, namely, mastery and continued fluency in both L1 and L2. What are the conditions that simultaneously permit mastery of L2 and maintenance of L1?

In our study, the best evidence for differentiation was found in Chinese–

English individuals who came to the United States between the age of 6 and 10. Presumably, these children had had time to develop native language fluency in Chinese before they were introduced to English. At the same time, they were young enough (under some version of the critical period hypothesis) to reach a native-like level of performance in their second language. Results of the regression analyses summarized in Table 2 suggest that differentiation is enhanced by use of English in the family, while backward transfer is reduced by use of Chinese in the family.

This latter fact may be related to the strong backward transfer (without differentiation) displayed by Chinese–English bilinguals who came to the United States between 12–16 years. Undoubtedly, these individuals had ample time to acquire native mastery of Chinese. Why, then, are they so vulnerable to backward transfer from English? One possibility is entirely sociological: young adolescents may suffer more than any other immigrant from the need to "be like other people," resulting in the rejection of L1 and full-scale acceptance of L2.

However, there are some other possibilities with more interesting implications for the psycholinguistics and neurolinguistics of bilingualism. We can speculate that backward transfer occurs more often at a midpoint in the acquisition of a second language. The second language may be fluent, but it still requires far more attention and effort than it does in a native speaker, resulting (paradoxically) in some degree of inhibition of L1. This active inhibition of L1 would show up in our experiments as backward transfer. Although this is (again) quite speculative, it is also (again) a testable hypothesis.

As we noted at the outset, the Competition Model offers some mechanisms for describing different kinds and different degrees of transfer. The cue validity principles in the model also offer clear predictions regarding the direction of transfer (i.e., cues that are high in cue validity should be the first to "invade" and the last to "relent"). However, in its current form, the model does not offer any explicit predictions about the conditions that foster backward transfer, differentiation, and/or amalgamation. Some of the ideas concerning excitation/inhibition could be used to enrich the interactive-activation principles of the model, leading to a more explicit and precise set of predictions about these forms of bilingual processing. A number of studies are currently underway in our laboratories to examine aspects of interlanguage facilitation and inhibition in on-line language-processing tasks, as a function of the language history and language use variables that we have discussed here.

APPENDIX 1
LANGUAGE HISTORY QUESTIONNAIRE

Name_____ Birth Date_____ Today's Date_____
Sex_____ Hand Preference_____ Telephone Number_____

1. Do you have any known visual or hearing problem?
2. What is your native language? i.e. language first spoken (if more than one, please indicate):
3. Please list all the languages you know, from the most to the least proficient, and indicate the age at which you were first exposed to each.
4. Was there any language spoken in your immediate environment but not included above?
5. How proficient are you currently in each of your languages? Please rate them using the following scale:
   1 = almost none 2 = very poor 3 = fair 4 = functional
   5 = good 6 = very good 7 = like a native speaker

	Language	Speech	Reading	Writing	Comprehension
1					
2					
3					

(etc.)

6. Estimate how often you use your two best languages, using the following scale:
   1 = always 2 = sometimes 3 = never

	Language___	Language___
a. employers/teachers		
b. mother/father		
c. brothers/sisters		
d. friends		
e. yourself		
f. classmates/peers		
g. pets		

7. In which language do you usually:

   add, multiply, etc? _____
   dream? _____
   express affection? _____
   swear? _____

8. How good are you at learning a foreign language?
worse than average___ average___ better than average___

9. When learning a language, what do you find the easiest? Please rank the following:
pronunciation ________
vocabulary ________
grammar ________

10. In what languages are your parents fluent?
Mother: ________
Father: ________

11. How many years have you formally studied (in a classroom or other structured situation) each of your languages except your first?

Language	Years of study
1.	
2.	
3.	

12. If you have lived or traveled in countries where languages other than your first languge are spoken please indicate the country, the length of your stay, and the language you used while you were in the country.

Country	Length of Stay	Language Used
1.		
2.		
3.		
4.		

13. If there is anything else about you or your language that you feel is important, please comment.

APPENDIX 2
NOUNS AND VERBS USED IN THE EXPERIMENT

Animate nouns		Inanimate nouns		Verbs	
Chinese	English	Chinese	English	Chinese	English
xiaoniu	cow	chuanghu	window	ti	hit
xiaomao	cat	qiqou	balloon	da	pat
nuhai	girl	xiangjiao	banana	chi	eat
xiaoxiong	bear	pinguo	apple	kan	smell
xiaoma	horse	yizi	chair	xi	push
xiaozhu	pig	luobo	carrot	wan	kiss
xiaogou	dog	yifu	rock	zhai	grab
xiaoyang	sheep	fengzheng	block	zhui	lick
xiaotu	rabbit		ball	qiao	bite
daxiang	elephant		pencil	fang	
nanhai	boy		door		
houzi	donkey		book		
mama	zebra				
daishu					
xiaohai					

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NOTES
1. It has been suggested that animacy should be regarded as a nonlinguistic type of variable, a backup that is only used when (for some reason) linguistic cues fail. We disagree with this suggestion, for several reasons. First, it ignores the fact that animacy plays a conventionalized role in the grammar of many languages. For example, gender and animacy interact to determine case marking in Serbo-Croatian (e.g., animate masculine and inanimate masculine nouns take a different form of the accusative case; Smith & Mimica, 1984). In a similar fashion, animacy and definiteness interact to determine case marking in Hindi (Vaid & Pandit, 1991). Second, if animacy were a nonlinguistic strategy, we would expect it to apply only in those circumstances in which a valid linguistic cue is unavailable. Instead, research within the Competition Model shows that animacy interacts in a wide variety of ways with word order, case marking, and agreement marking. For example, the hierarchy of importance of cues in Italian is agreement > animacy > word order. Because animacy strategies take a value in between two indisputably linguistic cues, it is difficult to see how animacy could be viewed as a nonlinguistic "last resort."
2. Examination of cell means suggests that a significant effect of testing order might emerge with a larger sample. Probability of forward transfer was appar-

ently unaffected by testing order, suggesting that subjects who show a strong forward transfer pattern may only have one set of strategies available. However, the other three transfer patterns did vary depending on the language tested first. In particular, effects of L2 on L1 were greater if the subjects were tested first in their second language. This finding is in the same general direction described by Vaid and Pandit (1991) and may indicate that subjects who have two sets of strategies available experience a kind of "short-term priming" between these two approaches to sentence interpretation. At present, we can only recommend this as an issue for further research.

3. It is often assumed that differentiation is the optimal form of bilingualism. This is based, in turn, on the assumption that the strategies used by monolinguals represent the optimal mode of processing for each language, considered alone. However, we must remember that bilingualism presents some additional challenges that monolingual users do not encounter (e.g., the need to prevent interference and, in some cases, the need to switch rapidly and efficiently from one language to the other). If we took these real-time considerations into account, it is possible that amalgamation would represent a more efficient solution to the bilingual condition.

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