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詞彙歧義解困的次要語義偏向效應再視：中文多義詞的眼動研究證據
REVISITING THE SUBORDINATE BIAS EFFECT OF LEXICAL AMBIGUITY RESOLUTION: EVIDENCE FROM EYE MOVEMENTS IN READING CHINESE

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論文是經歷了不斷修改的過程，只有自己才能體會箇中滋味，看到這本論文的完成，心中充滿了感動和感謝，雖然起步的較晚，但自己終究還是一步步的堅持到最後，雖然在這條研究與學習的路上也會有未知的恐懼與挫折感，但身邊的老師及朋友總會點著光引領著我讓我不至於迷失了方向、鼓勵我讓身心疲累的我隔天再充滿力量繼續往前邁進。

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國 立 政 治 大 學 研 究 所 碩 士 論 文 提 要

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論文名稱：詞彙歧義解困的次要語義偏向效應再視；中文多義詞的眼動研究證據

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過去二十多年來，心理語言學研究關注詞彙歧義解困 (lexical ambiguity resolution)歷程發生時，語義脈絡與多義詞的語義頻率之間的交互作用。許多研究發現，當語境支持非均勢同形異義詞 (unbalanced homograph) 的次要語義時，同形異義詞的凝視時間長於與其有相同字形頻率的單義詞 (unambiguous control)，此為次要語義偏向效應（subordinate bias effect）。根據再排序觸接模型 (reordered-access model)，次要語義偏向效應來自於主要語義與次要語義的競爭；相對地，選擇觸接模型 (selective access model)則認為只有與語境相關的語義被激發，因此，次要語義偏向效應是因為提取到一個使用頻率較低的語義。本論文進行兩個眼動實驗。實驗一檢視中文多義詞的次要語義偏向效應以區辨兩種詞彙歧義解困模型分別提出的解釋。本實驗的材料使用了低頻同形異義詞、低頻單義詞、以及高頻單義詞。結果顯示，當使用的單義詞與多義詞字形頻率相同時，在目標詞及後目標詞上(目標詞後一個詞)皆發生了次要語義偏向效應。實驗二利用口語理解—視覺典範中透過受試者理解語音訊息時同步記錄眼動的作業方式來探究次要語義偏向效應是否來自於主要語義的激發。當口語句子中

的目標詞被唸出後，會計算出隨著時間增加眼睛落在四個雙字詞的凝視比例。結果發現次要語義因為語境的選擇在聽到目標詞後大約 500 毫秒時就可被激發，主要語義則在一聽完多義詞後被激發。因此，多義詞的兩個語義在聽到目標詞後大約 900 至 1300 毫秒時(相當於在後目標詞時)發生競爭。整體而言，本研究顯示即使語境支持多義詞的次要語義，主要語義依然會被激發。因此，次要語義偏向效應是由兩個語義競爭後所造成的結果，符合再排序觸接模型的解釋。

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Abstract

Research in psycholinguistics throughout the last two decades has focused on the interaction between linguistic context and meaning dominance during lexical ambiguity resolution. Many studies demonstrated the *subordinate bias effect* when the preceding context biased for the subordinate meaning (i.e. infrequent meaning) of an unbalanced homograph. According to the reordered access model, the SBE is due to competition between the dominant and subordinate meanings. On the contrary, the selective access model assumes only the context-relevant meaning is activated and the SBE is a result of access to a low frequent meaning.

Two eye tracking experiments of sentence reading and sentence listening were conducted. Experiment 1 examined the SBE of Chinese homographs to differentiate the two accounts. We utilized low frequency homographs along with their matched low and high-frequency unambiguous words. The results showed the SBE emerging in fixation durations of the target region and post-target region (i.e. next two words of the target), when unambiguous controls were matched to the word-form frequency of ambiguous words.

Experiment 2 used visual world paradigm to explore temporal dynamics of dominant meaning activation responsible for the SBE in an instructional eyetracking-during-listening task. Fixation probabilities on four disyllabic printed words were analyzed during a time period after a target word was uttered in a spoken sentence. The results supported the reordered access model. The subordinate meaning was activated by contextual information at about 500 ms after the onset of acoustic homograph at the time when context penetrated to make its favored meaning available. Soon after the offset of homograph, the dominant meaning became active. Both meanings associated with the homograph were activated during the time windows of 901 ms to 1300 ms, which approximately corresponding to the acoustic onset of post target. In sum, our studies demonstrate that the dominant meaning is activated even when the contextual information biases to the subordinate meaning of a homograph. The subordinate bias effect is the result of competition from two meanings, conforming to the reordered access model.

Chapter 1

Introduction

"*If I accomplish nothing else in this story, I hope I will persuade you that human language is so vague and ambiguous that only a very clever brain could possibly understand it.*" *(Miller 2001)*

1.1 General background

Based on the theoretical linguistics, homonym and polysemy are two main types of ambiguous words (Cruse, 1986; Lyons, 1977). Homonym is the word which contains two or more etymologically and semantically unrelated meanings sharing the same orthographic form and phonology. For example, the word *ring* can refer to either "jewelry" or "sounds". On the contrary, polysemy is the word that contains two or more etymologically and semantically related senses. For example, the word *lamb* can refer to either "an animal" or "meat". Both homonym and polysemy have been studied in much psycholinguistic research and they have been demonstrated to be psychologically distinct based on empirical evidence. (Beretta, Fiorentino, & Poeppel, 2005; Frazier & Rayner, 1990; Rodd, Gaskell, & Marslen-Wilson, 2002). In the present study, we mainly focus on the one type of homonym which specifies words that have the same orthographic form and sound but differ in meaning. They are known as *homophonic homographs*.

Reading comprehension involves the processes from the building blocks of word meanings to the integrated semantic representation. Closely related to the nature of mental lexicon, generally, a word-form carries single phonological and semantic information. However, there is a group of words with mapping single word form to two or more meanings. The ambiguous words provide unique opportunities to examine how different meanings are activated and interacting with the contextual information. It is uncontroversial that context can facilitate meaning access in reading (Rayner, 1998). However, the temporal locus of contextual influence in lexical ambiguity resolution remains unresolved. Thus, the research casting questions of lexical ambiguity resolution serve as crucial evidence to understand the nature of the language-processing system. The modular and the interactive access hypothesis have been tested on the concept of exhaustive access, tying to the notion of whether this access process was impervious to contextual influences.

The proponents of modular access hypothesis (Fodor, 1983) maintains that the contextual information does not influence lexical access at the early stage. A number of early studies have provided evidence that all meanings of an ambiguous word would be activated in initial lexical access, and context affects the post-lexical integration stage (Onifer & Swinney, 1981; Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979). Thus, based on this result, *multiple or exhaustive access model*

(Onifer & Swinney, 1981; Swinney, 1979; Tanenhaus et al., 1979) was proposed. It views that all meanings of an ambiguous word are accessed autonomously and the contextual information can select an appropriate meaning at post-lexical stage. In contrast, the interactive access hypothesis (Marslen-Wilson & Tyler, 1980; McClelland & Elman, 1986) assumed that the information in lexical module can interact with discourse at the early stage. Thus, *selective access model* (G.B. Simpson, 1981; Tabossi, Colombo, & Job, 1987; Tabossi & Zardon, 1993) suggested that contextual information plays a very pronounced role in lexical access, and as a result, only contextually appropriate meaning of ambiguous words is accessed. In sum, these opposing findings have led to a question on the timing of contextual information could possibly influence lexical access.

However, the relative frequency of the various meanings is also important to determine the timing of lexical access. In the present study, we utilize the term *meaning dominance* to indicate the extent to which one meaning is more likely to occur than another. Meaning dominance effects observed in cross-modal priming studies show that two meanings of a balanced ambiguous word are activated approximately at the same time. However, the dominant meaning of an unbalanced ambiguous word becomes available prior to the subordinate meaning, suggesting that access is frequency ordered. Eye movement studies have also shown the evidence

of contextual and meaning dominance effects. For example, when the preceding context supported the subordinate (infrequent) meaning, fixation durations were longer on biased homographs (i.e. one meaning is much more frequent than the other) as compared with its unambiguous control words which were matched in word-form frequency (Duffy, Morris, & Rayner, 1988). This has been termed as the *subordinate bias effect* (SBE; Pacht & Rayner, 1993; Rayner, Pacht, & Duffy, 1994). Two hybrid models based on the interactive view manifested in eye-movement evidence were proposed to account for rapid activation of multiple meanings and early influence of the sentential context. The reordered access model embraces the account that the existence of SBE is two meanings of an ambiguous word compete for selection at the same time, and thus, it takes longer times to process. The results seem to indicate that the dominant meaning of an ambiguous word has been activated even when the context supports its subordinate meaning. However, alternative explanations of the SBE have been proposed by proponents of selective access model, which assumes only the contextually-appropriate meaning was activated given sufficiently constraining context. Sereno, Pacht, & Rayner (1992) and Sereno, O'Donnell, & Rayner (2006) examined the SBE from this perspective and argued that the SBE may be the consequence of taking the subordinate meaning of homographs as a low frequency word, rather than the competition of the dominate meaning to the

subordinate meaning. Therefore, there are two possible accounts, competition or low frequency account for the established subordinate bias effect.

The research of lexical ambiguity resolution in Chinese is relatively few and most of which have utilized a cross-modal priming paradigm to differentiate between modular and interactive hypothesis (Ahrens, 2001; Ahrens, Chang, Chen, & Huang, 1998; Li, Shu, Yip, Zhang, & Tang, 2002; Li & Yip, 1996, 1998). Chinese is considered to be a context-prominent language because of two linguistic properties, that is, the flexibility to omit the pronoun (i.e. Pro-drop) and topic-prominent, both of which require the contextual information to comprehend a sentence. Therefore, Ahrens et al. (1998) proposed language-driven hypothesis and maintained that language like Chinese relies more heavily on contextual information for semantic and propositional interpretation than Indo-European languages. Ahrens (2001) incorporated Chinese ambiguous word such as “背書”, which either means “memorize” or “endorsement” in the preceding subordinate-biased contexts and conducted a cross-modal lexical decision task. The evidence demonstrated that both meanings were accessed at the onset of ambiguous words even when the context was biased toward the subordinate meaning. Therefore, the author contended that the data supported modular access hypothesis, which implied the contextual influence at the post-lexical stage. Nevertheless, Li et al. (2002) used cross-modal paradigm to

explore the processing of biased homophones in Chinese. The results indicated that both frequency and context were critical at an early time. Thus, it was compatible with interactive access hypothesis. In sum, it is uncontroversial that the context plays an important role in arriving at the appropriate meaning; however, whether contextual effect is acting early or late in the time course of ambiguity resolution remains unclear in Chinese.

1.2 Research questions

The present study conducts two eye movement experiments to reveal the continuous and incremental processing of semantic ambiguity resolution. Experiment 1 manipulates three types of Chinese two-character words in sentence reading task: low frequent biased homographs (A), low frequent unambiguous word (LF), and high frequent unambiguous word (HF) and these words are all embedded in sentential contexts. More specifically, the biased homographs are incorporated in the subordinate-biased context. Experiment 2 uses visual world paradigm to probe the time course of lexical ambiguity resolution in an instructional eyetracking-during-listening task. The spoken sentences are similar to those in

Experiment 1 and the visual stimuli are four disyllabic printed words containing dominant and subordinate semantic associates and two other unrelated distractors.

Specific research questions to be addressed are as follows:

(1) Does the subordinate bias effect exist in lexical ambiguity resolution of reading Chinese homographs? And if the SBE was established, when does the contextual influence occur in Chinese lexical ambiguity resolution (early or late)?

(2) We attempt to differentiate between the reordered and selective access model in lexical ambiguity resolution. The reordered access model proposes the competition account of the SBE; however, the selective access model posits that the SBE is in essence a word frequency effect. Which account (i.e. competition or frequency account) could be supported from the present data? .

(3) What is the fate of the unselected meaning? The reordered access model assumes that the activations of the unselected meaning passively decay. In contrast, the selective access model assumes that the unselected meaning was not accessed at all.

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Chapter 2

Literature Review

2.1 Issues of lexical ambiguity resolution

Modular and interactive access hypotheses made different assumptions about the timing of contextual influence. Over the past few decades, researchers have used various approaches to investigate lexical ambiguity resolution. For example, cross-modal priming and eye-tracking methods have provided a substantial body of empirical evidence on theoretical accounts of how ambiguous words are processed. In particular, the subordinate bias effect has been found in eye movement studies when the preceding context supported the infrequent meaning of biased homographs. The existence of the SBE suggests that both linguistic context and relative frequency of the alternative meanings play an important role in lexical ambiguity resolution.

2.1.1 Processing models of lexical ambiguity resolution

A central issue in psycholinguistics is whether the successful and rapid meaning access is modular or interactive processing in nature. Although all models of lexical ambiguity resolution agree that context allows readers to determine the relevant

meaning of a homograph, the perspectives on the time locus of contextual influence are diverse. Modular access hypothesis (Fodor, 1983) proposed the autonomous bottom-up processing in which lower levels of information (lexical module) were not directly influenced by the higher levels of information (discourse module). That is, the contextual information does not penetrate lexical access at the early stage. A contrasting hypothesis, interactive access hypothesis (Marslen-Wilson & Tyler, 1980; McClelland & Elman, 1986) contended that the simultaneous bottom-up and top-down processing was operated interactively. Higher and lower levels of information can interact with each other at the early stage; therefore, contextual information can influence the activation of lexical meaning in early time. Models associated with the modular and interactive view were generated with their empirical evidence. Under the modular view, multiple and order access models were formed. According to the interactive view, reordered and selective access models were proposed. Four models of lexical ambiguity resolution are reviewed in the subsequent part in the order of considering the role of context and then meaning dominance in lexical ambiguity resolution.

First of all, according to *multiple or exhaustive access model* (Onifer & Swinney, 1981; Swinney, 1979; Tanenhaus et al., 1979), all of the meanings of an ambiguous word were accessed temporarily and the contextual information can only help to

select an appropriate meaning at post-lexical stage. The most compelling evidence of exhaustive access came from cross-modal priming studies. Participants were instructed to respond to the visual probes either by making a lexical decision or naming it after hearing the spoken sentences containing an ambiguous word. There were a related probe for each meaning and an unrelated probe. Participants saw one of the three possible probes. The reaction time of semantically related target to either meaning of ambiguous words was compared with that of semantically unrelated controls. For example, Onifer and Swinney (1981) presented sentences either biased for the dominant or for the subordinate meaning of an ambiguous word. Participants made lexical decision for the visual probe which may occur immediate at the auditory offset of the ambiguous words or 1.5 seconds delay. In the immediate condition, participants responded faster to either of the meaning-related probes than to an unrelated probe, thus, facilitation occurred for both dominant and subordinate meaning irrespective of context. In the delayed condition, facilitation was limited to one contextual-relevant probe as the time was lengthened between the occurrence of the ambiguous words and the probe. This implies that context only operates at post-lexical stage to select a single meaning after all meanings have been initially accessed. However, some researchers noted that the lexical decision or naming task is sensitive to backward priming or susceptible to guessing strategies, respectively, and

thus the results may reflect post-lexical integration instead of lexical access (Balota & Chumbley, 1984).

The *selective access model* (G.B. Simpson, 1981; Tabossi et al., 1987; Tabossi & Zardon, 1993) was developed to capture the results in the cross-modal priming studies. When the appropriate context conditions were given, participants were faster to respond to a probe related to the contextually-appropriate meaning of an ambiguous word than to a probe related to contextually-inappropriate meaning. This is consistent with the notion that the access may be limited to the information derived from the context. To summarize, the discrepancy between multiple and selective access models lies in the locus (early versus late) of contextual information affecting meaning activation of ambiguous words. However, neither of them considered the meaning dominance of ambiguous words, which is an important factor in lexical ambiguity resolution.

Two competing models were proposed with the consideration for meaning dominance. The *ordered access model* is proposed by Hogaboam and Perfetti (1975) and G.B. Simpson and Burgess (1985). They maintained that, like the exhaustive model, the preceding context cannot influence on lexical access until the post-lexical stage of selecting appropriate meaning. However, the meaning was not parallel activated but the order of the activation was determined by the relative frequencies of

alternative meanings of the ambiguous words, with the most frequent meaning being retrieved first (e.g., Hogaboam & Perfetti, 1975; Onifer & Swinney, 1981; Schvaneveldt & Meyer, 1976; G.B. Simpson & Krueger, 1991). On the contrary, Duffy et al. (1988) proposed the *reordered access model* to account for their eye-movement results. The lexical access was exhaustive but the meaning activation was determined by both preceding contextual information and meaning dominance. Generally, the most frequent meaning was activated but the contextual information can also boost the activation of context-appropriate meaning of an ambiguous word at the early stage. This led to the competition between multiple meanings when they were both available for the readers. To summarize, four models of lexical ambiguity resolution are classified with respect to considering the role of context and meaning dominance, and they are presented in Table 1.

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Table 1. Different types of models of lexical ambiguity resolution

Hypothesis / Variables: Models		Meaning dominance is considered	Time of contextual influence
Modular hypothesis	Multiple access	No	Late
	Ordered access	Yes	
Interactive hypothesis	Selective access	No	Early
	Reordered access	Yes	

2.1.2 Empirical evidence for lexical ambiguity resolution

2.1.2.1 Eye-tracking paradigm and lexical ambiguity resolution

Readers move their eyes through lines in order to acquire information. Readers recognize words, access meaning and in the end integrate all the information in the course of understanding a text. In eye-tracking experiment, reader's eye movements were monitored and recorded when the eyes proceed with a series of jumps (saccades) and stops (fixations). When readers recognize words and further integrate the obtained meanings into the constructed context for comprehension, the characteristics of words affect two types of decisions, where and when to move the eyes (Tsai & McConkie, 2003).There are some advantages of the eye-tracking paradigm comparing to cross-modal paradigm. First, the whole experiment is under the natural circumstance of reading sentences or texts. Second, unlike cross-modal paradigm, it is more sensitive to the on-line linguistic processing with readers' eye fixation duration and fixation probability being measured.

A large number of eye movement studies have investigated lexical ambiguity resolution (K. S. Binder, 2003; Dopkins, Morris, & Rayner, 1992; Duffy et al., 1988; Kambe, Rayner, & Duffy, 2001; Pacht & Rayner, 1993; Rayner, Cook, Juhasz, & Frazier, 2006; Rayner & Duffy, 1986; Rayner et al., 1994; S. C. Sereno, 1995; S. C.

Sereno et al., 2006; S. C. Sereno, J. M. Pacht, & K Rayner, 1992; Sheridan, Reingold, & Daneman, 2009; Wiley & Rayner, 2000) Most of the studies focus on two variables: (1) the meaning dominance[1], and (2) the instantiated meaning of supporting context. Meaning dominance concerns the relative frequency of alternative meaning of ambiguous words, thus, two types of homographs were differentiated. *Balanced homographs* have two fairly equally frequent meaning, and the *biased homographs* have one highly frequent meaning (dominant meaning) and one or more less frequent meanings (subordinate meaning). For example, a *balanced homograph* such as *case*, with one meaning related to legal proceeding, the other related to containers and both of which are equally common in the language. In contrast, a *biased homograph*, like *port*, the dominant meaning "harbor" is more prevalent in the language than its subordinate meaning, "a type of wine".

Duffy et al. (1988) embedded the biased and balanced homographs in disambiguating information which either preceded or followed the two types of homographs, thus creating four conditions. Each type of homograph had an unambiguous control word matched with same word frequency and length. In general, when preceding contexts instantiated the subordinate meaning of biased homographs, reading times were longer on biased homographs compared with those of balanced

[1] Meaning dominance could be operationally defined as the probability that a particular meaning associated with the homograph itself is given as the first response in word-association norming tasks.

homographs or control words. On the contrary, in the neutral contexts, readers fixate longer on balanced homographs than on biased homographs or unambiguous control words. The example sentences and findings are summarized in Table 2.

Table 2. The materials and results summarized from Duffy, Morris, and Rayner (1988)

Meaning Dominance / Preceding Context	**Balanced** / control	**Biased** / control
Prior context (Subordinate biasing)	Because they heard it from so far away, the **bark**/howl was difficult to identify.	When she finally served it to her guests, the **port**/soup was a great success.
Pattern of fixation times(GD)	**Balanced** = control	**Biased** > control
Prior context (neutral)	Unfortunately the **bark**/howl was difficult to identify, because they heard it from so far.	Last night the **port**/soup was a great success, when she finally served it to her guests.
Pattern of fixation times(GD)	**Balanced** > control	**Biased** = control

Note: the ambiguous targets were presented in bold.

The results demonstrated that processing difficulty resulted from certain combination of contextual information and meaning dominance, such as, when the preceding context biased for the subordinate meaning, gaze duration was longer on biased homographs than on its unambiguous control words. The SBE reveals that longer processing time is needed when the preceding contexts support infrequent

meaning of the biased homographs (e.g. with the infrequent meaning generated less than 8% of the time). However, the SBE is not consistently observed under certain conditions[2]. For example, Wiley and Rayner (2000) found no SBE when the ambiguous words were not strongly biased for frequent meaning (e.g. with the probabilities of infrequent meaning generated between 8% and 30% of the time) and the titles of the context passages were given to disambiguate the vague passage. It seems that SBE is consistently established only when the subordinate meaning is very infrequent but not moderately infrequent (see discussion in Duffy, Kambe, & Rayner, 2001, p. 36).

2.2 Subordinate Bias Effect (SBE) revisited

The existence of SBE implied that the language processing was likely to be interactive since the prior context influenced ambiguous word processing in an early time. Two models based on interactive hypothesis were thus proposed. The reordered

[2] In a number of experiments, Kellas and colleagues (Martin, Vu, Kellas, & Metcalf, 1999; Hoang Vu, Kellas, Metcalf, & Herman, 2000; H. Vu, Kellas, & Paul, 1998) have reported effective elimination of SBE through strong contextual manipulations. On the contrary, numerous others failed to eliminate the SBE from eye movement monitoring of skilled readers by manipulating characteristics of context, such as, contextual constraint, topic and conceptual repetition (Dopkins et al., 1992; Kambe et al., 2001; Morris & Binder, 2002; Rayner et al., 1994).

access model assumed that both meaning frequency and prior contextual information can influence ambiguous word processing, on the contrary, selective access model proposed that prior context determined and selected the appropriate meaning immediately regardless of the meaning dominance. Therefore, the reordered and selective access models accounted for the established SBE by proposing competition and frequency account respectively. The former assumed that the dominant meaning was activated, while, the latter was not. Sereno,et al. (1992) and Sereno,et al. (2006) have tested these two accounts. They argued that the appropriate control words should correspond to the frequency of component meaning since the overall word-form frequency was much higher than the subordinate meaning frequency. If only the context-appropriate meaning was activated, it was comparably fair to compare the fixation times between the homograph and its meaning frequency matched controls. In the following subsections, we focus on the two accounts for SBE based on the reordered access and selective access model and their explanations of the fate of the dominant meaning.

2.2.1 Reordered versus selective access model

Duffy et al. (1988) proposed the *reordered access model* for lexical ambiguity resolution. The model makes four basic assumptions: first, lexical access is exhaustive

and all possible meanings are accessed when the word form is activated. Second, meaning dominance determines the relative activation of multiple meanings. Third, lexical access is an interactive process, in which the preceding context participates in the initial access of word meaning and increase the contextually-appropriate interpretation of an ambiguous word. Fourth, the activation level of the contextually-inappropriate meaning is unaffected. The SBE has served as a test ground for investigating the assumption that access is exhaustive. The most accepted account of SBE is proposed by reordered access model which maintains that the dominant meaning is activated due to its relative frequent meaning and the subordinate meaning is boosted by context. Both meanings compete for selection, thus resulting in the longer gazes on ambiguous words. The competition was apparently manifested in eye movement behaviors. Reading was disrupted with longer fixation durations and ambiguous words received more regressions when they followed subordinate-instantiated context (Duffy et al., 2001; Kambe et al., 2001). Duffy et al. (2001) pointed out that although context supported the less likely meaning, the dominant meaning was not eliminated in the process. Rayner et al. (2006) suggested that the subordinate bias effect resulted from the automatic processing of the dominant meaning. Contextual information does not override the access of dominant meaning.

According to the selective access model, the SBE was a word frequency effect. In other words, a single meaning was activated without retrieving the other meanings associated with that form. It takes longer processing time to access to the infrequent meaning (Kellas & Vu, 1999; S. C. Sereno et al., 1992; G. B. Simpson & Kreuger, 1991). Sereno, et al. (1992) used two control conditions to examine the selective account of SBE as only the frequency effect instead of the meaning dominance which should determine processing time. One control was matched to the form frequency of an ambiguous word, namely HF control. Another LF control word was matched with the frequency of subordinate interpretation, which was estimated as the proportion of form frequency. That is, an interpretation with a meaning bias of .15 was estimated to have a meaning frequency that was 15% of the form frequency of ambiguous words. They obtained the typical SBE when the form frequency control was used to compare with biased homographs. Additionally, they reported longer fixations in post-target (fixation time on the next two words of target), which indicated that ambiguity continued to next region. On the contrary, when the meaning frequency control was the comparison condition, they found SBE in total viewing time and post-target duration but not in target GD. Sereno, et al. (2006) used similar control words to investigate the SBE. They hypothesized that the use of stronger contexts would decrease the SBE related to the word-form (HF) controls and eliminate the SBE

related to the word-meaning (LF) controls, as in Sereno, et al.(1992). They reported the SBE with respect to HF words in target measures, but not in spillover measures. In contrast, reverse SBE was found with respect to LF words in target measures, namely shorter fixation times for biased homographs compared with that for LF words. They claimed that the biased homograph represented a special case in which the word form was a high-frequency word, but the context it occurred intended a low-frequency meaning. Therefore, an ambiguous word's fixation-time can be determined by the contribution of its form and meaning during lexical access process. In terms of word form, the homograph should be processed no faster than an HF control but faster than an LF control (e.g., gaze durations: LF>A≧HF). In terms of word meaning, the homograph should be processed much slower than an HF control but no slower than an LF control (e.g., gaze durations: LF≧A>>HF). This finding indicated that only the subordinate meaning of the homograph was accessed. The comparison of results in Sereno,et al.(1992) and Sereno,et al. (2006) are summarized in Table 3.

To summarize, the studies of Sereno et al. (1992) and Sereno et al. (2006) addressed important claims regarding whether the SBE is due to the different manipulations of the control words. This raised the concern that the SBE, instead of reflecting the competition between two meanings, but the increased time may result from effort to access and integrate a lower frequency word. This provided another

theoretical explanation of the subordinate bias effect without retaining the activation of the dominant meaning (see also in Reichle et al. (2007)).

Table 3. The comparison of results in Sereno et al. (1992) and Sereno et al. (2006).

Literature	Type of control words	Results (GD)	Observed effects
Sereno et al. (1992)	1.form-matched, HF controls 2.meaninng-matched, LF controls	1. A>HF 2. A=LF	SBE – –
Sereno et al. (2006)	Exp1: form-matched, HF controls	A > HF	SBE
	Exp2: meaning-matched, LF controls	A < LF	Reverse SBE
	Exp3: Ambiguous word, HF, LF	LF> A> HF	SBE Reverse SBE Frequency effect

Note: A = ambiguous word; HF = form-frequency unambiguous control word; LF = meaning-frequency unambiguous control word.

Although the finding of Sereno et al. (1992) suggested that readers' access to the subordinate meaning of the homograph in essence was like a low-frequency word, the empirical data showed effects of meaning dominance beyond that observed in the low-frequency unambiguous behavior. Sereno et al. (2003) and Morris (2006) contended that the SBE was found in the post-target region (in both conditions) and total viewing time provided evidence of additional processing load, which was

different from the situation of only low-frequency meaning activation, suggesting that other factor, such as, the activation of the dominant meaning could be the result of the SBE. In addition, the reason of the reverse SBE (A < LF) found in Sereno et al. (2006) remained unclear. But, it was likely that the reverse SBE was influenced by word frequency effect because the form frequency of ambiguous words is higher than that of LF unambiguous words.

2.2.2 The fate of unselected meaning

A substantial body of research has been done to account for the subordinate bias effect. However, there is no general consensus on whether the dominant meaning is activated or not, which plays a key role to resolve the dispute in two possible accounts of the SBE. Reordered and selective access models have dealt with the change in the state of the unselected meanings differently. According to the reordered access model, the activations of unselected meanings are both unaffected by the context and passively decay since multiple meanings associated with a single form are activated independently. (Rayner, Binder, & Duffy, 1999). Thus, in subordinate-biased context, the subordinate meaning was facilitated, while the dominant meaning was unaffected by contextual influence. On the other hand, based on the selective access model, subordinate-biased context would serve to facilitate activation of the subordinate

meaning without accessing the dominant meaning. To observe the dynamic changes of meaning activation, an on-line task with visual world paradigm can provide the temporal information during the comprehension of the auditory sentential contexts.

2.2.3 Visual world paradigm

Recently, eye tracking has been used in a *visual world paradigm*, which allows continuous sampling of visual fixations and provided specific time course of spoken word recognition. The most important assumption of the visual world paradigm involves the nature of the *linking hypothesis*, which specifies the connection between language comprehension and visual processing. The processing of different levels of linguistic representations (i.e. phonological and semantic representation) has been examined with a looking-during-listening task in the visual-world paradigm. A visual display consisted of four objects or printed words, typically containing a target, a competitor (i.e. linguistically-related to the target word) and two unrelated distractors. As participants listened to continuous speech, the visual display was shown on the screen. Participants were instructed to click on a named object or a named word. The experimental procedure and the visual displays from Mcqueen and Viebahn (2007) are shown in Figure 1. Figure 2 presents the time-course graph that illustrated the *fixation proportions*. The *y*-axis represents the fixation proportion of each word types

in a given time window. And the *x*-axis showed time in milliseconds from the acoustic target-word onset, for 1 second period. The result showed that there were more looks to phonological competitors than to distractors starting in 600-700.

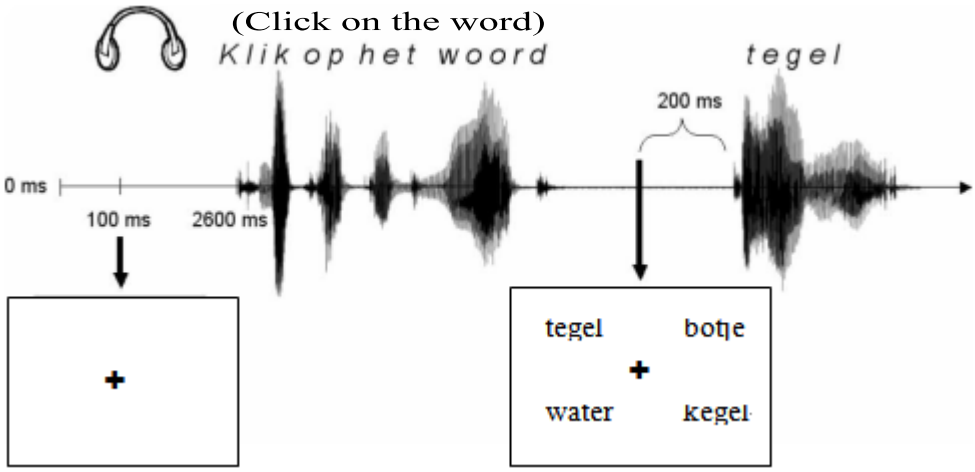

Figure 1. Experimental procedure and examples of a visual stimulus used in Mcqueen and Viebahn (2007). The display contained words: *tegel* (the target), *kegel* (the phonological competitor), *water* and *botje* (the unrelated distractors).

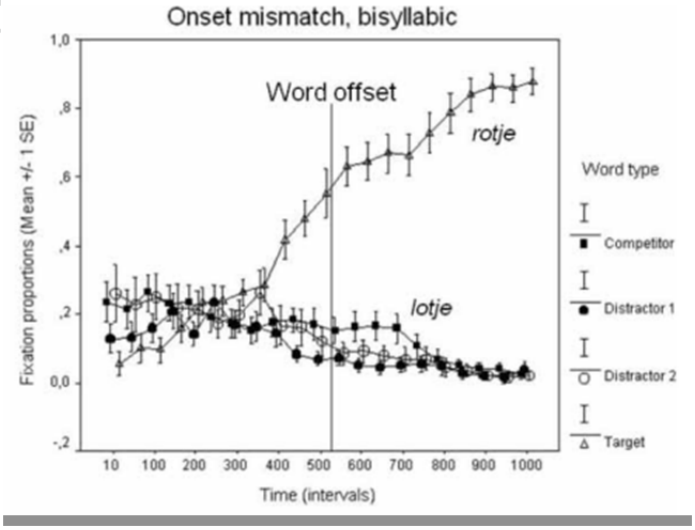

Figure 2. Mean proportion of fixations to printed-word targets, competitors, and distractors. The competitor in this condition was mismatched with target in its onset phoneme.

Dahan, Magnuson, and Tanenhaus (2001) presented a referent picture of either low-frequency or high-frequency name (e.g., *bed* or *bell*) along with three phonologically unrelated pictures on a computer monitor. The instruction contained two parts. First, participants were instructed to point to one of the distractor pictures using computer mouse (e.g., “Point to the sock”) and after a delay of 300 ms, they heard one of the referent names (*bed* or *bell*) and were asked to point to the target picture (e.g., “now the bed”).Then, they were asked to move it to the designated place (e.g., “Click on it and put it above the circle”). The results showed that at 400 ms after the target onset, fixation proportions to referent pictures with high-frequency names (e.g., *bed*) surpassed those to the low-frequency names (e.g., *bell*), indicating that word frequency effects on spoken word recognition emerged early and gradually.

Falk Huettig and McQueen (2007) examined the time course of retrieval of linguistic and perceptual knowledge by using both picture and printed words. Participants were told that as they listened to the sentences, they could look freely at the visual stimuli presented on the display, which contained phonological, semantic, and shape competitors. When the visual display was picture, fixation to phonological competitor preceded those to semantic, and shape competitors. Nevertheless, only

phonological competitors were fixated preferentially as displays contained the printed words. It indicates that pictures are more sensitive to semantic activation than printed words. However, F. Huettig and McQueen (2011) showed that participants did retrieve semantic information quickly in the mapping process and shifted overt attention to semantic competitors when there was no phonologically-matched printed word in the visual display. Therefore, they concluded that language-mediated eye-movement was determined partly by the nature of information in the visual display.

The issues of lexical ambiguity resolution have been conducted with visual world paradigm to explore the time course of semantic ambiguity resolution (L. Chen & Boland, 2008; F. Huettig & Altmann, 2004, 2007). In most of the studies, participants were presented an array of pictures containing one dominant-meaning-related picture, one subordinate-meaning-related picture, and two unrelated pictures as controls. The dependent variable was the fixation probability on a given picture. For example, F. Huettig and Altmann (2007) manipulated the context (neutral or subordinate-biased) preceding the ambiguous words (e.g., in subordinate-biased context: “First, the welder locked up carefully, but then he checked the *pen* and suspected that it was damaged.”). Participants viewed a visual array with four pictures of objects: the dominant referent (e.g., a writing pen), the

subordinate referent (e.g., an animal enclosure), and two unrelated distractors. The visual display was presented 1 second before the onset of the spoken sentence. The results showed that at the onset of the target word, there was a statistical difference in looks toward subordinate referent compared those toward the distracters. While, at the offset of the target word, there were more looks toward dominant referents relative to the unrelated distracters in the biasing condition. The effect of context was thus established when the subordinate pictures attracted more looks than the distractors. The results also implied that dominant referent eventually increased even the sentential context biased the subordinate meaning.

2.3 Chinese lexical ambiguity resolution

2.3.1 The linguistic characteristics of Chinese word

From the perspective of cross-linguistics, Chinese differs significantly from most Indo-European languages in its phonological, lexical, and syntactic structures. In particular, the unique property of Chinese lexicons provides key information for lexical and sentence processing. There are three types of homonymy, homophonic homographs (e.g. *bank* in English; *過節* in Chinese), heterophonic homographs (e.g.

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tear in English; *倒數* in Chinese), and homophones (e.g. *Beach-Beech* in English; *電源-店員* in Chinese). By definition, homophonic homographs are words with the same form and sound but differ in meanings. Heterophonic homographs are words with the same form but have different sounds (tone) and meanings. Homophones are words that sound the same while differ in forms and meanings. In Chinese, homophones (both monosyllabic and disyllabic ones) are the most frequent type. From the Modern Chinese Dictionary (Institute of Linguistics, 1985), 80 percent of the monosyllables in Chinese correspond to more than one meaning, and 55 percent correspond to five or more homophones(see Zhang, Wu, & Yip, 2006 for a review). The ambiguity resolution of homophones may differ from the homophonic homographs at the several level of linguistic processing. From the perspective of spoken word recognition, multiple meanings of homophones tend to be ambiguous at phonological level and require orthographic information to settle on form-meaning mapping. On the contrary, in the visual word recognition, homophonic homographs are ambiguous at the semantic level which depends heavily on the contextual information to resolve the ambiguity. Hue, Chen, Chang, and Sung (1996) reported that the proportion of homographs in Chinese was about 11%. They also found that most homographs contained one basic compositional meaning, and extended the other idiomatic meaning. Both meanings were essentially unrelated, such as “黃牛” which

the compositional meaning was a kind of bull, while its idiomatic meaning was a person who scalps. The present study focused on Chinese homophonic homographs.

2.3.2 Studies of lexical ambiguity resolution in Chinese

Both homophones and homographs have been investigated by studies using cross-modal priming. Li et al. (2002) investigated Chinese biased homophones following by two different contexts which were biased for either dominant or subordinate meaning. They found only the dominant meaning of homophone elicited priming effects when the dominant-related visual probe occurred 150 ms before the acoustic offset, but both meanings elicited priming effects when the visual probe occurred at the acoustic offset. The findings is compatible with the reordered access model, indicating that dominant meaning is activated early, and context takes precedence over frequency at the later stage. Moreover, Ahrens (2001) embedded balanced ambiguous verbs in subordinate biased contexts and the data showed that there was a significant priming for the primary- and secondary-related probes compared to their respective controls at the acoustic onset of ambiguous words. And both experimental groups were facilitated (reaction times: related probes < control probes). The author concluded that both meanings are activated even when the context biased for secondary meaning. Therefore, it supported modular access

hypothesis. However, the relative meaning dominance was not supposed to have any effect since the balanced ambiguous words were used. One possibility is that the experimental materials intermixed homonymy with polysemy. The related senses contributed to the facilitation of the contextually inappropriate meaning. Chen (2009) discriminated the biased monosyllabic homonymy and polysemy and incorporated both in the context that biased for the dominant meaning. The results indicated that only the dominant meaning of a homonymous word was activated, instead, both meanings of a polysemous word were activated. The author argued that the processing of homonymy was compatible with selective access model; in contrast, the processing of polysemy was compatible with modular access model. It seems that meaning dominance may not influence the processing of related senses. However, the subordinate-biased contexts are crucial to differentiate the two processing models. Previous studies of Chinese lexical ambiguity resolution are summarized in Table 4.

Table 4. Chinese studies of lexical ambiguity resolution

Factors / Studies	Ambiguity type	Meaning dominance	Experimental paradigm	Supporting models
Ahrens (2001)	Disyllabic homograph and polysemy	Balanced	Cross-modal priming	Modular
Li et al. (2002)	Disyllabic homophone	Biased	Cross-modal priming	Interactive (reordered model)
Chen (2009)	Monosyllabic Homonymy and polysemy	Biased	Cross-modal priming	Homonymy-selective Polysemy-modular

Researchers have investigated lexical ambiguity resolution of Chinese in cross-modal priming experiments. However, the studies of lexical ambiguity resolution showed inconsistent results and different theoretical hypotheses were supported. It is obvious that context has an influence on word processing, however, we are still far from reaching consensus on the processing mechanisms. Furthermore, a comprehensive understanding of lexical ambiguity resolution in Chinese is not yet available in the natural situation of sentence reading. The goal of the present study is to examine the role of contextual information in the processing of Chinese two-character homographs and to explore the dynamics of semantic activation and integration. Experiment 1 is analogous to that in Sereno, et al. (2006), manipulating three word types, low-frequency ambiguous word(A), low-frequency unambiguous word (LF), and high-frequency unambiguous word (HF). .LF unambiguous controls are matched to the form frequency of the homographs. Chinese homographs are inherently low-frequency words, therefore, the frequency was close in terms of word form and meaning, Experiment 1 aims to revisit the subordinate bias effect and to test which theoretical account that is more consistent with the empirical data in the course of reading for comprehension. Experiment 2 is designed with the purpose to obtain a clear time course of contextual influence and the activation of word meanings, in

particular, to examine the status of the dominant meaning that underlies the SBE when the subordinate-biased context is given.

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Chapter 3

Norming studies of word semantic and contextual constraint

Prior to the eye-tracking experiments, the biased homographs, unambiguous words, and these words' contextual constraints were determined by several norming studies. Four norming tasks of subjective rating were conducted to measure word's meaning preference, meaning relativeness, contextual predictability, and context biasing. First, in the interpretation preference task, word's meaning dominance was determined by the proportion of the participants' first interpretation response. The results were used to select the biased homograph and unambiguous control words for experiments. Second, a meaning relatedness task was conducted to make sure that the selected ambiguous words were homographs with two unrelated meanings. Third, a cloze task was conducted to ensure the targets' predictability values from the leading context were below .5. The last norming task was to determine that the context before target was biased for the subordinate meaning.

3.1 Norming study one: Interpretation Preference Task

This task was designed to determine the dominant and subordinate meanings of Chinese biased homographs.

3.1.1 Participants

Forty undergraduate and graduate students (8 males and 32 females) aged between 18-28 years old (mean age = 21.2) were paid to participate in the interpretation preference task. All of them were native speakers of Mandarin Chinese.

3.1.2 Materials

Fifty-eight disyllabic ambiguous words were selected from *現代漢語多義詞詞典*(袁暉, 2001) and *free association norm of common ambiguous word* (Hue et al., 1996). The meanings of these ambiguous words share either the noun category or verb category (26 NN and 32 VV ambiguous words). Fifty-eight HF and LF unambiguous control words were selected respectively from *Academia Sinica balanced corpus*. Ambiguous and unambiguous words were mixed and divided into two lists, each containing twenty-nine ambiguous words, twenty-nine unambiguous HF words, and twenty-nine unambiguous LF words. All the words were presented in a randomized order in each list.

3.1.3 Procedure

The participants were instructed to read the target word for the meaning that firstly came to mind and then were asked to make use of each target to generate a

comprehensive sentence. Specifically, the sentence should contain a preceding disambiguating or supporting context which clearly indicated the specific meaning of the target word. For example,“我聽到了風聲” was an ambiguous sentence, because the preceding context cannot disambiguate the ambiguous word “風聲”. Three examples were given before the task began. The entire questionnaire took about one hour to complete. The meaning preferences of the sentences were used to confirm the word types, namely, ambiguous and unambiguous words, and to determine the relative meaning frequency of ambiguous words.

3.1.4 Results

We classified participants' meaning preference of targets on the basis of dictionary definition in Chinese Wordnet (CWN) (Academia Sinica, 2008) and MOE Revised Chinese Dictionary (教育部國語推行委員會, 1998[2007]). Each ambiguous word were generated at least two difference interpretations. In addition, the corresponding HF and LF control words were all given only one interpretation. The biased ambiguous words were chosen when at least 70% of the subjects gave the same meaning preference. On this basis, forty-six biased ambiguous words met the proportion of meaning dominance for having a dominant meaning, with a mean bias of 90% (range: 80%-100%) and 10% (range: 0%-20%) for the subordinate meaning.

3.2 Norming study two : Meaning Relatedness Task

The task adopted the rating procedure in Rodd et al. (2002) to ensure that the selected ambiguous words were homographs with two unrelated meanings.

3.2.1 Participants

Twenty undergraduate and graduate students (6 males and 14 females) aged between 18-30 years old (mean age = 21.7) were paid to participate in the meaning relatedness task. All of them were native speakers of Mandarin Chinese. None of them had participated in the prior norming study.

3.2.2 Materials

Forty-six biased ambiguous words from the norming study one were used to construct two short sentences. One sentence conformed to the dominant meaning and the other to the subordinate meaning. Therefore, the whole questionnaire consisted of ambiguous words, sentences and together with short definitions of their two meanings.

3.2.3 Procedure

Four lists were created with randomized order and each list was read by five

participants. Participants were given each ambiguous word with short definitions of its two meanings. They were asked to read the meaning definition and sentence first, and then were instructed to rate how related they thought the two meanings described by the sentences were on a 7-point scale (1=not related, 7=much related). Two practices were given before the task began. The entire questionnaire took about 20 minutes to complete. Examples of the questionnaire were provided in Appendix A.

3.2.4 Results

The average relatedness between two meanings of a biased homograph was 2.19. Twenty-four ambiguous words that had a mean relatedness rating of 1.73 (range = 1.1-2.75) were retained as the homographs with two distinct meanings for the experiments.

3.3 Norming study three : Cloze Task

Contextual constrains which have typically been recognized as predictability of a word from preceding contextual information. Empirical evidence has shown that predictability tends to affect both the location and duration of fixation (K.S. Binder, Pollatsek, & Rayner, 1999), which are considered as the two main components in

readers' eye movements . Predictability rating is usually conducted via a cloze task to control the predictability scores for homographs, HF and LF control words. For instance, in a cloze task, raters wrote down a word to complete sentence fragments.

This task was conducted to ensure that the preceding sentential context was equally unpredictable to the succeeding target word.

3.3.1 Participants

Forty undergraduate and graduate students (10 males and 30 females) aged between 18-32 years old (mean age = 24.6) were paid to participate in the cloze task. All of them were native speakers of Mandarin Chinese. None of them had participated in any of prior norming studies.

3.3.2 Materials

For seventy-two target words, we constructed the preceding and succeeding disambiguating context biased for the subordinate interpretation of each homograph, and the sentential context for each unambiguous word. The questionnaire contained seventy-two sentence fragments preceding the targets.

3.3.3 Procedure

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There were four lists and the order of sentence fragments in each list was randomized. Participants were presented with the sentence fragments and were asked to write down the next potential word, which came to mind firstly to continue the sentences fragments. Instruction and four practices were given to make sure they know clearly about the whole procedure. The entire questionnaire took about 30 minutes to complete.

3.3.4 Results

The predictability values for target words were determined by the proportion of how many the exact targets were filled in across 20 participants. The predictability values corresponding to homographs, LF words, and HF words were 2.08%, 3.12%, and 4.20% ($F < 1$). Since participants used words with very similar meaning, the contexts were not predictive but were considered to be supportive for the targets. For instance, the target word “風聲” was generated only by 3 participants when the preceding context was “由於颱風肆虐，外頭傳來猛烈____”. The responses given by other participants (e.g., *巨響*, *風吹*, *風雨*, *颶風*, etc.) were semantically congruent with the preceding context.

3.4 Norming study four : Contextual Bias Task

The task was conducted to ensure that 75% or more of native speakers agree that both the preceding and succeeding sentences were biased towards the postulated meaning. Tabossi et al. (1987) suggested that this level of context was considered "strongly biasing."

3.4.1 Participants

Ten undergraduate and graduate students (1 male and 9 females) aged between 20-27 years old (mean age = 21.9) were paid to participate in the contextual bias task. All of them were native speakers of Mandarin Chinese. None of them had participated in any of prior norming studies.

3.4.2 Materials

Twenty-four complete sentential fragments of homographs, determined in previous cloze task, were used in the questionnaire.

3.4.3 Procedure

Prior to the task, instructions, examples and practices were provided to make the participants familiar with the procedure. Initially, participants saw the preceding

context up to the highlighted homographs and then were asked to judge which meaning of the homographs the prior context supported. When the participant selected the appropriate meaning, the succeeding context was presented. They were asked to complete the judgment of the meaning again. Two practices were given before the task began. The entire questionnaire took about 15 minutes to complete. Examples of the questionnaire were provided in Appendix B.

3.4.4 Results

A contextual bias was established by how many participants selected the instantiated meaning in both preceding and succeeding context. The average contextual bias for subordinate meaning was .99, which indicated that 99% of native speakers agree on the intended meaning of the context, thus, the linguistic contexts were strongly biased.

3.4.5 Interim summary

Twenty-four experimental stimuli, including the targets and the sentential contexts respectively, were selected from subjective ratings and met the requirement of the research purpose. Table 5 summarizes and presents the number of participants the rating results in four norming studies. .

Table 5. The norming data summarized from four norming studies

Norming study	Participant	A(low frequency)	LF	HF
1.Interpretation preference	40	92.9% (dominant-biased) (range = 80%-100%)	100%	100%
2.Meaning relatedness	20	1.72 (range = 1.1-2.75)	– –	– –
3.Cloze task	40	0.02 (range = 0-0.25)	0.03 (range = 0-0.4)	0.04 (range = 0-0.5)
4.Contextual bias	10	99% (subordinate-biased)	– –	– –

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Chapter 4

Experiment One:
The interaction between meaning dominance and linguistic context

The aim of this thesis is threefold. First, we examine the interaction between meaning dominance and contextual information and revisit the subordinate bias effect in Chinese lexical ambiguity resolution. Second, it is without doubt that context facilitates meaning selection of a homograph, but how early could this contextual effect be observed. Finally, we attempt to differentiate the competition and frequency accounts of the subordinate bias effect and, more generally, distinguish between the reordered access and selective access models of lexical ambiguity resolution. The homographs used in this experiment were inherently low frequency in terms of word form and meaning. LF unambiguous control words were thus matched to the word form frequency of the homographs. We predicted that if the dominant meaning was activated, a typical SBE (A > LF) would be found in both the target and the post-target (next two characters of the target) regions, which was consistent with competition account. In contrast, if only the subordinate meaning was activated, the SBE would be eliminated (A = LF) and this supported the frequency account. In addition, HF control words were added to obtain a word frequency effect (e.g. LF > HF) which can provide alternative evidence to separate two accounts. If the results

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supported the competition account, the SBE would be similar to or higher than the observed word frequency effect in the unambiguous case (A-LF > LF-HF); otherwise, the word frequency effect would be higher than the SBE and this result accorded with the frequency account (A-LF < LF-HF).

4.1 Method

4.1.1 Participants

Thirty participants, including 24 females and 6 males were paid to participate in the experiment. Their mean age was 21.5 years old, ranging from 19 to 28 years old. All participants had normal or correct-to-normal vision and were native speakers of Mandarin Chinese. None of them took part in the previous norming studies.

4.1.2 Materials and Design

There were three types of words in the experiment, LF homograph, LF control, and HF control. Twenty-four biased homographs were used in the present experiment, with a mean bias to dominant meaning for 92% and to subordinate meaning for 7%. The average word-form frequency obtained from the *Academic Sinica Balanced*

Corpus (ASBC, 2004), was 6.03 per million for homographs, 7.48per million for LF words, and 188.77 per million for HF words. Targets were all disyllabic words; in addition, they share the same syntactic category (NN or VV). Each homograph and LF and HF controls matched in word stroke and the neighborhood size of first constituent character (NS1) and syntactic category. The average word stroke for homograph, LF and HF was 19.92, 20.17, and 20.33 and the average NS1 was 40.92, 40.67 and 37. The result of one way analysis of variance on word-form frequency showed a significant main effect across LF and HF conditions [F (2, 69) > 1, p =.00] and no significant difference between A and LF [F < 1]. The ANOVA on word stroke or on NS1 revealed that there were no significant differences across three conditions [F < 1]. The means of word properties and example sentences are presented in Table 6.

Homographs were embedded in sentences in which preceding and succeeding context were semantically consistent with the subordinate interpretation. Targets were located on the range between the 14th to 16th characters of a sentence; the whole sentence contained 25 to 27 characters. The entire experiment consisted of 104 sentences in total, including 72 experimental sentences, 24 filler sentences and 8 practices. The filler sentences and practice trials were not included for analysis. The experimental and filler sentences were mixed and randomly distributed into three lists.

In each of the lists, the number of each condition was equal, namely, 8 items in each condition. Each sentence spanned one line and was presented in the middle of the PC screen. A participant saw each item only once, and about one-third of the trials were followed by the untimed true-or-false questions, which were designed to ensure that participants read for comprehension. There were four blocks of 24 trials, with block order counterbalanced across subjects, for a total of 96 trials. The experimental sentences are listed in Appendix C.

Table 6. Means of word frequency, strokes, and neighborhood size of first constituent character for the target words on each condition and example of materials used in each condition

Condition	Means of Frequency	Means of Strokes	Means of NS1	Example Sentences
A	6.03	19.92	40.92	百年餅舖保留傳統原味並堅持絕無***分號***希望穩定產品的品質。
LF	7.48	20.17	40.67	生物學家貢獻一生的心力在探索***雨林***中多樣且豐富的物種。
HF	188.77	20.33	37.00	電影上映前的廣告行銷策略不僅***達到***宣傳目的更拉高了買氣。

Note. A= ambiguous words; LF = low-frequency controls; HF = high-frequency controls; Means of Frequency = per million words; the targets were presented with bolds and italics in the example sentences.

4.1.3 Apparatus

Eye movements were recorded with an SR Research EyeLink 1000 Desktop

Mount eye tracking system. Viewing was binocular, and eye movements were recorded from the dominant eye. The eye tracker sampled gaze position every millisecond. Each sentence was presented in black on a grey background and displayed on a single line with up to 27 characters per line. The presentation of character size was 34x34 pixels. Participants were seated 70 cm away from the eyes to the screen, and the width of one character with the space before it equated about one degree of visual angle.

4.1.4 Procedure

When participants arrived for the experiment, they were given a consent form and tested for their dominant eye. Participants were tested individually in a dimly lit and noise-attenuated room. They seated in front of the monitor with their heads in a forehead and chin rest to eliminate head movement during the experiment. At the beginning, the instruction was given to the participants to read the sentences for comprehension without memorizing them on purpose. The five-point or three-point calibration and validation were performed in the first trial of each block (four blocks in total). After the calibration was checked, participants were asked to fixate on a cross, where located at the position of the first character of the sentence. Once they had accurately fixated on the assigned area, the cross disappeared and the sentence

was presented subsequently. Prior to reading experimental sentences, eight practice sentences were presented to participants in order to be familiar with the experimental procedure. Then they read 72 experimental and 24 filler sentences intermixed randomly. When the participants finished reading each sentence, they had to first fixate the right most cross located below the last character of the sentence. Then, they pressed a button on the response box and the next trial began. A comprehension question was asked approximately a third of the trials. Participants answered the true-and-false questions about sentences meaning by pressing either the left button 'yes' (*是 shi*) or the right button 'no' (*否 fou*). Feedback was given after they pressed the response key. The average accuracy rate was 94%. The experimental procedure is summarized in Figure 3.

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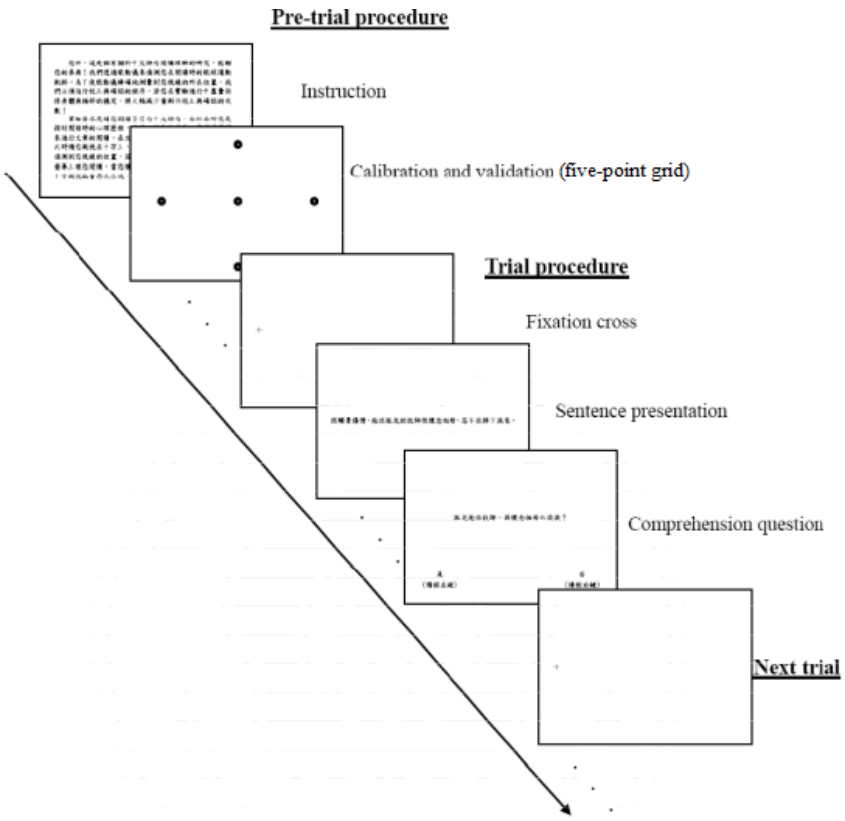

Figure 3. A diagram for the procedure of Experiment 1

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4.2 Data Analysis

Fixation duration and probability measures on three regions of interest (ROIs), target word, pre-target region, and post-target region, were analyzed. The pre-target region was two characters before the ambiguous word or control word; while the post-target region was two characters after the target word. Measures of first-pass time generally reflect word recognition process, while second-pass time measures or

post-target entail the time of semantic and syntactic integration. The first-pass and second-pass eye movement measures for the analyses are listed in (1) and (2).

(1) First-pass duration and probability:

a. *First fixation duration (FFD)*: the duration of the first forward fixation in the ROI.

b. *Single fixation duration (SFD)*: the duration of only one first-pass fixation within the ROI.

c. *Gaze duration (GD)*: the sum of all the first-pass fixations before moving out the ROI.

d. *Skipping rate (Skip)*: the probability of skipping the ROI in the first-pass reading.

e. *Refixation rate (RFR)*: the probability of refixating the ROI during the first-pass gaze.

(2) Second-pass duration and probability:

a. *Total viewing time (TVT)*: the sum duration of all fixations in the ROI, regardless of the forward or backward eye movements.

b. *Go-past time (GPT)*: the sum duration of all the fixations from the first fixation within the ROI before the fixation moving out to the right of the ROI.

c. *Rereading rate (RRR)*: the probability of returning to the ROI after the first-pass reading.

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The data of 7 participants, whose skipping rate of target words (A, LF and HF) higher than 40%, were dropped and replaced with new qualified data. The average skipping rate for the targets was 0.25. Data were excluded from the analyses for the following reasons: (a) there was a blink on the target or prior to target, (b) fixations were out of the ROI range, (c) the fixation was in the beginning or the end of each trial, (d) the first fixation on the target was longer than 800 milliseconds (msec) or shorter than 80 msec and (e) total viewing time on the target was more than 1500 msec or less than 80 msec. Overall, less than 1 percent of trials were removed. In the present study, the eye-movement data were analyzed using the linear mixed-effects (lme) model (Baayen, Davidson, & Bates, 2008). We evaluated the fixed effects of word ambiguity and word frequency while taking participants and items as crossed random effects by using the lmer program (lme 4 package; Bates, Maechler, & Mächler, 2009) in R 2.10.1 (R Development Core Team, 2009). For the lme models, we report regression coefficient (*b*s), standard errors (*SE*s) and t values estimated from priori contrast tests.

4.3 Results

4.3.1 Target word region

The means of first pass and second pass duration time and probability measures on the target word are shown in Table 7 There were totals of 1,553, 1,554, 1,370 and 1,661 observations available for FFD, GD, SFD and TVT analyses, respectively. No significant SBE was found in FFD or SFD (both t values < 1.5). There was a significant SBE (*b* = 0.08, *SE* = 0.03, *t* = 2.93*) in GD, with longer fixation time for ambiguous words than for LF control words, showing the SBE when the preceding context supported for the subordinate meaning. The SBE was also found in the second-pass measures: TVT (*b* = 0.17, *SE* = 0.05, *t* = 3.63*), RRT (*b* = 0.22, *SE* = 0.07, *t* = 2.93*), and GPT (*b* = 0.1, *SE* = 0.04, *t* = 2.82*). None of the duration measures showed the word frequency effect (all *t* values < 1.5).

For the probability measures, the average skipping rate for A, LF and HF was 0.23, 0.25, and 0.29 respectively. In general, the overall pattern of skipping rate in fact indicated the processing difficulty according to the characteristics of the word. Ambiguous words and LF unambiguous words were skipped lower than HF unambiguous words. For both A and LF, there were numerically lower than HF, but no statistically significant effect. Furthermore, the SBE was significant for both

refixation ($p < 0.01$**) and rereading rate ($p < 0.01$**). Readers refixated and reread A more frequently than LF after first encountering the ambiguous words. Greater refixation and rereading rates suggest that readers detected some difficulties for processing ambiguous words.

Table 7. Means and standard errors (in parentheses) of fixation durations and probability measures on three types of target words in Experiment 1

Duration measure(ms)	A	LF	HF	A-LF	LF-HF
FFD	265 (3.85)	255 (3.33)	260 (3.74)	10	-5
SFD	264 (4.37)	254 (3.57)	258 (3.89)	10	-4
GD	301 (5.58)	272 (4.33)	279 (4.88)	29*	-7
TVT	379 (9.28)	305 (6.13)	324 (7.32)	74*	-19
RRT	359 (19.97)	272 (14.87)	305 (14.55)	87*	-33
GPT	338 (7.93)	298 (6.56)	292 (6.2)	40*	6
Probability measure (%)	A	LF	HF	A-LF	LF-HF
Skip	0.23 (0.02)	0.25 (0.02)	0.29 (0.02)	-0.02	-0.04
Refix	0.17 (0.02)	0.10 (0.01)	0.08 (0.01)	0.07**	0.02
Reread	0.23 (0.02)	0.14 (0.01)	0.17 (0.01)	0.09**	-0.03

Note. A = ambiguous word; LF = low-frequency word; HF = high-frequency word FFD = first fixation duration; SFD =single fixation duration; GD = gaze duration; TVT = total viewing time; RRT = re-reading time; GPT = go past time; Skip = skipping rate; Refix = refixation rate; ReRead = rereading rate.

4.3.2 Pre-target and post-target region

Table 8 presents the means and standard errors of duration measures and probability measures in the pre-target region. There was no significant SBE in pre-target words for FFD, SFD, GD, TVT and GPT (all *t* values < 1.3). The only exception was a marginal effect in RRT (*t* = 1.84). No significant differences between HF and LF unambiguous words in the pre-target region. For probability measures, there was no significant SBE in refixation and rereading rate. But, the significant SBE was shown in skipping rate (*p* < .05*). No significant SBE and word frequency effect found in the first-pass duration measures in the pre-target region indicated that the pre-target words were basically identical across the three experimental conditions.

Table 8. Means and standard errors (in parentheses) of fixation durations and probability measures on three types of pre-target words in Experiment 1

Duration measure(ms)	A	LF	HF	A-LF	LF-HF
FFD	253 (3.39)	252 (3.77)	254 (4.29)	1	-2
SFD	248 (3.46)	249 (3.90)	251 (4.37)	-1	-2
GD	274 (5.05)	271 (5.17)	272 (5.27)	3	-1
TVT	329 (8.19)	302 (7.01)	314 (7.84)	27	-12
RRT	325 (17.17)	282 (15.57)	300 (13.56)	43•	-18
GPT	297 (7.25)	288 (6.84)	304 (8.48)	9	-16
Probability measure (%)	A	LF	HF	A-LF	LF-HF
Skip	0.28 (0.02)	0.34 (0.02)	0.34 (0.02)	-0.06*	0
Refix	0.10(0.01)	0.09(0.01)	0.10(0.01)	0.01	-0.01
Reread	0.18 (0.01)	0.14 (0.01)	0.13 (0.01)	0.04	0.01

The means and standard errors of duration measures and probability measures in the post-target region are shown in Table 9. No significant SBE found in post-target words for FFD, SFD, GD, RRT and TVT (all t values < 1.7). However, there was a significant SBE in GPT (b = 0.12, SE = 0.05, t = 2.53*). No difference was found in FFD, GD, RRT, TVT and GPT between LF and HF words. A reverse frequency effect was found in SFD. For probability measures, there was no significant SBE and word frequency effect in skipping and refixation rate. However, there was a significant SBE in rereading rate ($p < 0.05$*). In sum, the spillover measure provided evidence of processing difficulty. The SBE found in post-target for GPT may indicate the co-activation of alternative meaning of the ambiguous words.

Table 9. Means and standard errors (in parentheses) of fixation durations and probability measures on the post-target words in Experiment 1

Duration measure(ms)	A	LF	HF	A-LF	LF-HF
FFD	260 (4.53)	250 (3.87)	258 (3.50)	10	-8
SFD	258 (4.73)	245 (3.85)	258 (3.71)	13	-13*
GD	282 (5.58)	263 (5.00)	277 (4.87)	19	-14
TVT	337 (8.39)	307 (7.55)	326 (7.86)	30	-19
RRT	304 (14.96)	306 (16.52)	320 (16.24)	-2	-14
GPT	344 (10.42)	291 (7.11)	315 (8.31)	53*	-24
Probability measure (%)	A	LF	HF	A-LF	LF-HF
Skip	0.33 (0.02)	0.35 (0.02)	0.33 (0.02)	-0.02	0.02
Refix	0.11 (0.01)	0.08 (0.01)	0.08 (0.01)	0.03	0
Reread	0.20 (0.02)	0.13 (0.01)	0.18 (0.01)	0.07*	0.05

4.4 Discussion

Experiment one demonstrated the significant subordinate bias effect (A > LF) of Chinese homographs in sentence reading. It is obviously that the temporal locus of contextual influence on meaning activation occurred relatively early since the SBE was found in the first-pass duration. In agreement with Sereno et al. (2006), the SBE were evident in GD, TVT, RRT and GPT. However, the FFD and SFD failed to show the SBE in the present experiment. It is likely that the dominant meaning is not immediately activated but gradually activated while the context activates the context-favored meaning. The findings that most homographs received longer fixation times in gaze duration and total viewing time than LF words conform to our previous prediction of the competition account. However, the word frequency effect was not obtained here. One possible reason may be that HF did not fit into the passage as well as their LF counterparts. The norming study should be conducted in order to ensure that there are systematic plausibility differences across conditions.

Furthermore, in the post-target region, SBE was found significantly in GPT. Sereno et al.(1992) also reported longer fixations in spillover measures. The spillover effect indicated that the ambiguity resolution was lagged to the next region and additional time was needed, presumably due to the co-activation of the dominant meaning (Sereno et al. 2003). The results showed higher rereading rate of ambiguous

words than LF words, which may reveal that readers revise their interpretation to be integrated into the ongoing context. In general, the results have demonstrated that readers access multiple meanings, and the activation is influenced by meaning dominance of an ambiguous word and the context in which it occurs. In sum, the converging evidence of the SBE at both target and post-target lend some credence to the account that the SBE is the result of competition and thus more consistent with the reordered access model than the selective access model. The SBE extended to the post-target indicated that the lexical ambiguity may not be resolved completely at the target word region and the dominant meaning could be activated continually to the post-target region.

Sereno et al. (2006) found a reverse SBE for ambiguous versus meaning-matched LF controls (A < LF), which was not observed in the present experiment. The reverse SBE could be in fact a combination of SBE and frequency effect, thus it is likely that ambiguous word was facilitated due to high frequency in terms of its word form. In our manipulation, homographs are low-frequency words in Chinese both in terms of its word form and meaning, thus, it is well suited to be used to distinguish the competition and frequency accounts. Taken together with the broader literature, we may conclude that the subordinate bias effect is a well-established phenomenon under two conditions: (1) the homograph is polarized,

with subordinate meanings retrieved about 20% of the time. (2) The appropriate control word which is used to compare with fixation times for a homograph is likely to be matched to the homograph's form frequency.

It is of theoretical importance to find out whether the top-down contextual information can influence the activation of the context-inappropriate meaning. Reordered access model would predict that the dominant meaning of the ambiguous words was impervious to contextual influences while the selective access model assumed the access process was decidedly context dependent; therefore, only the contextually-appropriate meaning can be accessed.. Furthermore, although the empirical data tends to support the reordered access model, the fate of the dominant meaning and timing of dominant meaning activation deserve our attention to explore further into details of lexical ambiguity resolution. In Experiment 2, we used a visual world paradigm to examine the time course of semantic activation during semantic ambiguity resolution. More intriguing, this paradigm can reveal the underlying activation of the 'unselected' semantic representation over time.

Chapter 5

Experiment Two:
The time course of lexical ambiguity resolution

In Experiment 2, we utilize visual world paradigm to examine the time course of lexical ambiguity resolution. This paradigm can reveal the activation of context-unselected meaning over time given the context constraining for subordinate meaning. In the present experiment, two experimental conditions were manipulated to investigate whether the dominant meaning of a homograph attracted more fixations than the unrelated words when the context favored the subordinate meaning of it. There were two types of spoken targets: homograph (ambiguous word) and monograph (unambiguous word). For spoken targets, semantic associative words of their meaning were selected to serve as semantic competitors. The monograph condition severed as a baseline for the semantic competition effects in the homograph targets.

According to the reordered access model, the SBE has been taken as evidence that both dominant and subordinate meanings of ambiguous words are activated and compete for selection. In contrast, based on the selective access model, the supporting context activated only the context-selected meaning. Thus, if the access is selective, the existence of SBE reflects the processing difficulty to access the infrequent or

subordinate meaning. The reordered and selective access models have made different claims in regard to the status of the unselected meaning. The reordered access model claims that two meanings are activated simultaneously, which the contextual information speeds the activation of context-selected meaning but no effect on the activation of the unselected meaning. On the contrary, the selective access model claims that the rapid selection of the context-intended meaning suppress the unintended meaning.

We examine fixation proportions changing over time on two types of semantic competitors in the homograph condition. Therefore, specific predictions of the two models are made according to the effective time window after the ambiguous words unfold. First, in the early time window, both reordered and selective access models predict that the fixation proportions of subordinate-related associative words (SR) would be much higher than those to the dominant-related associative words (DR) or unrelated distractors (UR). However, in the later time window, only the reordered access model predicted that the activation of dominant meaning was impervious to the context, so the fixation proportions of the DR would be greater than those of the UR. Figure 4 diagrams the predictions of time course of semantic ambiguity resolution based on reordered access and selective access models.

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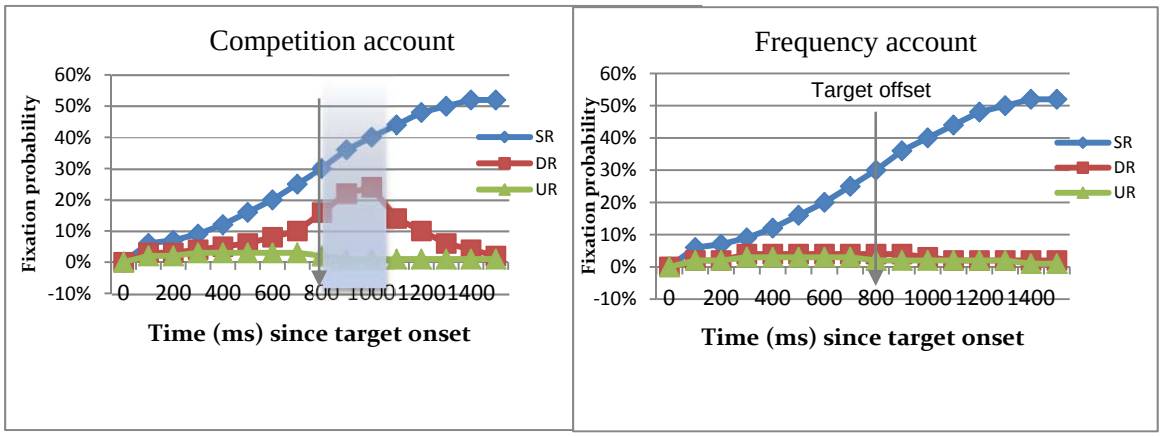

Figure 4. Predictions of reordered and selective access models for semantic ambiguity resolution

5.1 Method

5.1.1 Participants

Thirty-two participants, including 6 males and 26 females, were paid for their participation. Their mean age was 21.5 years old, ranging from 18 to 25 years old. All were native Mandarin Chinese speakers with normal or correct-to-normal vision.

5.1.2 Materials and Design

Twenty-four biased homographs and the sentences from Experiment one were used as auditory materials. Additional twenty-four monographs were selected,

embedded in the same location as homograph targets and semantic congruent with the sentential context. Some of the sentences from Experiment one were revised and their norming data were presented in subsection 5.1.3. Both spoken target words (homograph and monograph) were matched in word length, word frequency, word stroke, and neighborhood size of the first constituent character (NS1). The average word frequency for homograph and monograph was 6.03 and 5.8, the average word stroke was 19.92 and 20.92 and the average NS1 was 40.92 and 33.21. The results of paired *t* test showed that there were no significant difference between homograph and monograph for word frequency [$t(23) = .119$, $p = .906$], word stroke [$t(23) = -.882$, $p = .536$], and NS1 [$t(23) = 1.32$, $p = 0.201$]. The means of spoken targets and sentences used in this experiment are summarized in Table 10.

Quintuples of words were selected for 48 experimental trials (see Appendix D). The visual display containing four printed words was identical in both homograph and monograph conditions. Examples of visual stimuli were presented in Figure 5. For the homograph condition, each display consisted of two semantic competitors and two unrelated distractors. The meanings of two semantic competitors were related to the dominant and subordinate meaning (e.g., DR:*閒話* and SR:*易經*, respectively) for the spoken homograph target (e.g., *八卦*). For the monograph condition, there were three unrelated distractors and one competitor (e.g., MSR:*易經*) which was semantically

related to the spoken monograph target (e.g.,八(字).

Printed words were arranged in a diamond-shape on a grey background with a fixation cross in the center. The positions of the four words were at the top-center, left-middle, right-middle, and bottom-center locations of the screen. The printed words were presented vertically in Piao-Kai font. The horizontal distance between the centers of the words on the left and right was 4.9 cm and the vertical distance between the centers of the words on the upper and lower was 4.95 cm. Additional 24 sets of four words were selected for filler trials, all of which consisted of a fully matching word in the accompanying sentence, and the other three were unrelated.

For the auditory materials, the 48 experimental and 24 filler sentences were read aloud by a female native Chinese speaker at a normal speaking rate. The utterances were recorded in a sound-damped room, using the Praat software version 5.3.10 (Boersma & Weenink, 2009) with 44.1 kHz sampling rate and 16-bit resolution. The speaker read the each sentence fluently without the hesitation and pauses in a neutral intonation. The target word occurred on average 5 seconds after the onset of the spoken sentence and the average duration of the spoken target word was approximately 800 ms for the homograph and 770 ms for the monograph. The presentation of the stimuli were counterbalanced across subjects to ensure that all the sentences occurred only once in this experiment.

Table 10. Means of word frequency, strokes, and neighborhood size of first constituent character for the spoken target words in each experimental condition and example of materials used in each condition

Condition	Means of Frequency	Means of Strokes	Means of NS1	Example Sentences
Homograph	6.03	19.92	40.92	神祕的老者喜歡觀看天象並研究八***卦***所以很多人會找他算命。
Monograph	5.80	20.92	33.21	神祕的老者喜歡觀看天象並研究八***字***所以很多人會找他算命。

Note. Means of Frequency = per million words; the targets were presented with bolds and italics in the example sentences.

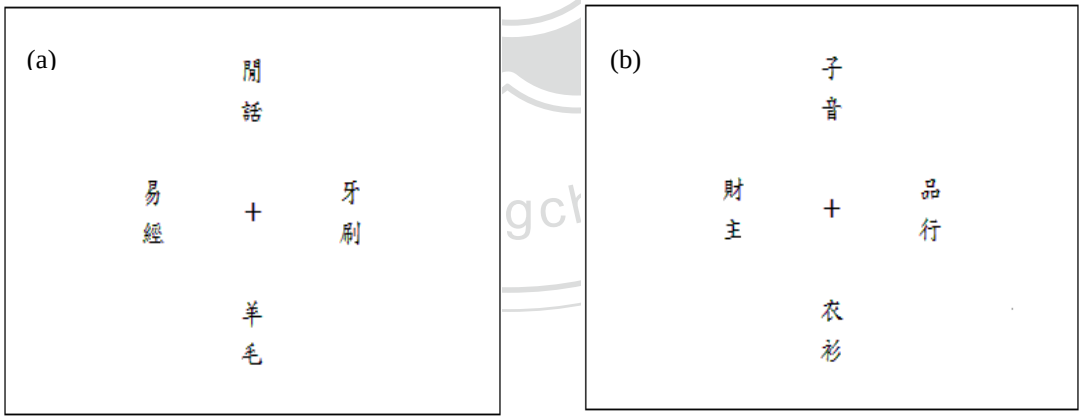

Figure. 5. Example of visual displays in Experiment 2: (a) in both the homograph and monograph trials, and the spoken targets are *八卦 and 八字*. (b) in filler trials, and the spoken target is *子音*.

5.1.3 Norming studies

Three norming studies were carried out for the stimuli in experiment two. The first norming was to ensure that the probability of words of the revised sentences met the criteria as in Experiment 1. In the second and third study, participants rated the plausibility of sentence context and the degree of semantic relatedness between the semantic associate we generated and each meaning of the homograph.

5.1.3.1 Norming study one: Cloze Task

Thirteen homograph-embedded sentences from Experiment one was revised and twenty participants were asked to write down the first word to continue the sentence (the procedure was identical to that in Experiment one). The averaging predictability value for the homographs was 0.03 (range = 0-0.2).

5.1.3.2 Norming study two: Plausibility Rating

To ensure that the sentences in both the homograph and monograph conditions were plausible to the same extent, a plausibility rating was conducted. Forty-eight sentences were intermixed and presented in a random order. Participants were instructed to assign a number from 1 (very implausible) to 7 (very plausible) based on how the event described in each sentence made sense to them. Twenty undergraduate

and graduate students (8 males, 12 females) participated in this norming survey. The average rating for homograph- and monograph-embedded sentences was 5.56 and 5.66 respectively. Paired *t* test showed that they did not differ significantly [$t(23) = -.628$, $p = .536$].

5.1.3.3 Norming study three: Semantic Relatedness Rating

This norming study is to assess semantic relatedness for spoken homograph target and its dominant- and subordinate-related associative words, and the unrelated words, also for monograph target and its semantic associative words.

Forty participants of undergraduate and graduate students took part in this norming study and they were in the age range of 18 to 26 years. They were given the definition of dominant or subordinate meaning and their semantic associative words and were asked to rate the definition–target pair on a 7-point scale ranging from 1(very unrelated) to 7 (very related). Ninety-six definition–target pairs were given to forty subjects in total. Materials were divided into two versions such that each subject saw an equal number of semantic related and unrelated words. Only semantic associative words that were considered highly-related (4-7 point at 7-point scale) were included in the main experiment. The unrelated words were excluded if the rating value was above 3. Twenty-seven items were dropped and replaced with new

qualified items. The dominant meaning–DR pairs received a mean rating of 5.75 and subordinate meaning–SR pairs received a mean rating of 5.27. In addition, the related meaning–MSR pairs had a mean rating of 5.16. Independent t-test was performed for dominant meaning–DR and subordinate meaning–SR, dominant-meaning–DR and related meaning–MSR. The results showed that DR and SR did not differ significantly [$t(46) = 1.691$, $p = .098$]. However, there was a marginal significance between DR and MSR [$t(46) = 1.965$, $p = .055$]. Paired t-test was performed for subordinate meaning–SR and related meaning–MSR. No significance was found [$t(23) = 0.419$, $p = 0.679$]. Furthermore, the semantic associative words with each meaning (e.g., dominant meaning-DR, subordinate meaning-SR and related meaning–MSR) were judged to be significantly semantically related to the target words than the other three stimuli (all $ps < .000$) and there was no difference among the other three. The results are summarized in Table 11.

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Table 11. Results of the semantic relatedness norming for Experiment 2. Mean (with standard deviations in parentheses) semantic relatedness between the target words and each type of printed word

Target word	Type of word in visual display			
	DR	SR	UR1	UR2
1. Homograph				
Dominant meaning	5.75 (1.00)	1.40 (0.41)	1.12 (0.16)	1.20 (0.33)
Subordinate meaning	1.56 (0.40)	5.27 (0.98)	1.17 (0.19)	1.20 (0.35)
2. Monograph	MSR	UR1	UR2	UR3
Related meaning	5.16 (1.07)	1.37 (0.39)	1.13 (0.15)	1.28 (0.40)

Note. DR= dominant-related associative words; SR= subordinate-related associative words; MSR= semantically-related associative words in monograph condition; UR= unrelated words

5.1.4 Procedure

Eye movements were monitored and measured with an SR Research EyeLink 1000 Desktop Mount eye tracker, sampling at 1000 Hz (the eye-movement recording procedure was identical to Experiment 1). The character size for visual display was 42x42 pixels. One character on the screen corresponded approximately to 3.4° of visual arc. Spoken sentences were presented to the participants through headphones. Prior to the experiment, the instruction and 6 practices were given. The structure of each trial was as follows (see Figure 6). First, a central fixation cross appeared on the screen as the auditory presentation of a sentence was initiated. Until 1200 ms before the acoustic onset of the target word, the cross disappeared and was replaced by a blank screen for 500 ms. Then, a cross appeared again for 500ms and subsequently

the display of four words appeared on the time 200 ms before the acoustic onset of the target word. The trial was terminated as the sentence utterance ended. Participants were instructed to listen to the sentence carefully and look whatever they want except taking their eyes off the screen throughout a trial. One-third of the trials were followed by true-and-false comprehension questions to ensure that they understand the sentences. The entire experiment lasted less than 35 minutes.

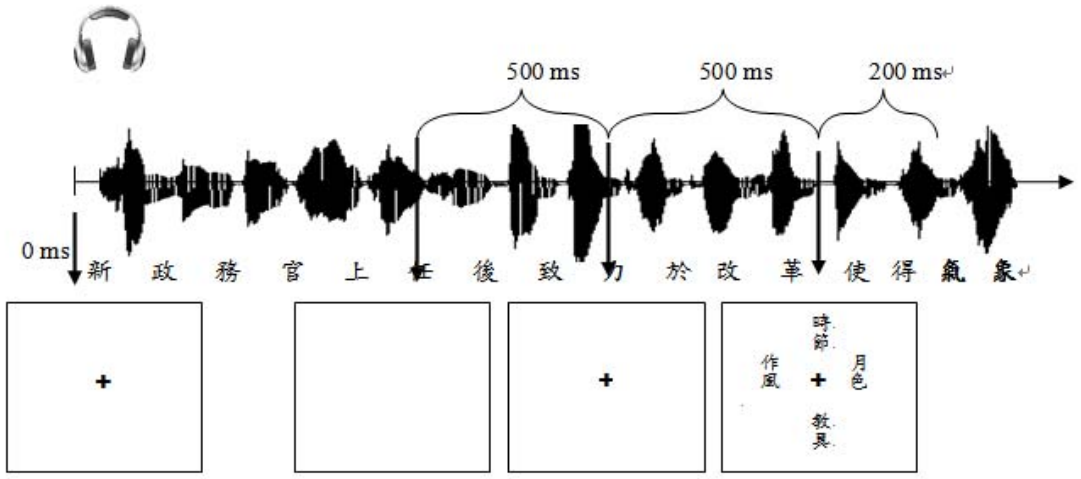

Figure 6. Experimental procedure of Experiment 2.

5.2 Results

The number of fixations on all types of the printed words was obtained every millisecond for the duration of 4000 msec. Fixation proportions were computed across trials. Fixation proportions of competitors represented the ratio between the number of fixations to a particular semantic competitor (DR, SR or MSR) and the sum of all fixations; in addition, fixation proportions of competitors represented the ratio between the average fixations of the distractors and the sum of all fixations Figure 7 plots the fixation proportions over time in all conditions. For the statistical analyses, we computed mean fixation proportions in 100-msec intervals. The means and standard errors of fixation proportions are shown in Table 12. The increase in looks to the printed target identical to the spoken target words in filler trials began less than 500 ms after target's acoustic onset and was earlier than SR and MSR in homograph and monograph conditions (Figure 8). We performed the analyses of variance (ANOVAs) by participants (F_1) and items (F_2) for each time period during 501-1300 ms (Table 13).

There were statistically significant differences among DR, SR, and UR both by participants and by items from 501 ms to 1300 ms. The statistical results were reported here, taking the 501-600 bin as an example. At 501 ms, $F_1(2, 62) = 5.50$, $p = .006$, $F_2(2, 46) = 4.59$, $p = .02$. The remaining results in different time bins can refer

to Table 13. At the acoustic offset of the initial character of target word (approximately 400 ms), the fixation proportions to SR in the homograph condition started to diverge. Starting at 501 ms, the subordinate-biased context increased looks to SR compared with unrelated distractors. This divergence was significant both by participants and by items [501 ms, z_1 = -3.088, p = .006, z_2 = -2.836, p = .01]. The large difference in fixating on the SR compared to that on the distractors continued at the later time points. It was assumed that any difference before the word was fully specified (i.e. acoustic offset of the target word) can be taken as the contextual influence. Fixation proportions to the DR did not differ significantly from those to the distracters from 501 ms to 900 ms by participants [all *ps* > 0.1] and 501 ms to 1000 ms by items [all *ps* > 0.1]. However, there were more fixations towards the DR, as compared with the distractors from 901 ms to 1300 ms, that was significant from 901 ms to 1300 ms [901 ms, z_1 = -3.13, p = .003] and marginal significant from 1001 ms to 1300 ms [1001 ms, z_1 = -2.375, p = .05].

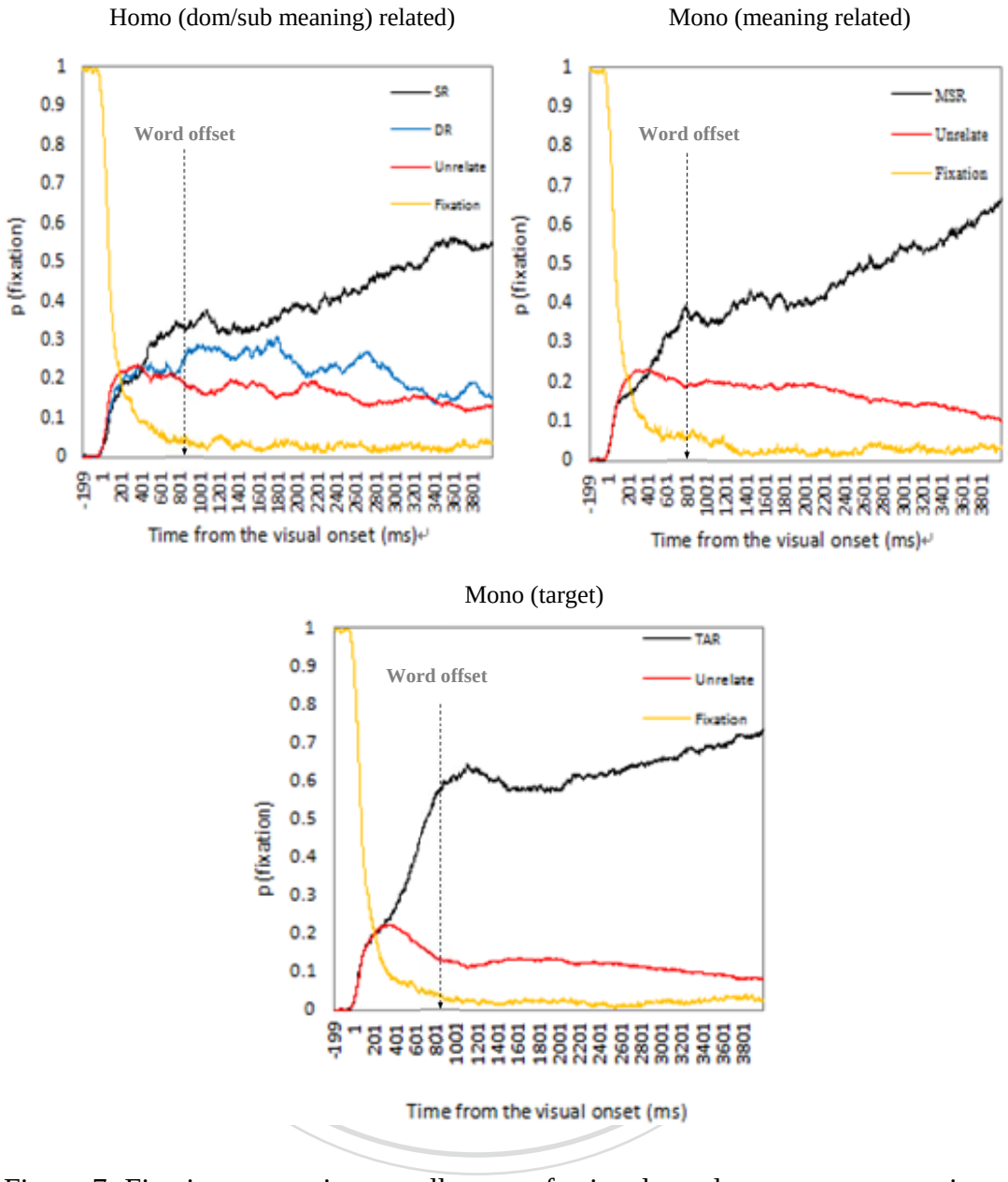

Figure 7. Fixation proportions to all types of printed words across two experimental conditions and one target (filler) condition in experiment 2. The x-axis shows time in milliseconds from the display onset, for 4000 ms

In the monograph condition, more fixations were directed to MSR compared to those to the unrelated distractors, starting at 501 ms, significant both by participants and by items [501 ms, z_1 = -2.671, p = .007, z_2 = -2.645, p = .008] and was maintained

at the later time points. This indicates that the strength of context for homograph and monograph is fairly consistent. In the filler condition, participants strongly shifted their eye gaze towards the matching printed words relative to the distractors at 401 ms, significant both by participants and by items [401 ms, z_1 =-4.714, p = .000, z_2 = -3.694, p = .000].

Table 12. Means and standard errors (in parentheses) of fixation proportions on three types of visual words in two experimental conditions from 1 ms to 1300 ms in Experiment 2

	Homograph			Monograph	
target onset	SR	DR	UR	MSR	UR
1-100	0.07(0.01)	0.09(0.02)	0.11(0.01)	0.10(0.02)	0.10(0.01)
101-200	0.15(0.02)	0.17(0.02)	0.19(0.01)	0.14(0.02)	0.18(0.01)
201-300	0.18(0.02)	0.19(0.02)	0.21(0.01)	0.17(0.02)	0.21(0.01)
301-400	0.20(0.01)	0.21(0.02)	0.22(0.01)	0.20(0.02)	0.22(0.01)
401-500	0.24(0.02)	0.22(0.02)	0.21(0.01)	0.22(0.02)	0.22(0.01)
501-600	0.29(0.02)	0.21(0.02)	0.20(0.01)	0.28(0.02)	0.21(0.01)
601-700	0.29(0.02)	0.21(0.01)	0.20(0.01)	0.31(0.02)	0.20(0.01)
701-800	0.31(0.02)	0.21(0.01)	0.20(0.01)	0.33(0.02)	0.19(0.01)
801-900	0.32(0.02)	0.23(0.02)	0.19(0.01)	0.35(0.02)	0.19(0.01)
901-1000	0.32(0.02)	0.26(0.02)	0.18(0.01)	0.36(0.02)	0.19(0.01)
1001-1100	0.35(0.02)	0.27(0.02)	0.16(0.01)	0.34(0.02)	0.19(0.01)
1101-1200	0.35(0.02)	0.26(0.02)	0.17(0.01)	0.35(0.03)	0.19(0.01)
1201-1300	0.31(0.02)	0.26(0.02)	0.17(0.01)	0.36(0.03)	0.19(0.01)

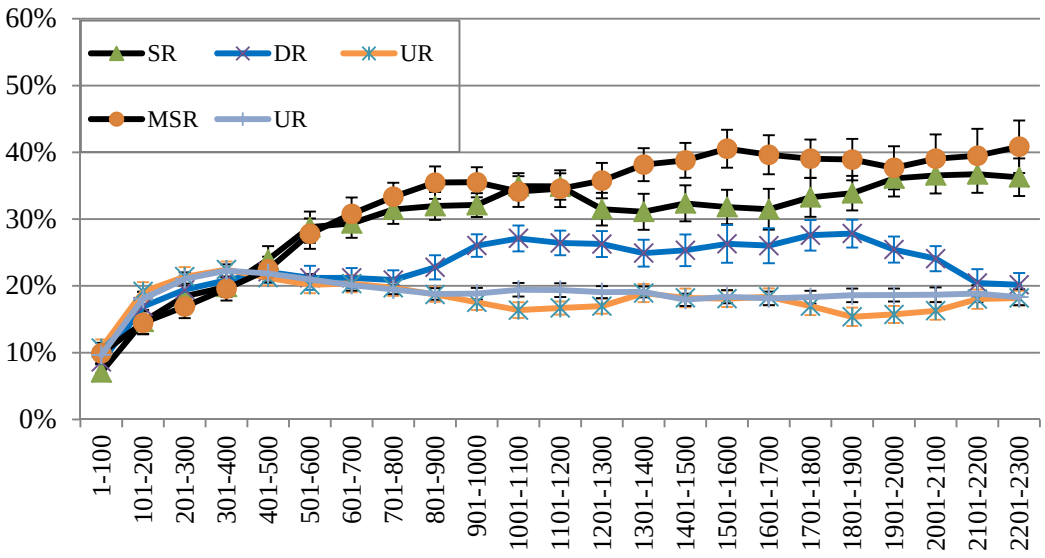

Figure 8. Time course of fixation proportions on different word types in two experimental conditions from 1 ms to 1300 ms

Table 13. Analyses of variance by participant and item comparing mean fixation proportions to competitors with those to the average of the distractors in 100-ms bins, from 501 ms to 1300 ms after acoustic target word onset in homograph condition in experiment 2

		Time bin							
Condition	*Test*	501-600	601-700	701-800	801-900	901-1000	1001-1100	1101-1200	1201-1300
Homograph, meaning related	F_1 (2, 62)	5.50	6.72	10.97	11.28	15.72	20.95	21.95	10.98
		p = .006	p = .002	p < .001	p < .001	p < .001	p < .001	p < .001	p < .001
	F_2 (2, 46)	4.59	4.26	5.86	5.53	5.89	8.13	7.90	5.56
		p = .02	p = .02	p = .005	p = .007	p = .005	p = .001	p = .001	p = .007
DR-SR	z_1	-2.712	-3.053	-3.895	-3.267	-2.361	-2.758	-3.127	-1.691
		p = .02	p = .007	p < .001	p = .003	p = .05	p = .02	p = .005	p = 0.27
	z_2	-2.49	-2.444	2.861	-2.299	-1.453	-1.727	-1.886	-1.21
		p = .04	p = .05	p = .01	p = .06	p = 0.4	p = 0.3	p = 0.2	p = 0.6
UR-SR	z_1	-3.088	-3.373	-4.316	-4.709	-5.67	-6.549	-6.726	-4.7
		p = .006	p = .002	p < .001	p < .001	p < .001	p < .001	p < .001	p < .001
	z_2	-2.836	-2.7	-3.17	-3.314	-3.49	-4.102	-4.057	-3.363
		p = .01	p = .02	p = .005	p = .003	p = .001	p < .001	p < .001	p = .002
UR-DR	z_1	-0.367	-0.319	-0.422	-1.442	-3.13	-3.791	-3.599	-3.009
		p = 1	p = 1	p = 1	p = .45	p = .003	p < .001	p < .001	p = .008
	z_2	-0.346	-0.256	-0.31	-1.015	-2.037	-2.375	-2.171	-2.153
		p = 1	p = 1	p = 1	p = 0.9	p = 0.1	p = .05	p = .09	p = .09

Note. F_1/z_1 = 32 participants. F_2/z_2 = 24 items.

5.3. Discussion

The key finding in Experiment 2 was that a greater fixation proportions were towards contextually appropriate semantic associates (SR) when participants heard the first character of ambiguous words. However, fixations on the contextually inappropriate semantic associative words (DR) increased as identifying information of lexical semantics was perceived. Table 14 summarizes the fixation proportions of competitors, filler-targets and distrators across three conditions. Statistically greater fixation proportions of SR and MSR comparing with their UR in homograph and monograph condition respectively were firstly found at the target offset, while a greater fixation proportions of DR comparing with UR was found at 200 ms after target offset. Contextual information influenced a relatively greater fixation proportions on the SR and MSR comparing with those on their respective distractors, starting from 500 ms after the target onset. This may suggest the successful manipulation of the contextual strength. Furthermore, the DR varied greatly as compared with the distractors from 901 ms to 1300 ms entailed that context influence emerged 400 ms earlier for contextually-selected semantic associative words than they did for the contextually-unselected semantic associative words. This is consistent with all accounts of the subordinate bias effect, which reflected the rapid use of context. The intriguing findings were that first, DR attracted more fixations than its

relative distractors even in the strongly subordinate-biased context. Second, the time course of the activation of dominant meaning revealed that the associated semantic representation of the context-unselected meaning was fairly weak since the context-selected meaning arrived early prior to the target-offset. Together, these finding showed the subordinate bias effect and thus supported the competition account and reordered access model, but it is not consistent with frequency account and selective access model.

Table 14. The average fixation proportions to each type of words at acoustic target offset and 200 ms after the target offset across three conditions in Experiment 2

Time Region (milliseconds)	Type of word		
	DR	SR	UR
1.homograph condition			
p(fix) at offset	0.21	0.31***	0.20
p(fix) at offset+200 ms	0.26***	0.32***	0.18
2.monograph condition	MSR	UR	
p(fix) at offset	0.34***	0.19	
p(fix) at offset+200 ms	0.35***	0.19	
3.target condition	TAR	UR	
p(fix) at offset	0.49***	0.15	
p(fix) at offset+200 ms	0.56***	0.11	

Note: Difference score to UR $p < .05$ for participants*
Difference score to UR $p < .01$ for participants **
Difference score to UR $p < .001$ for participants ***

The average utterance duration of target homographs was 800 ms, so the linguistic context began to affect looking to SR prior to homograph offset. It is likely that context influences reflect initial lexical access of spoken word before the information of whole word was available. In our experiment, the meaning relatedness of SR was not different from that of DR according to the rating results. Therefore, it is likely to rule out the possibility of any preference of looks towards either semantic associate. In the subordinate biasing context, subordinate meaning was activated earlier than dominant meaning before the ambiguous word was available. In subsequent, from 901 ms to 1300 ms, both meanings are activated in the same time window. At later time, the meaning was revised and selected in order to arrive at a coherent contextual interpretation. As for the status of the unselected meaning under the constraining context of subordinate meaning, we may also provide the temporal evidence of dominant meaning activation the time course from 901 ms to 1300 ms. It appears that the subordinate-biased context did not completely eliminate the dominant meaning, instead, it was activated independently and took its advantage gradually on the basis of lexical dominance, namely, the stronger strength of form and meaning mapping. In short, the dominant meaning was activated but was delayed because of the contextual biasing to the subordinated meaning. This evidence seems to rule out the selective access model, which posits the dominant meaning should not be

activated at all. On the contrary, our data tend to support the predictions of the fate of unselected meaning proposed by reordered access model. That is, even the strong subordinate biased context did not override the automatic activation of the dominant meaning. However, the fixation proportions to the dominant meaning are rather fewer than those to the subordinate meaning. It seems that we cannot completely rule out the possibility that the initial activation of the dominant meaning was modulated by the contextual information. It is likely that a strong subordinate biasing context may decrease activation of the dominant meaning.

Falk Huettig and McQueen (2007) have shown that semantic information was not retrieved when using printed words as visual stimuli. They suggested that because reading a word provided much more direct access to phonological knowledge. It was true for alphabetical languages and may be not the case for Chinese. We found fixation proportions towards the printed word fully matched with the spoken target diverged from those towards the unrelated distractors at 400 ms. The results were also similar to Mcqueen and Viebahn (2007) which found significant fixation proportions towards offset mismatched bisyllabic word at about 400 ms (corresponding to the onset of the final phoneme). The semantic information was retrieved at 500 ms in the present study, finding that phonological and semantic information are accessed at different time and play comparable roles during word recognition in Chinese.

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Chapter 6

General Discussion

6.1 Dynamic processing of context influence and meaning dominance

The results from the present two eye-tracking experiments demonstrate the interaction of contextual influence and lexical activation during lexical ambiguity resolution. In Experiment 1, the fixation times of homographs were compared to those of low frequency unambiguous words. Subordinate bias effect emerged consistently as the control used form-matched unambiguous word (Sereno et al., 1992). Sereno et al. (2006) found SBE was not attenuated even in a strongly biasing context. They suggested the reason may be due to the special situation that the word form of ambiguous word was a HF word but its functional link to context was subordinate in terms of meaning. However, the results from Experiment 1 indicated that SBE occurred as the homograph was an LF word both in terms of its word form and meaning.

Experiment 2 provides a comprehensive time course of lexical ambiguity resolution on spoken word recognition which reveals the temporal information of the contextual influence on lexical activations. When listeners are given sufficient contextual information, they produce a greater fixation proportions towards the contextually-selected semantic associative words. The consistent results were found in

both homograph and monograph conditions that context influences occur from about 500 ms, shortly after the acoustic onset of the target word. This may indicate that at an earlier stage, the context is acting on the access of the subordinate meaning of the homograph. We found the dominant meaning was activated from 901 ms to 1300 ms, approximately after the acoustic offset of the spoken target and before the completion of next word. The converging evidence from both visual and auditory presenting experiments shows the robust SBE and the activation of the dominant meaning.

We then compare our results with those in cross-modal priming studies to gauge the theoretical implications of temporal dynamics of lexical activation and contextual influence. Generally, two levels of semantic access are distinguished based on the results of lexical decision studies. Pre-lexical stage involves word recognition and meaning activation, while post-lexical stage deals with semantic selection and integration. Onifer and Swinney (1981) presented sentences that biased for the dominant or for the subordinate meaning of an ambiguous word. The results demonstrated the activation of multiple meanings irrespective of the context when presenting visual target word at the auditory offset of ambiguous words. According to the exhaustive or multiple access model, context can only penetrate lexical activation at post-lexical stage, but not at the earlier stage. It is likely that the frequency effect emerged after the multiple meanings associated with a word were accessed.

Seidenberg et al. (1982) delayed the presentation of visual target until 200 ms or more after the spoken homophone, by that time, demonstrating that a single meaning had been selected after initially activating multiple candidates. It is assumed to reflect post-lexical stage of using context to select an appropriate meaning.

From the results of our Experiment 2, sentential information aids the processing of Chinese homographs from early on within the acoustic boundary of the homograph in natural speech. The influence of sentential context is thus pushed to a much earlier stage than what has been proposed by the multiple access model. At a subsequent time, after the homograph is being heard, the dominant meaning is activated, thus semantic competition occurs. However, it was hard to separate the stage of this activation possibly occurred at the level of lexical or post-lexical processing. So it may be more likely to view the lexical ambiguity resolution as the continuous graded constraint of context and frequency effects rather than an order-based of two-stage processing for different meanings (Mirman, 2008). In terms of continuous graded constraints, it seems that both contextual bias and meaning dominance are used in parallel by the comprehenders. Two implications thus can be drawn from these findings, first, contextual information affects the ambiguity resolution occurring early before the acoustic offset of homograph. Second, the context reorders the processing of different meanings, the unselected but frequent meaning becomes activated later.

6.2 The competition account of subordinate bias effect

Both reordered-access and selective-access models predicted the rapid and early use of context. Consistent with both models, experiment one have shown context affected the fixation proportions on the subordinate meaning (SR associate), starting from 500 ms after the homograph onset. However, the discrepancy of the two models lies in whether the dominant meaning was activated. Our results are more consistent with the reordered access model according to the two findings reported here. First, in Experiment one, longer processing time is demonstrated in both target and post-target region when readers process ambiguous words. Under the selective view, no initial processing time cost should be observed when the context is sufficiently constraining. Second, in Experiment two, the dominant meaning (DR associate) attracted more looks of fixations than those to the unrelated distractors and above chance level even in the subordinate-biased context. Two meanings were activated at the same time, therefore, competition or processing difficulty occurred which were evident in longer fixation durations in experiment one, supporting the reordered access model. In sum, the dominant meaning was still available though it was delayed. Therefore, the selective access view was ruled out and the homographs were not merely treated as low frequency words.

Another issue was how the context affected the status of contextually-

inappropriate meaning. According to reordered access model, two meanings are activated independently. Contexts speed access to the appropriate meaning, while no effect was on the activation of the inappropriate meaning. On the other hand, based on selective access model, given sufficiently constraining contextual information, only the contextually-appropriate meaning should be activated; therefore, the inappropriate meaning is not supposed to be activated after selection. In Experiment two, the dominant meaning occurred shortly after the offset of the homographs. The theoretical implication lies in the automatic processing in terms of their relative meaning dominance associated with the ambiguous words.

6.3 Time course of activation of 'unselected' semantic representation

Multiple access of both selected and unselected meanings is inconsistent with the prediction of selective access model, which posits the elimination of the SBE in strongly biasing contexts. As we have discussed, both our norming data and the immediate effects of context suggest that our subordinate-biased contexts were truly strongly biasing. Generally, both reordered access and selective access model are capable of accounting for the early penetrate of the context. However, although the activation of dominant meaning is consistent with reordered access model, the relative time of activation is not accounted by reordered access model.

The meanings of individual homonymy are also represented separately in the mental lexicon which may lead to the ambiguity effects. Therefore, there would be more differentiated semantic representations for the dominant and subordinate meanings of biased homographs. The advantage for high-frequency meaning of lexical ambiguity resolution is that higher frequency words have stronger bottom-up connections since they have been used more. The results of Dahan et al. (2001) and Magnuson, Dixon, Tanenhaus, and Aslin (2007) showed that word frequency or meaning frequency effects on spoken word recognition occurred early and increased gradually. The dominant meaning activation from the present results can become active only after the activation of the subordinate meaning.. It indicates that the biasing contextual information may change the order of activation, which demonstrated the situation of contextual re-ordering. However, in the present study, the activation of subordinate meaning may be due to both contextual facilitation and lexical meaning itself. Therefore, the context effect should be build up first in an attempt to separate two sources of meaning activation. Alternative possible explanation for the delay of the dominant meaning is taken from the perspective of speech perception. Frauenfelder et al., (1990) suggested that lexical effects tend to be strongest after the uniqueness point when the context become explicit to a particular word. Therefore, the stronger form-meaning mapping in lexicon represented the

dominance after uniqueness point. Moreover, the dominant meaning somewhat maintained active until 2800 ms. It may result from the task demand in experiments of visual world paradigm. Listen-only task features its unconstrained nature of free viewing and listening; however, no explicit selection of visual targets may be the reason that the fixations proportions of the dominant meaning did not gradually decrease even though it was the contextually-inappropriate meaning.

The relative timing of accessing form and semantic information of ambiguous word can be demonstrated by the time course of activating contextually-selected and -unselected meanings. When listeners hear an ambiguous word embedded in context, contextual information and meaning dominance are combined to resolve the ambiguity. The initial activation of semantic representation was due to the function of context biasing. At subsequent, the unselected semantic representation was also activated because of its meaning dominance. After revising the inappropriate meaning, a single plausible meaning was selected and integrated into text representation. In short, we can conclude the successful ambiguity resolution depends on the continuous on-line interaction among contextual, lexical, and syntactic information carried in the sentences. This is similar to the real world communication, the discourse, pragmatic, and syntactic factors are combined to determine sentential interpretations.

6.4 Future Research

First of all, in order to further investigate how the context affects the activation of both dominant and subordinate meanings, additional neutral contexts would be needed, so as to further provide strong evidence to support the context reordering. Then, in terms of the experimental stimuli, we did not use meaning-frequency matched unambiguous words because Chinese homographs are basically low-frequency words. If the homographs with relatively higher frequency can be utilized, it may provide more direct evidence to examine the frequency account. More specifically, if the access is selective, processing of a biased homograph in a context that supports the subordinate interpretation should be similar to processing of an unambiguous word matched the subordinate meaning frequency.

On the other hand, another issue is the relationship between syntactic-category information and semantic ambiguity resolution. Most research of lexical ambiguity resolution have used ambiguous nouns or verbs as the target words, but the homograph with syntactic category ambiguity, such as *過節* which bears two meanings with different word class: “celebrate the day” or “enmities” is another interesting issue for further research. Whether the syntactic category information can facilitate ambiguity resolution and the subordinate bias effect is eliminated by the syntactically legal continuation of the sentential context can provide theoretical

explanations for the interplay of syntactic and semantic processing.

Moreover, one of the advantages of using visual world paradigm lies in its simple and natural task. The unconstrained nature of free viewing of picture displays and listening are particularly suited for studies with young children or some special populations, such as, individuals with specific language impairment, with mild Alzheimer's disease or with autism. The issue of ambiguous words' processing can also be applied to examine the developmental differences on how context influences homonym processing as children acquire more knowledge of lexical meaning at different ages. Booth, Harasaki, and Burman (2006) investigated both lexical and sentence level context effects by asking children (9-, 10- and 12-year-olds) to read aloud written sentences that biased either the dominant or subordinate meaning of a sentence-final homonym or that were ambiguous. The results showed a lexical level facilitation for dominant and subordinate meanings regardless of biasing context for younger children or lower skill readers. In contrast, no lexical level, but a reliable sentence level facilitation was found for targets consistent with the sentence context for older children or high skill readers. It seems that the older or higher skill readers are better to use sentential context to facilitate the contextually-appropriate meaning of homonymy than younger or lower skill readers. Numerous studies with adults have shown processing differences between unbalanced and balanced homonyms. The

factor of meaning dominance could be examined in age differences in future developmental studies.

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Appendixes

A. Examples of questionnaire in Norming study two: Meaning Relatedness Task (Experiment 1)

同學您好：

非常感謝您參與本測驗。

此測驗為**中文多義詞語義關聯性評定量表**，每道題目中會有一個一詞多義(一個詞彙具有2個詞義，詞義間彼此有不同程度的關聯)，每道題目皆提供2個依多義詞所造出的句子，並附註詞意，請您**評斷詞義間彼此的語義關聯程度高低。**

測驗進行請見下面說明。請您耐心並細心地作答，您的答案將會影響本測驗後續的實驗結果，務必審慎作答。非常感謝您的參與與配合。謝謝！

[測驗說明]

每個多義詞會列舉出兩個句子及詞義，請**評斷兩個詞義之間的關聯程度(1至7分)，1分代表關聯程度最低，7分代表關聯程度最高**。請您耐心地評定彼此的詞義關聯性高低，並寫下適當的數字。

目標詞	句子	詞義解釋	請評兩個語意關聯性高低
青天	我們國家的國旗代表著**青天**白日滿地紅。	藍色的天空	
	古代人稱一位公正廉明的官員為**青天**。	比喻清官	
泡湯	因為這場突如其來的大雨讓這次的旅遊**泡湯**了。	落空	
	周末時我和同學去烏來**泡湯**享受這美好的假期。	浸泡在水裡	
氣象	換了校長後，學校有一番新**氣象**。	景況、氣派	
	氣象報告說明天會下雨因此要帶雨傘出門。	氣候	
修理	媽媽把家裡壞掉的風扇拿到對街的電器行**修理**。	使損壞的物件恢復原來的功能或形狀	
	他偷東西被爸爸狠狠地**修理**了一頓。	對不合己意的人使用言語暴力	
口氣	口香糖會讓你的**口氣**清新宜人。	口中散發出難聞氣味	
	她回應的**口氣**實在太差了因此被老闆教訓了一頓。	說話的語氣及措辭	

B. Norming study four: Contextual Bias Task (Experiment 1)

同學您好：

非常感謝您參與本測驗。

此測驗為**中文語境的語意偏向與句子通順度評定量表**，每道題目中有語境以及多義詞，請依每道題目提供的語境來判斷該語境應該符合多義詞的哪個語意，並評斷整個句子的合理性。

測驗進行請見下面說明。請您耐心並細心地作答，您的答案將會影響本測驗後續的實驗結果，務必審慎作答。非常感謝您的參與與配合。謝謝！

[測驗說明]

每個題目會列舉出兩個語境(前後語境)及多義詞，第一，請**評斷語境的語意偏向性(第一或第二語意)，第二，請評斷整個句子的通順度，1分代表句子通順度最低，5分代表最高**。請您耐心地評定語意偏向性及通順度，並寫下適當的數字。

句子	目標詞	語意偏向	詞義選擇(1or2)	語境後	詞義選擇(1or2)
縝密的作戰計畫讓軍隊順利由後側	抄襲	1.抄錄他人作品以為己作 2.軍隊突擊	2	敵軍取得致勝的關鍵。	2
航行世界一周的艦隊回到港口順利	拋錨	1.車輛發生故障，無法行駛 2.將錨投入水中，使船停泊			
韓式料理店的老闆想做出正統	銅板	1.銅製的錢幣 2.銅製板子			
飲食不均衡維生素不足會造成	口角	1.嘴邊 2.言語上的爭執			

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C. Experiment materials of Experiment 1

set1	Homographs (LF)	**銅板**	韓式料理店的老闆想做出正統銅板烤肉讓客人品嚐道地滋味。
	HF	**協會**	國際青年團體在世界各區域設立協會負責統籌舉辦各項活動。
	LF	**外幣**	隔壁那位先生表示自己有收藏外幣的習慣，願意和眾人分享。
set2	Homographs (LF)	**把柄**	隔壁鄰居總愛抓著自製的加長把柄擦遍所有窗戶的上層玻璃。
	HF	**兒童**	根據世界展望會指出各地有許多兒童未能受到完善的照料。
	LF	**政見**	選舉抹黑在所難免故有人呼籲政見才是選民應該聚焦的重點。
set3	Homographs (LF)	**八卦**	神祕的老者喜歡觀看天象並研究八卦所以很多人會找他算命。
	HF	**婦女**	東方的傳統文化與宗教習俗對於婦女地位與權益不斷打壓。
	LF	**歌手**	受到盜版及非法下載的影響之下歌手及唱片業者處境甚憐。
set4	Homographs (LF)	**分號**	百年餅鋪保留傳統原味並堅持絕無分號希望穩定產品的品質。
	HF	**人數**	前往偶像劇中出現的觀光景點人數與日俱增，促進觀光發展。
	LF	**雨林**	生物學家貢獻一生的心力在探索雨林中多樣且豐富的物種。
set5	Homographs (LF)	**青天**	申冤時能夠遇到清廉公正稱作青天或父母官的機會實屬難得。
	HF	**選手**	總統在電視上公開表揚這些優秀選手努力及永不放棄的精神。
	LF	**牙刷**	有些人習慣在飯後和睡前使用牙刷清潔齒垢以保持口腔健康。
set6	Homographs (LF)	**風聲**	由於颱風肆虐，外頭傳來猛烈風聲像頭野獸不停地敲擊窗戶。
	HF	**電話**	為了更方便使用，旅客可透過電話網路自動連接訂位中心。
	LF	**電器**	以安全考量，出遠門前要記得檢查電器電源或瓦斯是否關妥。
set7	Homographs (LF)	**底線**	大會規定書寫專有名詞要使用底線作標記，否則會喪失資格。
	HF	**軟體**	主辦大型國際盛事前必先做好軟體及硬體的整備缺一不可。
	LF	**禮服**	明年將會舉辦一場大型的新式禮服設計競賽，歡迎報名參加。
set8	Homographs (LF)	**儀表**	世界首富的私人飛機使用新款儀表導航，全面提升航行安全。
	HF	**價格**	要培養出通勤人口首先要對於價格進行調整提高搭乘意願。
	LF	**攤子**	春假時期市政府廣場前的眾多攤子吸引了十三萬的民眾前往。
set9	Homographs (LF)	**氣象**	希望新的政務官上任後能使得氣象一新進而帶動景氣繁榮。
	HF	**預算**	因財政收入下滑，市長宣布實施預算刪減計畫作為因應之道。
	LF	**車禍**	大量的警車和救護車前往發生車禍的交通要道展開救援行動。
set10	Homographs (LF)	**口角**	飲食不均衡維生素不足會造成口角發炎可別一味以偏方治療。
	HF	**方法**	目前天候觀測已可使用太空遙測方法來增加預報的準確度。
	LF	**指甲**	這群可憐的農民因為黴菌感染造成指甲變色變形甚至脫落。

set11	Homographs (LF)	方丈	到日本旅遊時總能見到尺寸有如方丈大小般的庭園極富禪意。
	HF	比例	每面國旗的長寬尺寸會形成固定比例即使放大也不至於失真。
	LF	木魚	為了那場表演她使用電腦音效模擬木魚敲擊聲結果維妙維肖。
set12	Homographs (LF)	口氣	避免吃重口味的食物可以保持口氣清新並避免尷尬情況發生。
	HF	特色	所有入選的設計師皆依照自己特色構圖來表達對藝術的看法。
	LF	馬車	歷史記載十八世紀時的歐洲已使用馬車作為主要交通工具。
set13	Homographs (LF)	拋錨	航行世界一周的艦隊回到港口順利拋錨停泊受到熱烈歡迎。
	HF	達到	電影上映前的廣告行銷策略不僅達到宣傳目的更拉高了買氣。
	LF	錄製	國文老師特別指導學生朗讀並且錄製有聲書送給視障朋友。
set14	Homographs (LF)	抄襲	縝密的作戰計畫讓軍隊順利由後側抄襲敵軍取得致勝的關鍵。
	HF	辦理	風災過後，政府提供災民快速辦理補助金申請及領取的管道。
	LF	圓夢	書店邀請人氣作家分享自己努力圓夢的歷程來勉勵社會大眾。
set15	Homographs (LF)	報銷	採買完畢後別忘記要留下發票報銷方便總務記錄活動支出。
	HF	提高	使用活潑且多元的教學方法可以提高學生的學習興趣與動機。
	LF	借來	暑假圖書館會閉館進行裝修所以借來的書可能無法全部看完。
set16	Homographs (LF)	插花	他雖沒有辦法參與計畫但依然插花出席以代表自己的祝福。
	HF	協助	主辦單位於近期內打算招募志工協助這次畫展義賣會的進行。
	LF	打翻	秘書在開會時心不在焉因而不慎打翻要端給總經理的咖啡。
set17	Homographs (LF)	打發	製作海綿蛋糕別忘了要把蛋白打發才能做出鬆軟可口的成品。
	HF	發生	由於食品控管的程序不周延因而發生了集體食物中毒的意外。
	LF	打造	藝術家運用現地創作的概念期望打造專屬於在地的城市美學。
set18	Homographs (LF)	放水	媽媽總叮嚀我泡完澡不要馬上放水可以將水拿來做其他用途。
	HF	出版	逃亡海外的領袖透過媒體傳達希望出版年輕時所寫下的手稿。
	LF	排成	在老師的引導下學生將手中的綠豆排成各種美麗的幾何圖形。
set19	Homographs (LF)	輸給	大海嘯後，世界各地紛紛將物資輸給災區協助救援活動。
	HF	加強	想要出國進修前的首要之務就是加強英語的口說能力及聽力。
	LF	寫給	年節掃除時我不小心發現從前寫給心儀同學的卡片及信件。
set20	Homographs (LF)	背書	以前國中老師嚴格地要求同學背書給她聽，使全班哀嚎連連。
	HF	擔任	新聞局決定投入更多資源來爭取擔任安古蘭漫畫節的主題國。
	LF	誘人	想要吸引外資，該國官員提出誘人政策使得商人趨之若鶩。
set21	Homographs (LF)	開動	雖然暴雨即將來襲，但他仍然選擇開動遊艇前往外海的小島。
	HF	獲得	智慧型手機傑出的效能及設計獲得產業界的認同後大量生產。
	LF	開往	警方在得到線民的消息後已準備開往中央公園展開監視行動。
set22	Homographs (LF)	找錢	到了收銀機前才急急忙忙開始找錢恐怕會造成其他顧客不便。
	HF	發表	李醫師在多次蒐集相關資料之後發表醫學文章於國際期刊上。
	LF	划算	春天到韓國賞櫻對國人而言是相當划算且具吸引力的選擇。

set23	Homographs (LF)	**打點**	許多企業為了圖利以宴會和美人打點官員助長了貪污的風氣。
	HF	**符合**	申請各企業贊助的獎學金需要符合學歷年齡等條件限制。
	LF	**行駛**	縣長下令全面重新規劃市區的機車行駛路線保障用路人安全。
set24	Homographs (LF)	**過關**	航空公司網站更新了隨身行李過關規定，出國前記得查閱。
	HF	**強調**	那位著名理財顧問在演講當中強調多元經營與管理的重要。
	LF	**逗留**	教官特別提醒學生放假期間不要逗留網咖應多從事正當休閒。

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D. Experiment materials of Experiment 2

Exp set	Critical spoken word (homograph/monograph)	Dominant Competitor (DR)	Subordinate Competitor (SR)	Unrelated 1(UR)	Unrelated 2(UR)
SET1	銅板/銅盤	硬幣	餐具	課堂	歌手
SET2	把柄/拖把	要害	掃帚	典故	雨林
SET3	八卦/八字	閒話	易經	羊毛	牙刷
SET4	分號/分店	文法	商家	國片	清流
SET5	青天/賢良	白日	功臣	苦瓜	油汙
SET6	風聲/聲響	傳聞	雷鳴	家境	輪廓
SET7	底線/記號	限度	箭頭	戲曲	禮服
SET8	儀表/地圖	容貌	方位	岩漿	攤子
SET9	氣象/景況	時節	作風	教具	月色
SET10	口角/嘴角	爭執	舌頭	夜空	指甲
SET11	方丈/方格	住持	地坪	工友	香料
SET12	口氣/口腔	談吐	異味	草皮	馬車
SET13	拋錨/停泊	故障	靠岸	猜測	迎親
SET14	抄襲/圍剿	剽竊	突擊	敘舊	辭行
SET15	報銷/報帳	損壞	查核	預演	圓夢
SET16	插花/插手	修剪	闖入	導引	列舉
SET17	打發/打散	清場	攪拌	行善	開往
SET18	放水/放掉	作假	流出	加班	排成
SET19	輸給/輸往	落敗	運送	揭幕	寫給
SET20	背書/背誦	擔保	記住	跑步	彈出
SET21	開動/搭乘	上菜	啟航	自嘲	打造
SET22	找錢/掏錢	退款	尋出	訪察	刻畫
SET23	打點/收買	安頓	行賄	中獎	相見
SET24	過關/通關	晉級	出境	歸納	聯想
Filler	**Critical spoken word**	**Visual Target**	**Unrelated 1**	**Unrelated 2**	**Unrelated 3**
SET25	子音	子音	財主	衣衫	品行
SET26	雨鞋	雨鞋	戲份	母雞	貨款
SET27	腮紅	腮紅	菁華	溼度	稜角
SET28	葉脈	葉脈	煤油	淨值	騎兵
SET29	瀏海	瀏海	話劇	帳簿	屬地
SET30	織女	織女	臉孔	湖泊	危樓
SET31	淨土	淨土	志向	棋子	屋主
SET32	池塘	池塘	奴僕	呆帳	緣分
SET33	極光	極光	毛髮	球門	洋酒
SET34	峭壁	峭壁	姻緣	醬油	唾液
SET35	蠟燭	蠟燭	罐頭	夢魘	纖維
SET36	坡道	坡道	瑜伽	瞳孔	倦容
SET37	刮痧	刮痧	陷害	塗改	躲雨
SET38	直視	直視	招惹	求情	認字
SET39	空投	空投	作客	收押	成事
SET40	堵塞	堵塞	捏造	渺茫	刷新
SET41	擦乾	擦乾	趕路	掌廚	閃避
SET42	精通	精通	過問	作證	收聽
SET43	徘徊	徘徊	駕車	喚起	捨棄
SET44	揮霍	揮霍	品嚐	遮掩	創辦
SET45	防範	防範	徵求	擊出	移送
SET46	錄製	錄製	撫摸	遵照	研讀
SET47	行駛	行駛	打斷	出錢	主演
SET48	逗留	逗留	伴隨	奪得	討好