

Context Effects in Lexical Ambiguity Processing in Chinese: A Meta-Analysis*

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Context effects in lexical ambiguity processing have been extensively examined in various languages including Chinese. A meta-analysis was performed on seven studies conducted in Chinese in order to determine how the Chinese data as a whole agree or disagree with previous findings in other languages. All seven studies reviewed in our analysis used the priming technique to determine the degree of activation of alternative meanings of an ambiguous word in sentence context. The analysis reveals a small but consistent effect of context on lexical access: the contextually appropriate interpretation of a word consistently shows greater priming than the inappropriate interpretation. We further show that sentence contexts interact closely with the meaning frequency of an ambiguous word. We also identify variables in these studies such as length of context and timing of presentation that could influence the strength of the context effect.

Keywords: Context effects; Lexical access; Lexical ambiguity; Chinese sentence processing; meta-analysis.

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1. A Meta-analysis

Lexical ambiguity has been a focus in the study of context effects in word recognition in the past 30 years (Onifer & Swinney, 1981; Simpson & Kreuger, 1991; Swinney, 1979; Tabossi, 1988). Results from these studies point to two major hypotheses of lexical access. The multiple access hypothesis argues that all meanings of a homophone will be accessed momentarily following the occurrence of the word; semantic context can only help to select the appropriate meaning at a post-access decision/selection stage. This hypothesis assumes a modular account of lexical processing in which context does not penetrate lexical access (Fodor, 1983). In contrast, the selective access hypothesis argues that the contextually appropriate meaning of a homophone can be selectively accessed early on, if prior context provides a strong bias to one of the meanings. It assumes an interactive process in which lexical and contextual information can mutually influence each other at a very early stage (McClelland, 1987).

The above competing hypotheses, along with variants of the hypotheses, have been extensively examined in a large number of studies of Indo-European languages (e.g., English and Italian). Lucas (1999) reviewed a total of 25 studies that were relevant to the testing of these hypotheses. Her review and meta-analysis indicated an overall effect of context in lexical ambiguity resolution, thus disconfirming the modular account of lexical access. However, due to differences in the methodologies used in various studies—including task, timing of presentation, and type of context—researchers have not reached a general consensus on the role of context in lexical access, and more specifically lexical ambiguity resolution.

Most studies on this topic have focused on whether it is multiple or selective access that lexical ambiguity processing reveals. Context effects, however, might also be reflected in the relative degree of activation of the various meanings of the ambiguous word. An alternative to the extreme ends of multiple versus selective access hypotheses is the recorded access hypothesis (Simpson, 1981; Simpson & Burgess, 1985; Simpson & Kreuger, 1991; Rayner, Pacht, & Duffy, 1994), according to which 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. This alternative hypothesis has received relatively less attention in the literature because it involves relatively small effects that conventional significance testing may easily miss. The actual size of the effect could vary with the statistical power in different studies. In Lucas's (1999) review, a meta-analysis was performed on 17 of the 25 studies in which effect size (ES) information was provided. The analysis indicated a small but consistent effect of context across studies: although multiple interpretations of a word were sometimes accessed, the contextually appropriate interpretation was consistently more strongly activated. The variability observed across studies was due to sampling errors as well as other moderator variables such as task, timing of target presentation, meaning frequency, type of target, and type of context.

Lexical ambiguity processing and the accompanying theoretical debates have been mainly tested in Indo-European languages. In recent years, however, there has been a growing interest in this topic from a Chinese perspective (see Zhang, Wu, & Yip, 2006 for a summary; see also Li, 1998; Li, Shu, Yip, Zhang, & Tang, 2002; Li & Yip, 1996, 1998). Given the language-specific properties in lexical, phonological, and syntactic structures and the prevalence of lexical ambiguity, Chinese provides an excellent test case for issues in lexical ambiguity processing. A very large number of homophones and homographs exist at both the lexical and morphemic level, due to the limited inventory of syllables that are used to create the words and morphemes in Chinese. We can roughly divide Chinese ambiguous words into three categories: (1) homophonic homographs (e.g., 杜鹃 *dujuan*, cuckoo or azalea), which have the same writing and same pronunciation but indicate different meanings; (2) heterophonic homographs (e.g., 东西 *dong-xi* or *dongxi*, east-west or things), which have the same writing but different pronunciations for the two meanings; and homophonic heterographs (e.g., 电源—店员 *dianyuan*, power source versus shop assistant), which have different writings but the same pronunciation. These categories have all been examined in previous studies (see analyses below).

In this study we present a meta-analysis of seven studies that have been conducted in Chinese, although the total number of Chinese ambiguity studies

is more than seven. Here we restrict our analysis to those studies that have used the semantic priming paradigm to examine the degree of activation of alternative meanings of ambiguous words. For example, in a typical experiment using cross-modal semantic priming, Shu, Tang, and Zhang (2000) investigated the processing of meaning access of disyllabic homophones in Chinese. The results showed that in the 0-msec inter-stimulus interval (ISI) condition, the same priming effects were found for both dominant and subordinate meanings of the ambiguous word in appropriate contexts, but in the -150-msec ISI condition, a priming effect was observed only for the dominant meaning. These results, consistent with findings from previous studies in other languages, suggest that listeners can make use of the prior sentence context in the resolution of lexical ambiguity from early on, and that sentence context interacts with meaning frequency.

Following the approach of Lucas (1999), our analysis here attempts to identify if there are systematic context effects in lexical ambiguity processing in Chinese. The type of ambiguous words used, the modality of stimulus presentation, and the timing of presentation may have differed in the studies reviewed here, but the studies together provide a good collection of empirical data that could allow us to access the consistency of context effects across experiments with Chinese materials. They would also allow us to identify similarities and differences between Chinese data and previous findings from Indo-European languages. In our analysis we will consider methodological issues carefully, including frequency, modality of presentation, length of context, and timing of presentation in the explanation of larger or smaller context effects in lexical access.

2. Method

2.1. Selection of studies

Seven studies were selected for our meta-analysis, including four journal articles, one doctoral dissertation, and one master's thesis that contained two different studies (Shu et al., 2000; Wu, 2001; Wu & Shu, 2002; Wu, 2002; Zhou, Chen, Yang, & Chen, 2003a; Zhou, Chen, Yang, & Chen, 2003b). They all used priming techniques to investigate the degree of activation of dominant versus subordinate meanings in both dominant- and subordinate-biasing

contexts. In all seven studies the participants completed a lexical decision task. Among the seven studies five examined homophonic homographs, while other two investigated homophonic heterographs.

2.2. Procedures

We have closely followed the analytical procedure used by Lucas (1999). First, most of the studies analyzed here included multiple observations within an experiment. For example, different ISI conditions might have been manipulated within a single experiment. Such manipulations were counted as separate observations in our analysis; for example, the Shu et al. study described above contained two observations, each with its own context effect (see Table 1 for details on number of observations each study or experiment had). There was a total of 13 observations across the seven studies in our analysis. However, multiple observations within a single study may not be independent, and thus we will report effect size (ES) results based on both individual observations and combined mean observations of multiple-observation studies.

Second, ESs were calculated for the amount of priming for related targets in both appropriate and inappropriate contexts. All seven studies reported priming effects for a target presented after a related prime relative to the same target presented after an unrelated (control) prime. Usually the control prime was an unambiguous word matched in length and frequency to one of the meanings of the ambiguous word. The targets were related either to the dominant meaning of the prime or to the subordinate meaning of the prime. ESs were calculated both for priming for the appropriate target (i.e., the dominant meaning in the dominant-biasing context and the subordinate meaning in the subordinate-biasing context) and for the inappropriate target (i.e., the dominant meaning in the subordinate-biasing context and the subordinate meaning in the dominant-biasing context). The ES for the inappropriate target was then subtracted from the ES for the appropriate target to get the appropriateness (or context) effect size. A positive appropriateness ES would indicate that priming exists for the appropriate target relative to the inappropriate target, whereas a negative appropriateness ES would indicate that priming goes in the other direction: the inappropriate target had greater priming than the appropriate target.

Finally, ESs were specifically calculated as follows: Each observation was

converted to a standard ES. When a study reported means and standard deviations of two groups (treatment and control), our index of ES changed from $(M_1 - M_2) / \sigma_{\text{pooled}}$, which was Cohen's d (Cohen, 1977), where σ_{pooled} was based on pooled variations of the two groups: $\sqrt{[(\sigma_1^2 + \sigma_2^2) / 2]}$. Cohen's d was positive if the mean difference was in the predicted direction. Our ESs were calculated only from subject analyses (ignoring item analyses). Because of a concern with the independence of observations within single studies, an overall mean ES as well as ESs for individual observations for each study were calculated.

3. Results

3.1. Distribution of effect sizes

Table 1 presents the ESs for the seven studies. The results indicate that all 7 studies show positive appropriate effect sizes. The ratio of positive ESs for all 13 observations is 0.85 (11/13). This ratio was significantly different from chance, as indicated by a chi-square goodness-of-fit test [$\chi^2(1) = 6.23, p < .05$]. The distribution of effect sizes in our analysis thus provides no support for the multiple access hypothesis, according to which context has little effect on initial lexical access and only error variances could cause greater priming in some conditions for appropriate meanings over inappropriate meanings. In other words, priming effect due to appropriateness would occur only by chance such that half of the appropriateness ES would be in the positive direction and the other half the negative direction.

3.2. Central tendency and variability

For central tendency and variability, we report both medians and means of ESs. In the seven studies analyzed, the median number of participants per observation was 40, and the total number of participants across all observations was 459. For the 13 observations, the mean ES was .18, and the median ES was .22. Based on combined mean observations of the seven studies, the mean ES was .20, and the median was .17. The standard deviation was .13 for the mean of the observations and .11 for the seven studies. We also calculated weighted means with the sample size of each study as the weighting factor, but the weighted and unweighted means were not significantly different. Thus, our

Table 1. *Effect Sizes (ESs) for the Seven Studies (and Multiple Observations) in the Meta-Analysis*

Study	ES per Study	Observation	N per Observation	ES per Observation	Timing of Target Presentation*
Shu et al. 2000 (Experiment 2)	0.17	1	40	0.05	-150-msec ISI 0-msec ISI
		2	40	0.29	
Wu, D. 2002 (Experiment 3)	0.23	1	43	0.23	90-msec SOA
Wu, D. 2002 (Experiment 4)	0.17	1	40	0.17	90-msec SOA
Wu, N. & Shu, 2002	0.02	1	40	0.1	Onset ISI
		2	38	-0.03	IP ISI
		3	41	-0.01	0-msec ISI
Wu, N. 2001 (Experiment 3)	0.15	1	42	0.22	Onset ISI
		2	39	0.08	IP ISI
Zhou et al. 2003a (Experiment 2)	0.28	1	24	0.26	-150-msec ISI
		2	24	0.3	50-msec ISI
Zhou et al. 2003b	0.35	1	24	0.3	200-msec SOA
		2	24	0.4	400-msec SOA

Note: ISI = inter-stimulus interval, cross-modal manipulations; SOA = stimulus onset asynchrony; visual-only manipulations

subsequent analyses will use only the unweighted mean ESs.

3.3. Heterogeneity of variance

Although ESs were consistently positive, the variability across studies was clear. A critical question to ask is whether this variability represents random sampling variation around a single, normally distributed ES value (roughly .18 for our study) or reflects the existence of two or more underlying populations that differ in a principled way. These possibilities were investigated, using the

test statistic provided by Rosenthal and Rubin (Rosenthal & Rubin, 1982). This statistic is approximately distributed as a chi-square with $K-1$ *df*, where K is the number of ESs. In this test, it is essential that ESs be independent, and therefore only the ESs based on the combined mean observations were used. Rosenthal and Rubin's formula applied to the ESs yielded $\chi^2(6) = 5.5, p > .05$. Thus, the heterogeneity of variance across studies might be simply due to sampling error.

However, a failure to find statistically significant heterogeneity does not mean that we cannot look for moderator variables (Light & Pillemer, 1984; Rosenthal, 1995) that may have caused significant differences in various studies. In particular, the test for heterogeneity in our analysis may not have been powerful enough to detect variation, due to the small sample size (seven studies and thirteen observations) in our analysis. Therefore, a search for moderator variables still is warranted, as it could provide important clues for future research directions.

3.4. Moderator variables

To assess the influence of moderator variables on context effects, we subdivided the ESs according to specific characteristics of the reviewed study. Comparisons of specific ESs should indicate whether the observations differed in ES on the basis of differences in methodology or stimuli. Mean ESs were computed for each characteristic by study, as shown in Table 2.

3.4.1. Frequency and context

Ambiguous words usually have a dominant meaning that is more frequent than other meanings (subordinate meaning). The ordered search hypothesis, originally proposed by Hogaboam and Perfetti (1975), considers the frequency effects on the processing of lexical ambiguity. It claims that the most frequent meaning is always accessed, regardless of context. All seven Chinese studies reviewed here investigated the frequency effects by using ambiguous words that had both a dominant and a subordinate meaning in both biasing contexts.

Our analyses indicated that context and frequency had a complex interaction. When the meaning and the context were consistent, the ES for dominant meanings in the dominant-biasing context was the greatest (.27). This was almost twice as large as that for subordinate meanings in the

Table 2. *Effect Sizes (ESs) and Characteristics of Experiments (By Studies)*

Characteristics	Average ES	SD	N of Studies
Frequency and Context			
Dominant meaning in appropriate contexts	0.27	0.22	7
Dominant meaning in inappropriate contexts	0.01	0.15	7
Subordinate meaning in appropriate contexts	0.12	0.21	7
Subordinate meaning in inappropriate contexts	0.02	0.19	7
Dominant meaning overall	0.14	0.22	7
Subordinate meaning overall	0.07	0.20	7
Modality			
Visual	0.25	0.09	3
Cross-modal	0.16	0.11	4
Length of Context			
Short (< 6words)	0.32	0.05	2
Long (6-10words)	0.15	0.08	5
ISI* (for cross-modal experiments/observations)			
ISI < 0msec	0.12	0.1	4
ISI = 0msec	0.14	0.21	2
ISI > 0msec	0.3		1
SOA* (for visual-only experiments/observations)			
90-msec SOA	0.2	0.04	2
200-msec SOA	0.3		1
400-msec SOA	0.4		1

Note: * indicates manipulations for which multiple observations may be obtained in a given study.

subordinate-biasing context (ES = .12). When the meaning and the context were inconsistent, the ES for dominant meanings in the subordinate-biasing context (ES = .01) was virtually identical to the ES for subordinate meanings in the dominant-biasing context (ES = .02). On average, the ES for dominant meanings was twice as large as the ES for subordinate meanings (.14 and .07, respectively) in both dominant- and subordinate-biasing contexts, and the ES for appropriate contexts was ten times as large as the ES for inappropriate contexts (.20 and .02, respectively). These results seem to require a more

complex explanation than a simple frequency-based (ordered search) or a simple context-based explanation (selective access). The explanation must emphasize both context and frequency and their interactions. A good candidate in this respect is the reordered access model (Duffy, Morris, & Rayner, 1988; see also Simpson, 1981; Simpson & Kreuger, 1991; Rayner et al., 1994), a model that considers both context and frequency effects in lexical ambiguity processing. It incorporates the relative meaning frequency of ambiguous words into the interactive hypothesis. It proposes that the alternative meanings of ambiguous words are accessed in order of their relative frequencies, but sentence context can have a prelexical influence on the activation of contextually appropriate meanings. The picture that emerges from our above analysis seems to be most compatible with the reordered access model.

3.4.2. Modality of sentence presentation

Although there is no *a priori* reason to assume that context effects on lexical access might differ as a function of listening versus reading, the modality of the presentation of sentence materials clearly differed among the various studies and could have affected the results. Some researchers (Shu et al., 2000; Wu, 2001; Wu & Shu, 2002; Zhou et al., 2003a) used a cross-modal priming paradigm in which the sentence was heard and the target word was presented visually; others (Wu, 2002; Zhou et al., 2003b) used a visual-only presentation (see Table 1 for details). Comparisons indicated that the ES in the cross-modal studies (.16) was slightly smaller than the ES in the visual-only studies (.25). However, due to the small number of studies reviewed here one has to be cautious about any conclusions drawn regarding the role of modality of sentence presentation.

3.4.3. Length of context

The context length for a study was the average number of words preceding (not including) the prime in all the experimental sentences. Among the seven studies reviewed, two of them had very short sentences (fewer than six words); others used longer sentences between six and ten words. If context effects take time to build, they may not show up in short contexts, as compared with longer ones (Tanenhaus & Donnenwerth-Nolan, 1984). We determined the role of context length by comparing the ESs across two different lengths: short (fewer

than 6 words) and long (between 6 and 10 words). Our analyses showed that longer contexts did not lead to larger ESs, and in fact, the reverse was true: the ES for the short contexts was larger (.32) than that for the long contexts (.15). We discuss the implications of this unexpected context length effect in the Discussion section.

3.4.4. Timing of target presentation

Among the seven studies reviewed here, two of them attempted to confine their results to the lexical access stage by presenting the target at the end of the prime (ISI = 0 msec; see Table 1 for details). However, four studies looked at earlier presentation points (ISI < 0 msec), on the hypothesis that access might be occurring earlier. Only one study used an interstimulus interval longer than 0 millisecond (ISI > 0 msec). In the three visual-only studies (of which Zhou et al. 2003b contained two observations/experiments), the targets were presented after the onset of the prime (SOA > 0 msec). Among the four cross-modal studies that had ISI < 0 presentations, two chose the location of the target simply by presenting the target at some fixed point before the acoustic offset of the prime (such as 150 msec, i.e., ISI = -150). This method is less accurate than that used by the other two studies that relied on the gating paradigm in determining the access point (Grosjean, 1980). Using a separate pretest of all the homophones used in the experiments, the other two studies carefully identified the unique recognition point (isolation point, or IP) for each word through the gating paradigm. They then presented the visual probe at three separate presentation points: the onset of the prime, the isolation point (ISI = IP) and the acoustic offset of the prime (ISI = 0ms). The IP point varied from word to word, and the average IP for the Chinese spoken words used in the two studies was 55% of the acoustic duration of the word.

If enough auditory information was available prior to the end of the word for uniquely determining the word's identity, studies using a 0-msec or longer ISI may have been unintentionally tapping into the selection phase of lexical processing, rather than the access phase. This would not be too useful in tackling issues concerning modular accounts (see earlier discussion) as these accounts focus on the access rather than the selection or integration stage. Simpson and Kreuger (1991) also noted other problems with regard to timing of presentation because the task demand (e.g., to shift quickly from hearing or

reading the sentence to making a response) may impede the participant's performance. This problem could make a 0-msec ISI functionally longer than that intended by the experimenter, effectively placing the participant's response in a post-access stage. For these reasons, our analyses compared the ESs from studies using an early presentation point with the ESs from studies using a standard 0-msec ISI or longer. Surprisingly, our comparisons indicated no significant differences between the two presentation points: the ES for the early condition was .12, as compared with .14 for the later condition. However, for the four experiments that presented targets only visually, the mean ES was .25, with .20 at the 90-msec SOA, .30 at the 200-msec SOA, and .40 at the 400-msec SOA. The increment of ESs with increasingly larger SOAs suggests that at least in the visual-only experiments the size of the priming effects may increase as the target presentation point becomes delayed relative to the prime.

4. 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 along these lines (see Li & Yip, 1998; Li, et al., 2002; Zhang et al., 2006). Here we use the method of meta-analysis to provide a quantitative and qualitative review of seven studies on lexical ambiguity resolution in Chinese. Our analyses provide support for the interactive view of language processing. The studies reviewed here all show a small but consistent effect of context on lexical access, consistent with studies in other languages (see Lucas, 1999 for a review): the contextually appropriate meaning of an ambiguous word shows greater priming than the inappropriate meaning.

Perhaps the most important finding from our analyses is that sentence context interacts closely with frequency in Chinese lexical ambiguity processing. This interaction, as discussed earlier, is most compatible with the re-ordered access model according to which context and frequency together contribute to lexical ambiguity resolution. Our analysis shows that on average, the ES for dominant meanings is twice as large as that for subordinate meanings in both dominant- and subordinate-biasing contexts. This dominant-

meaning advantage, however, disappears when the meaning and context are inconsistent with each other. This suggests that the relative frequency of the meaning and the contextual bias jointly affect the processing of Chinese ambiguous words. These patterns are consistent with the cue-based competition view (Bates & MacWhinney, 1991; Li, Bates, & MacWhinney, 1993): when you have both context and frequency in agreement the effect size becomes larger, but when the two variables are in competition, the effect size becomes smaller, given that the competition requires additional cognitive resources to resolve.

As in many psycholinguistic domains, lexical ambiguity research has yielded mixed patterns, and one may attribute these different patterns to the different methodologies used in different studies. Thus, the search for moderator variables is a necessary step for meta-analysis. However, the results of our variance heterogeneity analysis suggest that the wide variation in ESs across the seven studies may have been simply due to sampling error. Our analysis also gives no indication that modality of sentence presentation influences lexical access, consistent with Lucas's (1999) analysis for most studies of Indo-European languages. On the other hand, our analysis does show that meaning frequency (discussed above), length of context, and timing of presentation might influence the probability for a context effect to occur. The effect of length of context in the seven Chinese ambiguous studies agrees with that found by Lucas, where the ES for long contexts is smaller than that for medium-length and short contexts. This length effect, although significant, is counterintuitive, since one would expect longer contexts to yield stronger context effects. One possible reason for this seemingly counterintuitive pattern is that the shorter contexts in the reviewed studies have been actually constructed with stronger biases toward one particular interpretation of an ambiguous word; in principle, length of context does not have to correlate with the strength of contextual bias. Thus, future research needs to pay more attention to the strength of the constraining context rather than the context length per se.

In the visual-only (but not the cross-modal) experiments in our analysis, we have also found that presentation of the target after the end of the prime increases the size of the context effect as a function of SOA length. This suggests that visual studies that use later presentation points for the target might

actually be tapping into the selection or post-access stage rather than the access stage of lexical processing. However, for the four studies that use cross-modal priming, the timing of presentation effect is not apparent from our analysis. This pattern differs from that in Lucas's analysis, where there is a stronger timing of presentation effect. This discrepancy might be due to the haphazard nature of the selection of presentation points in the Chinese studies, or it could be due to the small number of studies analyzed (which effectively reduces the power in detecting significant effects). Our analyses suggest that future studies should consider the use of the gating paradigm in determining the exact isolation points for individual target words, so that the effects of lexical access versus lexical selection/integration can be more accurately evaluated in cross-modal studies of this kind.

In conclusion, the meta-analysis presented here makes a first attempt to integrate the rapidly growing number of studies of lexical ambiguity processing in Chinese. Our analysis also makes a direct comparison between findings from Chinese and those from previous studies conducted in other languages as reviewed by Lucas (1999). The comparison shows that the Chinese data agree with data from other languages in pointing to a consistent context effect and an interaction between context and frequency. Although the number of studies available for our meta-analysis is limited as compared to the total number of studies in the literature, here we have systematically evaluated the size of the context effect in the available studies, and linked the effect sizes to various variables that have been considered significant to such studies. Identification of methodological issues and the consequences therein is very important in a domain like lexical ambiguity resolution, where theoretical controversies remain after much research. We hope that this short review will help researchers to develop better, more sensitive experimental paradigms and tasks in the investigation of the time course of lexical ambiguity processing. Future research using convergent behavioral and neuroimaging techniques (e.g., event-related potentials or ERPs) might also take advantage of the lessons gained from the existing studies to resolve important theoretical issues in the domain.

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