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Lexical Ambiguity in Sentence Processing: Evidence from Chinese*

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1 Introduction

Lexical ambiguity has been the focus for the study of context effects in word recognition in the past twenty-five years (Small, Cottrell, and Tanenhaus 1988, Onifer and Swinney 1981, Simpson and Krueger 1991, Swinney 1979, Tabossi 1988). Most of this literature has been concerned with the study of Indo-European languages, in particular, English. However, the phenomenon of lexical ambiguity is pervasive in almost all languages, and it surfaces particularly strongly in Chinese. Thus, the study of lexical ambiguity in the processing of East Asian languages is important, especially given that the previous findings in this domain are claimed to be relevant to fundamental problems of language processing. In this study, we set out to

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examine the processing of lexical ambiguity in Chinese, a language that has a massive number of homophones at the lexical and morphemic level.[1]

It is without doubt that listeners, in most instances, arrive at a unique semantic representation of an ambiguous word during the comprehension of a sentence in discourse. That is, they resolve the ambiguity at some point in time during comprehension. It is rather undesirable from a discourse processing perspective that listeners/readers should allow competing meanings of the same word to linger on through the sentence (see Simpson and Adamopoulos, in press, for a discussion of this point). Of course, just when lexical ambiguity is resolved is the issue at stake. The major debate concerns whether the access and selection of a contextually appropriate meaning from among several possible meanings depends on the prior sentence context, and how early, if at all, context can influence the access and selection process. Two competing hypotheses have emerged in the past twenty-five years from research with psychological, linguistic, and computational perspectives (Glucksberg, Kreuz, and Rho, 1986, Grosjean 1980, Marslen-Wilson 1987, 1990, Onifer and Swinney 1981, Small, Cottrell, and Tanenhaus 1988, Simpson 1981, Simpson and Kang 1994, Simpson and Krueger 1991, Swinney 1979, Tabossi 1988). First, the exhaustive or multiple access hypothesis argues that all meanings of an ambiguous word will be accessed momentarily following the occurrence of the word, and that sentence context can only help to select the appropriate meaning at a post-access stage. This hypothesis is based on the premise that language processing is a modular, bottom-up process in which non-lexical, sentential information does not penetrate lexical access (Fodor 1983). A contrasting hypothesis, the context-dependency or selective access hypothesis, argues that the contextually appropriate meaning of an ambiguous word can be selectively accessed early on if the preceding sentence context provides a strong bias to the appropriate meaning. This hypothesis assumes that language processing is operated by an interactive mechanism in which information can flow both bottom-up and top-down and that lexical access and sentential context can mutually and simultaneously interact with one another at a very early stage (McClelland 1987). In either case, researchers believe that the time course of lexical ambiguity resolution reflects the general mechanisms of language processing.[2]

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[1] In this article we use "Chinese" as a generic term to refer to all dialects of Chinese, including Cantonese and Mandarin. In the discussion of specific experiments, however, we will refer specifically to Cantonese or Mandarin Chinese.

[2] Note that there are also hybrid models between the two competing hypotheses. In particular, the re-ordered access model (e.g. Rayner et al. 1994) argues for an interaction effect of meaning frequency and context: the dominant meaning is always activated irrespective of context, and

As a major Sino-Tibetan language, Chinese differs significantly from most Indo-European languages in its phonological, lexical, and syntactic structures, which offer unique properties for psycholinguistic investigations of lexical and sentence processing (see Li, Bates, and MacWhinney 1993, Li 1996a, 1998, for a review). In particular, Chinese has a massive number of homophones at the lexical-morphemic level. According to *the Modern Chinese Dictionary* (Institute of Linguistics 1985), 80% of the monosyllables (differentiated by tones) in Chinese are ambiguous between different meanings (with different characters), and 55% have five or more homophones. The single syllable *yi* with the dipping tone has up to ninety homophones (e.g. skill, justice, benefit, discuss, intention, translate, hundred-million, etc.).[3] Upon hearing *yi* in a sentence, do Chinese listeners access all ninety homophonic meanings of the syllable? The strong version of the multiple access hypothesis would predict so, according to which lexical access is an autonomous and capacity-free process. However, the context-dependency hypothesis predicts that only the contextually appropriate meaning(s) will be accessed.

Because of the unique cross-linguistic properties of Chinese and the important role that lexical ambiguity plays in sentence processing, recently, research from our laboratories has been concerned with testing the above-mentioned competing hypotheses in Chinese. In particular, Li and Yip (1996, 1998) and Li (1998) have explored the processing of Chinese homophones, using cross-modal and gating paradigms (Grosjean 1980, Li 1996a, b) to examine the effects of sentence context, homophone frequency, homophone density, and lexical tonal information on native Cantonese speakers' access and selection of homophone meanings. Our cross-modal experiment showed that context effects take place immediately following the occurrence of the spoken homophone, and the gating experiment showed that listeners can recognize the contextually appropriate meaning with less than half of the acoustic information of the homophone. These experiments indicate that Chinese speakers are sensitive to the contextually biased meaning at an early stage, probably within the acoustic boundary of the word. Our results have also been confirmed by other studies in Mandarin Chinese. For example, Chen and Cui (1997) tested Mandarin speakers in Beijing in a reading task and their results showed that prior sentence contexts affect the different levels of activation of the dominant (the more frequent meanings) versus the subordinate meanings (the less frequent meanings) of ambiguous words:

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context can only help in elevating the activation level of the subordinate meaning. We will return to this model in General Discussion.

[3] This number would increase to 171 if identical syllables with different tones were considered as homophones.

dominant meanings have faster and stronger activation than subordinate meanings. Ahrens (1998) tested Mandarin speakers in Taipei in a cross-modal lexical decision task and her data indicate that the context-biased meaning receives significantly more priming than the meaning not biased by the sentence context.[4]

In the present study, we extend this line of research by using the cross-modal priming technique to examine the processing of homophones in both Cantonese and Mandarin Chinese. Experiment 1 extends the study of Li and Yip (1996, 1998) and examines Cantonese speakers' processing of homophones more systematically, taking into consideration word-gating results in the selection of ISI (inter-stimulus-interval). Experiment 2 investigates Mandarin speakers' processing of homophones, using a cross-modal priming method in a lexical-decision task. Converging results from the two experiments would allow us to select between the competing hypotheses in the processing of lexical ambiguity in sentences.

2 Experiment 1

2.1 Method

2.1.1 Participants

One hundred and forty-four native Cantonese speakers who reported no speech or hearing deficits participated in this experiment. All participants were students at the Chinese University of Hong Kong. They took part in the experiment as a laboratory requirement for credits in an introductory psychology course.

2.1.2 Materials

Thirty monosyllabic spoken homophones in the same tone were selected, each with at least two different meanings (syllables with different tones are not considered homophones in this experiment). Each homophone was embedded in three different sentences with prior context biased to different meanings. There was a total of ninety test sentences (thirty biased to the dominant meaning, thirty to the subordinate meaning, and thirty neutral). A

[4] But Ahrens (1998) had a different interpretation of the data, on the basis of which she argued against the context-dependent hypothesis. Our examination of her data reveals that the data are compatible only with the predictions of the context-dependent hypothesis. Note that there is *no* significant priming for the related probes for the primary meaning, contrary to her report (the *p* value of F (1,44) = 3.01 would be above and not below the .05 significance level).

separate group of twenty native Cantonese speakers was asked to judge the degree of constraint of the prior context on the target homophone. They were given the sixty test sentences with the prior biasing context (excluding the thirty neutral test sentences) but without the homophone, and were asked to fill in the word. They were told to think of a Chinese word that would naturally complete the sentence. Their responses were scored on a 1-4 scale, based on the scale proposed by Marslen-Wilson and Welsh (1978): 1 was given for a word identical to the test word, 2 for a synonym, 3 for a related word, and 4 for an unrelated word. Responses were pooled across the twenty judges, and the mean rating was 1.6 (s.d.= 0.43). This score was above the high constraint condition in Marslen-Wilson and Welsh (1978). An effort was also made to have prior sentence context of equal length, and the average length of the test sentences, counting the target homophone, was fourteen syllables (ranging from twelve to seventeen syllables). In addition, we tried to eliminate potential intrasentential associations between words in the sentence context and the target words, as such associations could lead to possible priming effects (Moss and Marslen-Wilson 1993).

Five independent variables were manipulated in this experiment:

(a) *Context type*: The preceding semantic context was (i) biased to the dominant meaning of a homophone, or (ii) biased to the subordinate meaning of the homophone, or (iii) neutral (i.e., compatible with both meanings).
(b) *Dominance*: The visual probe was related to either the dominant meaning of the homophone, or to the subordinate meaning of the homophone. The dominance information was based on the frequency counts in Ho and Jiang's (1994) analyses of Cantonese speech. In the example given below, the 'window' meaning of *coeng* has a higher frequency count than the 'gun' meaning of *coeng*, and therefore the former was the dominant meaning of the homophone while the latter the subordinate.
(c) *ISI*: The visual probe occurred at three interstimulus-intervals relative to the acoustic offset of the spoken homophone: the isolation point (ISI=IP), the acoustic offset of the homophone (i.e. ISI=0ms), or 300ms after the acoustic offset (i.e. ISI=300ms). The IP point for each homophone was derived from a separate study using the gating method (Yip & Li 1997). The IP point varies from word to word, and the average IP for the words used in this study was 54% (s.d. = 22%, range = 28%-79%) of the acoustic length of the word.
(d) *Relatedness*: The visual probes were either semantically related to the spoken homophone or unrelated controls.

(e) *Homophone Density*: A given homophone had either many potential competitors (four or more alternative meanings) or few competitors (two to three alternative meanings).

An example *coeng* (window/gun) and the three corresponding test sentences are given below.

(1) a. Sentence context biased to the dominant meaning
Gaan uk gam guk nei faaidi zau heoi hoi sai di ***coeng.***
This room so muggy you quick walk go open all these window
'This room is so muggy that you should rush to open all the *windows*.'

b. Sentence context biased to the subordinate meaning
Gwanfo zyungaa waa ledi cyunbou dou hai zan ***coeng***.
Military expert say these every all be real gun
'Military experts said that all of these are real *guns*.'

c. Ambiguous sentence context
Ngo jiu neidei yigaa zikhak zau heoi hoi ***coeng***.
I order you now immediate walk go fire/open gun/window
'I order you to go immediately to fire/open your *guns/windows*.'

The four visual probes to *coeng* in these sentences are: *men* 'door' (related-dominant), *dan* 'bullet' (related-subordinate), *yi* 'clothes' (unrelated-dominant), and *ji* 'set' (unrelated-subordinate). All the visual probes were selected on the basis of a semantic relatedness judgment task from another separate group of 20 native Cantonese speakers. They were asked to think of three Chinese single characters that have the same or closely related meaning to each homophone, and their most frequent response was selected as the related visual probe for the homophone. The unrelated visual probes were randomly selected from the same source.

2.1.3 Design

The participants were divided into three groups of forty-eight according to the three context types. Context type was treated in a between-subject design, and all other variables were in a within-subject design. Within each context condition, the forty-eight participants were randomly assigned to twelve groups of four. Each group randomly received an equal number of sentences for each context condition in the 3 (ISI) x 2 (dominance) x 2 (relatedness) x 2 (homophone density) design. This yielded a total of twenty-

four different experimental conditions. The order of presentation for the sentences was pseudorandomly arranged such that the visual probes did not consecutively bias spoken homophones. The order of presentation was counterbalanced across participants. No participant heard the same homophone twice.

2.1.4 Experimental Apparatus

The test sentences were read by a native Cantonese speaker at a normal conversation rate, and were tape-recorded and then digitized into a PowerMac computer. The presentation of the auditory and visual stimuli was controlled by the PsyScope program (Cohen, MacWhinney, Flatt, and Provost 1993). Participants' naming latencies were recorded and calculated (counting from the onset of the visual probe) by the CMU button-box (Cohen et al. 1993). A unidirectional microphone to register listeners' vocal responses was connected to the button-box through the box's voice-activated relay. Listeners' response accuracy was also recorded over a remote-controlled SONY tape-recorder by the experimenter in another room.

2.1.5 Procedure

Before the experiment began, the experimenter explained the task in Cantonese to the listener. Listeners were told that they would be hearing a Cantonese sentence on a pair of headphones, and immediately afterwards they would see a single Chinese character (visual probe) on the computer screen. Their task was to name the visual probe aloud into the microphone as accurately and quickly as possible. Listeners were given a maximum of two seconds to respond, counting from the onset of the visual probe. This length of time was sufficient for most participants to give their responses while at the same time putting them under time pressure. All participants did the experiment individually. Before the actual test began, they were given a practice session in which they heard a separate set of similar sentences. The whole experiment took about twenty minutes.

2.2 Results

Mean response latencies, counting from the onset of the visual probe to the participant's vocal response, are presented in Table 1. We conducted three separate statistical analyses on the data from neutral sentence context, sentence context biased to the dominant meaning, and sentence context biased to the subordinate meaning.

First, in the neutral context, a 3 (ISI) x 2 (dominance) x 2 (relatedness) x 2 (homophone density) repeated-measure ANOVA revealed a main effect of dominance, $F(1,47) = 23.34$, $p < .01$. Collapsed over other variables,

the mean response time to access the dominant homophone meaning was 697ms and that to the subordinate meaning was 722ms. This result indicates that the most frequent meaning of a given homophone will be activated first if no biasing contextual information is available. There is also a main effect of ISI, $F(2,94) = 52.26$, $p < .01$. Collapsed across other variables, the mean response times to the three ISI conditions were 738ms (IP), 725ms (0ms), and 666ms (300ms), respectively, with the fastest response latencies occurring at the 300ms condition. This result indicates that when no strongly biasing context is available, the access of a given meaning occurs relatively late (300ms after the homophone's offset). No other effects are significant.

	Dominant**		Subordinate	
Context type	Related	Unrelated	Related	Unrelated
Biased to dominant				
IP	690	695	699	701
0 ms	667	670	663	690
300 ms	657	635	611	665
Biased to subordinate				
IP	704	741	761	739
0 ms	699	707	717	723
300 ms	638	646	700	750
Neutral				
IP	728	746	734	743
0 ms	706	689	745	738
300 ms	644	650	659	711

*Because the effect of homophone density was absent in our data, data for this variable were not included here.

** Dominant vs. Subordinate means whether the visual probe was related to the dominant meaning or the subordinate meaning (see discussion in Method). Same in Table 2.

Table 1. Response latencies (ms) as a function of context type, dominance, ISI, and relatedness in Experiment 1*

Second, in the sentence context that was biased toward the dominant meaning, a 3 x 2 x 2 x 2 repeated-measure ANOVA also revealed the main effects of dominance and ISI, similar to the conditions of the neutral sentence context. However, a post hoc comparison (Tukey HSD) shows that the ISI main effect was due to the significance difference between the IP level and the 0ms level ($p < .05$), and there was no significant difference between the 0ms level and the 300ms level ($p > .01$). This result is in contrast to that in the neutral context, where the difference between the IP level and the 0ms level was relatively small, while the difference between the 0ms level and the 300ms level was relatively large. Such a contrast sug-

gests that the sentence context is playing an earlier role (i.e., within the acoustic boundary of the word) in this case than in the neutral context case.

Third, in the sentence context that was biased toward the subordinate meaning, a 3 x 2 x 2 x 2 ANOVA revealed again the main effects of dominance and ISI. When data from the two biased context conditions were compared, we found that sentence contexts biased to the dominant meaning produced stronger priming effects than contexts biased to the subordinate meaning, $F(1,94) = 3.9$, $p = .05$. A full five-way factorial analysis with type of contexts as an independent variable further confirmed that there was an interaction of context type by ISI by dominance, $F(2,188) = 8.11$, $p < .01$. These results show that when sentence context is biased toward different homophone meanings, the processing time will differ under different ISI levels: at the 0ms and the 300ms conditions (but not the IP point), the dominant meaning was accessed significantly faster than the subordinate meaning.

Finally, we conducted a separate analysis to compare the processing times in biased versus neutral sentence contexts, collapsing the two biasing context types. There was a clear effect of context, as revealed by ANOVA, $F(1,94) = 4.09$, $p < .05$. The average response latency in the biasing sentence contexts was 670ms and that in the neutral sentence context was 709ms. This shows that the access of homophone meanings occurs much earlier in the biasing context than it does in the neutral context. In sum, our data indicate an early context effect and its mutual interaction with word frequency during sentence processing, providing further evidence to the context-dependency hypothesis.

In this experiment, we examined the processing of homophones in Cantonese. To further corroborate the results, we conducted a similar but slightly different experiment in Mandarin Chinese, Experiment 2. In contrast to Experiment 1 in which monosyllabic homophones were tested, Experiment 2 investigates the processing of bisyllabic homophones.[5]

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[5] Although both experiments used the cross-modal task, they are not exact replicates of each other, because the testing materials are different, and some information (e.g., dominance information, or IP information) that is available in Cantonese may not be available in Mandarin, and vice versa.

3 Experiment 2

3.1 Method

3.1.1 Participants

Eighty native Mandarin speakers who reported no speech or hearing deficits participated in this experiment. All participants were students at Beijing Normal University, and were paid for taking part in the experiment.

3.1.2 Materials

Twenty-four disyllabic spoken homophones were selected, each with two different meanings. Each homophone was embedded in two different sentences with prior context biasing either the dominant meaning or the subordinate meaning. There was a total of twenty-four test sentences (twelve biasing dominant meaning and twelve subordinate meaning). We also used twenty-four control sentences that were made up by replacing the homophone in each of the test sentences with an unambiguous word.

Four independent variables were manipulated in this experiment:

(a) *ISI*: The visual probe occurred at two interstimulus-intervals relative to the acoustic offset of the spoken homophone: the acoustic offset of the homophone (i.e., ISI=0ms), or –150ms before the acoustic offset (i.e., ISI=-150ms). We did not use the IP point ISI because no gating results were available for Mandarin homophones. However, the –150ms ISI can roughly approximate the function of the IP point, since for most of the disyllables in our experiment –150ms is at the beginning of the second syllable, which is comparable to the 54% for the IP of the monosyllables (see Experiment 1).
(b) *Context type*: The preceding semantic context was (i) biased to the dominant meaning of a homophone, or (ii) biased to the subordinate meaning of the homophone.
(c) *Dominance*: The visual probe was related to either the dominant meaning or the subordinate meaning of the homophone. The dominance information was determined by asking a separate group of thirty-one students to listen to the sentences and write down the homophone (the last word of the sentence). The dominant meaning of the homophone would elicit twenty-five or more written responses in this task, and the subordinate meaning would elicit five or fewer responses.

(d) *Prime type*: The prime (last word of the sentence) was either the homophone or an unrelated control word, matched to the frequency of one of the meanings of the homophone. The control words were all unambiguous words.

An example *fayan* (speak/infect) and the corresponding test sentences are given below.

(2) a. Sentence context biasing the dominant meaning
Homophone:
Qunchang dunshi bian-de anjing qilai, yinwei xianzai yijing
place suddenly become quite up because now already

kaishi ***fayan*.**
start speech

'The place suddenly became quiet because it's time to begin the *speech*.'

Control:
Qunchang dunshi bian-de anjing qilai, yinwei xianzai yijing
place suddenly become quite up because now already

kaishi ***fangying***.
start show

'The place suddenly became quiet because it's time to begin the *show*.'

b. Sentence context biasing the subordinate meaning
Homophone:
Yisheng gei bingren kai-le xie zhenyao, yinwei xianzai yijing
doctor give patient give–LE some medicine because now already

kaishi ***fayan*.**
start infection

'The doctor gave the patient some medicine since there was already *infection*.'

Control:
Yisheng gei bingren kai -le xie zhenyao, yinwei xianzai yijing
doctor give patient give –LE some medicine because now already

kaishi ***jiangwen.***
start colder

'The doctor gave the patient some medicine since there was already *lower temperature*.'

The visual probes to sentences in the (a) conditions are *jianghua* 'talk' and to sentences in the (b) conditions are *huanong* 'fester', if they were designed to relate to the dominant meaning. When the visual probes were supposed to relate to the subordinate meaning, the conditions in which the above two probes occur would switch. All the visual probes were selected on the basis of a semantic relatedness judgment task from another separate group of forty-four native Mandarin speakers. They were asked to evaluate the relatedness of the homophones and the visual probes on a 9-point scale, and all twenty-four visual probes that were selected had an average rating of 8 or above.

3.1.3 Design

The participants were divided into two groups of forty according to the two ISI conditions. ISI was treated in a between-subject design, and all other variables were in a within-subject design. Within each ISI condition, materials were arranged according to a Latin-square design so that each of the forty participants received 24 sentences in the 2 (context type) x 2 (dominance) x 2 (prime type) design and another 24 sentences that contained control words and no homophones. The order of presentation for the sentences was counterbalanced across participants. No subject received the same target word or the visual probe twice.

3.1.4 Experimental Apparatus

The auditory materials were read by a native Mandarin speaker at a normal conversational rate, and were tape-recorded and then digitized into a PC. The presentation of the auditory and visual stimuli was controlled by the Vmaster and Dmaster programs developed by Kenneth Forster at the University of Arizona (Forster and Forster 1990).

3.1.5 Procedure

Before the experiment began, the experimenter explained the task in Mandarin Chinese to the listener. Listeners were told that they would be hearing a Chinese sentence on a pair of headphones, and immediately afterwards they would see a Chinese word (two characters) on the computer screen. Their task was to, as accurately and quickly as possible, decide whether the characters on the screen were true Chinese words (lexical decision). They should press the 'Yes' key if these would make up true words, and the 'No' key if they were not Chinese words. The non-words were two randomly scrambled characters. All participants did the experiment individually. Before the actual test began, they were given a practice session in which they heard a separate set of twelve similar sentences. The whole experiment took about fifteen minutes.

3.2 Results

Mean response latencies, counting from the onset of the visual probe to the participant's key press, are presented in Table 2. We conducted two separate statistical analyses on the data from the 0ms ISI condition and the data from the –150ms ISI condition.

First, in the 0ms ISI condition, the homophone elicited faster (though not statistically significant) responses than the unrelated control word when the biasing context and the visual probe were consistent, that is, when the context biased the dominant meaning of the homophone and the visual probe was related to the dominant meaning, or when the context biased the subordinate meaning and the visual probe was related to the subordinate meaning. A priming of 28 ms ($t(39) = 1.84$, $p > .05$) and 33 ms ($t(39) = 1.74$, $p > .05$) were obtained for the two consistent conditions, respectively. When the biasing context and the visual probe were inconsistent, the homophone and the unrelated control word elicited similar responses ($p > .10$). Although none of the paired differences between homophones and the controls reached statistical significance, it is clear that at 0ms ISI sentence context already started to play a role to influence the access of the homophone meanings. Unfortunately, a potentially interesting condition, 300ms ISI (comparable to Experiment 1), was not manipulated in this study. We would expect, on the basis of our results from Cantonese, that the priming effects would become more significant at relatively later stages of processing.

	Dominant**		Subordinate	
Context type	Homophone	Control	Homophone	Control
Biased to dominant				
0 ms	545	573	600	617
-150 ms	581	616	631	639
Biased to subordinate				
0 ms	553	572	567	600
-150 ms	586	606	613	610

Table 2. Response latencies (ms) as a function of context type, dominance, ISI, and relatedness in Experiment 2

Second, in the -150ms ISI condition, we found that only if the context biased the dominant meaning of the homophone and the visual probe was related to the dominant meaning, the homophone elicited significantly faster responses than did the unrelated control word (a priming of 35ms, $t(39) = 2.52$, $p < .05$). In all other situations there were no significant differences between the homophone and the control word ($p > .10$). This indicates that at an earlier stage, context effects influence the access of only the dominant meaning of the homophone, and does not influence the access of the subordinate meaning. We can compare the absence of difference here with the presence of a 33ms priming when ISI was 0ms in the subordinate conditions, which shows clearly that it takes time for the subordinate meaning to become activated. This result is also consistent with results from Experiment 1 that there was a significant interaction between context type and dominance, and that in the neutral context condition, the dominant meaning was accessed first.

4 General Discussion

Much of our existing knowledge about lexical ambiguity in sentence processing has been limited to English and other Indo-European languages. The present study is an attempt to broaden this knowledge base by examining this important phenomenon in one of the major East Asian languages, following our previous work in Chinese language processing. We used the cross-modal method to examine the processing of ambiguous words in both Cantonese and Mandarin Chinese. The two comparable experiments have yielded converging evidence on how Chinese speakers face the massive homophony problem during sentence processing.

Our results indicate that in both Cantonese and Mandarin, listeners make early use of prior sentential context in the resolution of lexical ambiguity. Sentence contexts aid the processing of Chinese homophones from early on, probably within the acoustic boundary of the ambiguous word in natural speech. This claim pushes the effect of sentence context to a much earlier stage than what has been proposed by the multiple access hypothesis, e.g., about 1.5 seconds after the word offset (see Onifer and Swinney 1981). The converging results from the two experiments provide further support to the context-dependency or selective access hypothesis. They are consistent with findings from other studies (Ahrens 1998, Chen and Cui 1997), as well as our own previous findings (Li 1998, Li and Yip 1996, 1998).

One important finding from the current set of experiments is that sentence context effects interact closely with frequency/dominance effects. In Experiment 1, we found that when there was no biasing context available (the neutral context condition), the dominant meaning elicited significantly faster responses than the subordinate meaning. However, when there was biasing context, dominance and context type had a complex interaction, along with ISI. In Experiment 2, we found that only the dominant and not the subordinate meaning of the homophone elicited priming effects when the ISI was at –150ms, but both dominant and subordinate meanings elicited priming effects when the ISI was at 0ms. These results seem to require a more complex explanation than a simple version of the context-dependency hypothesis, an explanation that emphasizes the interaction between context and frequency. To account for this type of interaction, we turn to the reordered access hypothesis (Hogaboam and Perfetti 1975, Simpson 1981, Simpson and Burgess 1985, Rayner et al. 1994), a model that considers both context and frequency effects in lexical ambiguity processing.

The reordered access hypothesis assumes that the access of ambiguous words is frequency-based: the dominant or primary meaning of the word is accessed first, irrespective of context, followed by the access of the subordinate or secondary meaning. Context can help in elevating the activation level of the subordinate meaning, but has limited role in the case of dominant meaning. Our data from both experiments support this general claim. However, this hypothesis would be indistinguishable from the context-dependent hypothesis when one looks at the sentence context that biases the dominant meaning, in which case both hypotheses predict that only the dominant meaning would be activated. This is true with our results from Experiment 1, in which the dominant meaning was accessed faster than the subordinate meaning and with results from Experiment 2, in which only the dominant meaning elicited priming. However, the re-ordered access hy-

pothesis may also be indistinguishable from the multiple access hypothesis when one looks at the sentence context that biases the subordinate meaning, in which case both hypotheses predict that subordinate as well as dominant meanings would be activated; the dominant meaning is activated because of frequency, and the subordinate meaning is activated because of context according to the re-ordered access hypothesis. With regard to contexts biased to the subordinate meaning in our data, Experiment 1 shows that the dominant meaning is in general activated faster than the subordinate meaning, both at early and late stages of processing, although the subordinate meaning elicits priming effects at later but not early stages. In Experiment 2, similarly, the subordinate meaning elicits priming only at the later stage (0ms), but not at the early stage (-150ms). Thus, these data indicate that there is a time course to the effects of frequency and context: both frequency and context are important early on, but contexts take precedence over frequency at later stages. In addition, our data show that the frequency of homophone meanings can operate relatively early (probably within the word boundary), in contrast to the assumption that frequency effects can occur only at a later selection stage (see Onifer and Swinney 1981, Swinney 1979).

Note that there were no effects of relatedness or homophone density in Experiment 1. The absence of these effects may be due to two problems. First, there have been no semantic associate norms for Cantonese, and we approximated the variable of relatedness by using a separate semantic relatedness judgment task (see Method). As mentioned before, we selected the most frequent responses as the related visual probes while randomly selected other characters as the unrelated probes from the same source of the characters proposed by the participant judges. Therefore, the unrelated items might still have served to activate meanings related to the homophone, though to a lesser extent. Second, the lack of a good control for the frequency of the visual probes might be a source of confound in the current study, thereby obscuring the density effects.

To conclude, results from the present study along with our previous findings suggest that the successful recognition of spoken homophones depends on the continuous on-line interaction between contextual and lexical (including frequency) information in the sentence. These results are consistent with interactive models at large, as discussed in Kawamoto (1993), Marslen-Wilson (1987), McClelland (1987), and McClelland and Elman (1986), according to which language processing is a highly interactive form of information processing, and that prior sentence context can influence lexical access at an early stage.

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