

ON-LINE SENTENCE COMPREHENSION OF AMBIGUOUS VERBS IN MANDARIN

The current work explores the issue of category in lexical ambiguity resolution. The central question is whether the preceding sentential context can influence access of lexical meaning in on-going sentence comprehension. Previous studies have concentrated on lexical ambiguity resolution of nouns. These studies, on the whole, have demonstrated that the lexical access system operates independently of previous sentential context. However, previous psycholinguistic work on semantic change suggests that verbs are more susceptible to coercive change than nouns. I explore the possibility that this susceptibility of verbs to semantic change will allow sentential context to influence their lexical access. I find, instead, that the lexical access system still operates independently of preceding sentential context. The implications of this finding are presented in terms of two different views of cognitive processing – the modular and the interactionist view.

1. INTRODUCTION

Two differing perspectives exist concerning the design of the cognitive processing system. According to one perspective, the cognitive processing system is made up of a set of processing modules that are functionally autonomous. This perspective is known as the modularity hypothesis. Under these assumptions, a module computes the same output given a particular input. The output of one module cannot be influenced by information from other modules. Two possible advantages for the modularity hypothesis are that it is more efficient because fewer mistakes are made and that it is safer because the source of the input can be adequately discriminated (Fodor (1983)).

According to an alternative perspective, the cognitive processing system is made up of processing modules that are not functionally autonomous and that can, instead, interact and share information across levels (Marslen-Wilson and Tyler (1980), McClelland and Rumelhart (1981), McClelland (1987)). Under this perspective, the output of a module can be influenced by information from other modules. The advantage of this type of model is that allowing feedback permits higher-level constraints to guide lower-level processes and lower the amount of noise in the processing system.

The modular and interactive theories concern cognitive processing in general, but these hypotheses have also been tested at the level of language processing. One issue that is tested is whether sentential context, or information from the discourse level of processing, can influence the access of



a word's meaning, that is, influence access at the lexical level. This question is tested on ambiguous words in particular because ambiguous words have more than one meaning, which allows researchers to test and see which meanings are accessed. This is done by varying preceding sentential context and testing to see which meanings of an ambiguous word are primed relative to their respective control words. In a modular system, sentential context (a higher-level subsystem) cannot interfere with lexical access (a lower-level subsystem). In an interactive system, however, sentential context can influence lexical access. The two basic theoretical models of language processing associated with the modular and interactive hypotheses are context-independent and context-dependent models, respectively. I will discuss these models in more detail in section 2.

To date, lexical ambiguity resolution has focused on only one lexical category – nouns. However, verbs have been postulated to be more mutable than nouns in English (Gentner and France (1988)). Moreover, Ahrens (1999a) demonstrated that verbs in Mandarin Chinese are more mutable than nouns under coercive semantic conditions. Thus, it might be the case that verbs are more susceptible to contextual influence than nouns.

In addition, Ahrens (1998) hypothesizes that in languages which are context-prominent, such as Mandarin Chinese, context will be able to influence lexical access automatically and immediately (the language-driven hypothesis) although this hypothesis did not hold for nouns in Mandarin (Ahrens (1998)). This paper takes another look at the language-driven hypothesis and at the same time examines what role, if any, lexical category plays in lexical ambiguity resolution.

The paper is set up as follows: I first review the experimental tasks that are brought to bear on the above questions and present the various models within the context-independent and context-dependent views of lexical ambiguity resolution. I next review the areas that have been postulated to influence lexical ambiguity resolution including: context, probe position, and language. I point out that one variable that has yet to be manipulated concerns lexical category.

I test the category-driven hypothesis in an on-line cross-modal sentence comprehension experiment that looks at lexical ambiguity resolution for verbs in Mandarin Chinese. This experiment tests whether or not context, when biased to the secondary meaning of an ambiguity, can influence lexical access when the ambiguous word is a verb (i.e., only the contextually appropriate meaning is primed relative to its control). I find that context does not influence lexical access (i.e., both the contextually appropriate and inappropriate meanings are primed relative to their respective controls), which is evidence in favor of a modular view of lexical access. In the concluding

section, I review the findings to date. I suggest that future work in lexical ambiguity resolution concentrate on manipulating timing issues while at the same time being cognizant of the various effects of context, language, and category.

2. MODELS OF LEXICAL AMBIGUITY RESOLUTION

As mentioned in the introduction, there are two basic models for lexical ambiguity resolution: the context-independent model and the context-dependent model. The context-independent model predicts that context will not influence lexical access. Within this model, there are two accounts that could handle the data. The first is the multiple access account, which says that all meanings will be accessed regardless of context (Swinney (1979), Onifer and Swinney (1981)). The second account is the ordered access account (Hogaboam and Perfetti (1975)). In this account, the most frequent meaning is accessed irrespective of the preceding context. If the most frequent meaning does not fit into the context, the next most frequent meaning is retrieved until a match is made. Both models are compatible with a modular account of language processing.

On the other hand, the context-dependent model predicts that context will allow only the contextually appropriate meaning to be accessed, which is in line with an interactionist account of language processing. The context-dependent model, for example, predicts that if the context is biased towards the secondary meaning of a word, only the secondary meaning is accessed. However, if the context is biased towards the primary meaning of a word, only the primary meaning is accessed.¹

Experimental evidence has been found to support both the context-independent and context-dependent models in lexical ambiguity resolution experiments (cf. discussion in Simpson (1994) and Lucas (1999)). One reason for the differences in the findings has to do with the fact that the experimental tasks used to obtain the results operated over different modalities (i.e., the visual as opposed to the auditory modality). Ahrens (1998, 1999b) points out that when experiments on lexical ambiguity resolution involve *on-going* and *natural speech* comprehension, the data for the most part falls on the side of a modular, context-independent account.²

In order to test natural speech comprehension, speakers must be able to listen to speech without interruption when the test stimulus is presented. Cross-modal priming experiments allow the gathering of precise reaction time data while at the same time allowing native speakers to engage in on-going natural speech comprehension. They involve subjects listening to a sentence (spoken by a native speaker at normal speed) over headphones

and either making a lexical decision to a visual target that appears on the screen (cross-modal lexical decision task) or naming the visual target (cross-modal naming task). There is no pause in the auditory presentation of the sentence when the visual target appears. The subject hears a complete and natural sounding sentence.

The cross-modal technique is advantageous for studying the time course of language processing because subjects are listening to natural speech, the presentation of the visual target can be precisely controlled, and the speed of natural speech does not permit conscious reflection on the nature of possible relationships between the information being heard over the headphones (i.e., the ambiguous word) and the visual target (i.e., a semantic prime or a control word) (Nicol et al. (1994), Love and Swinney (1996), Ahrens (1998)). The priming task also indicates whether the meaning of the word has been accessed.

Once the distinction is made concerning visual versus auditory processing, it is difficult to find evidence for the context-dependent model in on-line auditory sentence comprehension experiments. Simpson (1981) presents the only cross-modal experiment to find evidence for this account, and there are methodological reasons (see section 3.1 below) why his evidence does not hold. The clearest evidence for the context-dependent model would come from a cross-modal sentence processing experiment where the context is biased towards the secondary meaning of the word, and only the secondary meaning is immediately primed relative to its control word. This would indicate that context selected only the appropriate meaning of the word, and moreover that context had not allowed the more dominant meaning to be accessed. If, to the contrary, contextual bias does not select the appropriate meaning of the word, then both meanings should be facilitated relative to their respective control words. Such a finding would be in line with both accounts in the context-independent model. Either finding, moreover, would refute the null hypothesis, which is that neither the primary nor secondary meaning of the ambiguity will be primed relative to its control word.

Following the above line of reasoning, in this paper I will take the first step to determine if preceding sentential context influences lexical access when it is biased towards the secondary meaning of an ambiguous word. In this way, I will be able to determine the viability of a context-dependent account as compared with a context-independent account.

I turn now to a discussion of three major factors that have been postulated to influence on-line lexical ambiguity resolution: position, context, and language. Following this discussion, I will present a fourth area that has yet to be explored: lexical category differences. To foreshadow the dis-

cussion that will follow, I will look at lexical ambiguity resolution in Mandarin Chinese at the onset of ambiguous verbs in sentential contexts biased towards the secondary meaning of the ambiguities.

3. ISSUES IN LEXICAL AMBIGUITY RESOLUTION

Researchers investigating lexical ambiguity resolution in on-going cross-model sentence comprehension have in the past manipulated visual probe position, strength of the sentential context, and language type.

3.1. *Position*

The position of the visual target in relation to the auditory perception of the ambiguity is of paradigmatic importance in understanding the time course of ambiguity resolution in on-line sentence processing. As a number of researchers have pointed out (McClelland (1987), Onifer and Swinney (1981), Simpson (1994)), when an interval occurs between the offset of an ambiguous word and the presentation of the visual target, any activation found cannot be considered indicative of immediate processing. The cross-modal study that found evidence for a strictly selective-access account (Simpson (1981)) presented the visual target with a 120-millisecond delay at the offset of the ambiguity. This finding might represent the effects of context once the word has been accessed and cannot be construed as supporting a model of selective access. Experiments which have argued for the context-independent model have all had the visual probe presented no later than the offset of the ambiguous word.

Experiments have also been designed to look at lexical ambiguity resolution earlier than the offset of the ambiguity. Li and Yip (1996) and Ahrens (1998) both looked at ambiguity resolution at the onset of the ambiguity. In both of these experiments, the subject is starting to say or make a decision on the visual probe when they are hearing or have just finished hearing the ambiguous word.³

Li and Yip (1996) created contexts for both the dominant and subordinate meaning of the ambiguity and ran a cross-modal lexical naming task where the ambiguity occurred sentence-finally. They found that both meanings of an ambiguity were accessed when the visual probe was presented at the onset of the ambiguity but that only the contextually appropriate meaning was accessed when the visual probe was presented at the offset of the ambiguity.⁴ These results held when the sentence was biased towards either the dominant or subordinate meaning of the ambiguity.⁵

Ahrens (1998) created contexts for the subordinate meaning of nominal ambiguities and ran a cross-modal lexical decision experiment where the ambiguities occurred sentence-medially, and the visual probe was presented at the onset of the ambiguity. This study also found that both meanings of the ambiguity were accessed. Thus, immediate processing can be viewed experimentally as soon as the onset of the ambiguity (in which case the subject is in the middle of hearing or has just finished hearing the ambiguity). Furthermore, any evidence for immediate processing must occur by the offset of the ambiguity. If the visual probe is presented after the offset of the ambiguity, then any context effects found may be indicative of post-lexical processing and not of immediate lexical access.⁶

3.2. *Context*

The issue of context is a potentially complicated one. Questions arise concerning the strength of contextual bias in the experimental sentences. One way to deal with this issue is to use sentences where 75% or more of native speakers agree that the sentence is biased towards the postulated meaning. Tabossi et al. (1987) suggest that this level is needed for the context to be considered "strongly biasing."

It is also important that at the same time that context is being adequately biased, lexical priming will not take place. For example, if there are lexical associates to the ambiguous word in the immediate vicinity preceding the ambiguous word, it is possible that lexical priming, and not contextual selection, is taking place (cf. Seidenberg et al. (1982), Experiments 2 and 4, for further discussion).

Simpson (1994) has also pointed out that the notion of context should be expanded beyond looking just at the meaning conveyed in a single sentence. He points out that different sentence types, different types of experimental design, and different types of experimental procedures can all be thought of as contextual influence. The latter two issues should be kept separate from the issue of context although they are of great importance concerning replication and validation. The first issue, concerning sentence types, is a valid concern for future research. However, it is arguable that emphasis should first be placed on understanding the time course of lexical ambiguity resolution. Once the time course has been ascertained, then effects of difference sentence types and the effects of different sentential context can be explored. Thus, in this experiment I use declarative sentences which are strongly biased enough that 75% of native speakers agree on the intended aspect of meaning and, moreover, which do not have lexical associates immediately preceding the ambiguity.

3.3. *Language*

Ahrens (1998) tested the hypothesis that the different linguistic properties of English and Italian might be behind the differences found in lexical ambiguity resolution results (i.e., the English data support the context-independent model while the Italian data have been argued to support the context-dependent model).⁷ This language-driven account suggests that when contextual information is necessary to interpret sentences in a language, it will also be available to influence lexical access. The language-driven hypothesis is formulated as in (1).

- (1) *Language-driven hypothesis*: If a language is context-prominent, then context will be able to influence lexical access immediately and automatically (Ahrens 1998, 18).

A language is defined as being context-prominent if "contextual information plays a prominent role in interpreting a sentence" (Ahrens (1998)). Italian, which has been shown to rely more on agreement cues for semantic interpretation in psycholinguistic experiments, is considered to be more context-prominent than English, which relies more heavily on word order for semantic interpretation (Bates et al. (1982, 1999), MacWhinney et al. (1984)). Furthermore, Ahrens (1998) argued that Mandarin Chinese is a context-prominent language because it may rely solely on contextual information to assign an interpretation instead of on structural information such as word order, which may either be missing or unreliable (cf. examples (4) and (5) in Ahrens (1998)).

The typology suggested by context-prominency is similar to that of "hot" and "cool" languages, as proposed by Ross (1982) and discussed in Huang (1984), where English is considered to be a "hot" language because pronouns cannot be omitted, and information required to understand the sentence is overtly present in the sentence. Chinese, on the other hand, is considered to be a "cool" language because pronouns can be omitted, and comprehending a sentence often requires contextual information. Under this system, Italian is characterized somewhere between the two because the subject may be omitted from a tensed clause.

Huang (1984) points out that the distinction is somewhat more complicated. He argues that Chinese and Italian are pro-drop languages while English is not. On the other hand, English and Italian pattern the same for the Empty-Topic parameter but differently from Chinese. What is crucial for the discussion here, however, is that with respect to these two parameters, Italian falls between English and Chinese, sharing a parameter with each, while English and Chinese differ with respect to both the

Pro-Drop parameter and the Empty-Topic parameter. Thus, even when English, Italian, and Chinese are examined from the point of view of their respective syntactic typologies, parallels can be drawn with respect to the notion of context-prominency as pertains to the relationships among the three languages.

If the language-driven hypothesis is correct, perhaps the reason that Tabossi et al. (1987) found evidence for the context-dependent model in Italian could be that Italian has different underlying linguistic properties from English. Furthermore, if this hypothesis is plausible, then context should influence ambiguity resolution in Mandarin Chinese since Mandarin relies even more heavily than Italian on contextual information for semantic and propositional interpretation.

This hypothesis was tested on nouns in Mandarin Chinese (Ahrens (1998)) and did not hold because both meanings of the ambiguity were still accessed when the sentential context was biased towards the secondary meaning of the ambiguity. Using Mandarin Chinese in testing for lexical ambiguity resolution of verbs will again test the language-driven hypothesis. If it holds in the following experiment, it might indicate that it is the combination of the contextual-prominence of the language, in combination with the contextual sensitivity of verbs (see following section), that allows context to influence lexical access.

4. LEXICAL CATEGORY DIFFERENCES

To date, lexical ambiguity resolution has dealt with ambiguous nouns, or nouns that also can function as verbs (Seidenberg et al. (1982)). However, verbs have a different function from nouns and therefore behave differently from nouns syntactically. The different functions and behaviors of these lexical categories extend to a speaker's ability to acquire and process the words in that category. In terms of acquisition, Gentner (1982) proposed that the greater simplicity of nouns allows them to be acquired earlier than verbs. However, Gopnik and Choi (1995) present evidence that children acquire verbs before nouns in Korean and argue that research that supports the noun-before-verb point of view has been conducted mainly on English-speaking children. What is important for our discussion here is that in both the English and Korean cases, acquisition of nouns and verbs occur in distinctly different time periods. Moreover, in terms of processing, aphasic subjects with different lesion types often have difficulty with one lexical category as compared with another. Broca's aphasics have difficulty naming actions, and Wernicke's aphasics have difficulty naming objects (for a summary of the relevant literature see Bates et al. (1991)).⁸

However, just because the function and behavior of one category is different from another does not necessarily mean that a certain category should be more susceptible to sentential context effects. There are additional independent reasons to think that verbs are more susceptible to contextual influence than nouns. First, Gentner and France (1988) show that English verbs are more likely than nouns to change their meanings when they occur in novel sentences that do not allow for a usual interpretation, such as in "The lizard worshipped." Second, Ahrens (1999a) tested Gentner and France's hypothesis in Mandarin and concluded that verbs are more susceptible to meaning changes under coercive or semantically strained situations than nouns in Mandarin. The hypothesis is given in (2) below.

- (2) Mutability Hypothesis (for Verbs): [A verb is] more likely to change in meaning under coercive situations when the change in semantic features is not crucial to its meaning (Ahrens, 1999a).

The term "coercive" covers the concept of semantically-strained contexts, where the perceiver is forced to arrive at an interpretation.

Evidence for this hypothesis comes from off-line data where subjects were asked to choose between two possible meanings (3b or 3c) for a sentence (3a).⁹

- (3) a. shizi zai zhufan.
lion PROG prepare meal
"The lion is preparing a meal."
- b. weiwu de nanren zai junbei wancan.
fierce DE man PROG prepare dinner
"The fierce man is preparing dinner."
- c. wanshouzhiwang zai junbei gongji liewu.
King of the Jungle PROG prepare attack prey
"The King of the Jungle is preparing to attack its prey."

Subjects chose sentence (3c), which has the verb change its meaning, in order to arrive at a possible interpretation of (3a).¹⁰

In contrast to the coercive contexts in which verbs change meaning, nouns changed meaning only in non-coercive contexts, i.e., when there was no forced choice task and when the context was not semantically strained. In addition, nouns changed only slightly in meaning: they preferred to become more specific and not to change their referent.

The main relevance to our discussion here is that context perhaps is

less likely to influence nouns, or to do so quickly. Verbs, on the other hand, undergo a meaning change when the context warrants it. The category-driven hypothesis put forward is given in (4).

- (4) *Category-driven Hypothesis*: If the ambiguous word is a verb, then the language processor will allow context to influence lexical access.

The assumption underlying this hypothesis is that verbs allow the language processor to influence their lexical access because they are more mutable in meaning than nouns. If, then, sentential context is biased such that only one meaning is available, verbs are potentially more likely to allow context to select an appropriate lexical meaning.

As mentioned in the preceding section, I will test this hypothesis in Mandarin Chinese. If I find that only the contextually appropriate meaning is accessed, it will be the first time in auditory natural speech sentence comprehension that the context-dependent model has received support. It will then be necessary to look further into how much of the effect is due to the language-driven hypothesis and how much is due to the category-driven hypotheses. If both meanings are accessed, however, neither the context-dependent model, nor the language-driven hypothesis, nor the category-driven hypothesis will be supported. Instead, the context-independent model of lexical ambiguity resolution will gain additional support.

5. EXPERIMENT: LEXICAL AMBIGUITY RESOLUTION OF VERBS IN MANDARIN CHINESE

The goal of this experiment is to test whether biasing sentential contexts towards the secondary meaning of an ambiguous verb will cause the processor to access only the contextually appropriate meaning, or, instead, whether both meanings will be accessed. The context is biased to the secondary meaning in order to test whether context alone can influence lexical access. In particular, I examine the possible influences of language and lexical category to see whether under certain circumstances the context-driven model will hold.

5.1. *Subjects*

All subjects used in the pretests and the on-line tests were native speakers of Mandarin Chinese, had lived in Taiwan since birth, and were undergraduate or graduate (M.A. level) students of National Chung Cheng University (NCCU), in Chia-yi, Taiwan.¹¹ In Taiwan, there is often another

language spoken in the home in addition to Mandarin, such as Taiwanese, Hakka, or an Austronesian language. In order to keep the subject pool as homogenous as possible in terms of language background, all subjects used in the following experiments were exposed not only to Mandarin but also to Taiwanese in the home before the age of seven and, moreover, were not exposed any other language such as Hakka, an Austronesian language, or English during this time.

Subjects were also screened for any brain injury, learning disability, visual impairment, or auditory impairment. All subjects were paid NT\$100 (equivalent to US\$3.60) for their participation, which lasted approximately one-half hour. The number of subjects used in each pretest or experiment is presented in each of the appropriate sections below.

5.2. Pretest for Ambiguity Bias

Thirty NCCU undergraduates were presented with ninety disyllabic words (52 nouns, 38 verbs) which had at least two meanings. Presentation was auditory since words often have different auditory and visual biases. For each word, subjects were asked to write down the first meaning that came to their mind in the first column and then to write down any additional meaning or meanings that came to mind in their respective orders in the additional columns. Tallies of the numbers of the first and second choice for each meaning of the words were carried out by two linguistically-trained native speakers and then compared, and a master list of the responses was drawn up.

For the present study, verbs were chosen which fulfilled the following criteria. First, at least 60% of the subjects gave the same (or similar) meaning as their first choice response (i.e., at least 18 out of 30 subjects). Second, 50% of the subjects listed the same (or similar) meaning as their second choice response (i.e., at least 15 out of 30 subjects).¹² Sixteen verbs met the above requirements for having a primary and a secondary interpretation.¹³

5.3. Pretest – Reaction Times

Probes for the Primary and Secondary meaning of the ambiguity were chosen by using one of the three most frequently provided meanings from the previous pretest above. The following restriction applied: if these meanings were not disyllabic, a disyllabic word closely related to the most frequent associate was used. A large number of words that equated to the “related” associates with respect to the bases of frequency, length, and

form class were included with the experimental/related associated words in an isolated lexical decision task. The purpose of the isolated lexical decision task is to determine the lexical decision times of the words independently of the sentential stimuli in the cross-modal experiment.

Twenty-one subjects participated in this experiment. After screening for errors, the average reaction time for each word in the list was calculated over all subjects. After the average for each word was calculated, a "matched" control word was chosen for each "related" associate for each meaning of the ambiguity (i.e., Primary and Secondary). Overall, the mean reaction time was 489ms for the Primary experimental and control condition and 500ms for the Secondary experimental and control conditions. In addition, the experimental and control conditions were matched across individual items for syllable length. The frequency of the control conditions was always higher than for the experimental conditions overall. This works against our hypothesis since higher frequency words are likely to be accessed more quickly. The frequency data is based on written norms (CKIP (1993)).

5.4. *Creation and Pretest of Sentential Materials*

Each ambiguous word was placed in a sentence biased toward its secondary meaning. Twenty-one new subjects were given the experimental sentence in written form up to the point just before the ambiguity and asked to complete the sentence. A contextual bias was established when at least 75% of the subjects filled in the blank with an item that exhibited the contextually favored interpretation.¹⁴ Only the items that fulfilled this criterion were considered for use in the main cross-modal experiment.

In the case of (5) below, for example, at least sixteen subjects had to complete the sentence with an answer related to the meaning of *beishu* "guarantee" (i.e., either the word itself or a synonym).

- (5) Xiaoli pingshi de xinyong feichang cha, yinci ta yao
 Xiaoli often DE credit very bad, thus he want
 xiang yinghang jie qian, xiwang you ren ti
 from bank borrow money, hope have person for
 ta _____
 he _____

"Xiaoli's credit was lousy, so when he went to the bank and needed someone to _____."

5.5. On-line Experimental Materials

The entire experiment consisted of 42 sentences: 16 experimental sentences and 26 filler sentences. An example of a complete experimental stimulus is given in (6a) below.¹⁵ The experimental and control visual targets for the primary and secondary meanings are given in (6b).

- (6) a. Xiaoli pingshi de xinyong feichang cha, yinci ta yao
 Xiaoli often DE credit very bad, thus he want
 xiang yinghang jie qian, xiwang you ren ti
 from bank borrow money, hope have person for
 ta beishu deshihou, mei you yi ge pengyou
 he guarantee when, no have one CL friend
 yuanyi bangmang, dajia dou bizhiweikong
 willing help, everyone all avoid
 buji, shenpa he ta cheshang guanxi.
 not-fast-enough, afraid with him pull relationship
 "Xiaoli's credit was lousy, so when he went to the bank to
 borrow money and needed someone to guarantee (his loan), no
 one would help – everyone ran away as fast as they could, and
 were afraid to be involved with him."

b. ambiguous word: beishu

	Related visual target	Control visual target
Primary meaning	<i>jiyi</i> 'memorize'	<i>guolai</i> 'come'
Secondary meaning	<i>baocheng</i> 'guarantee'	<i>tishi</i> 'hint'

All sentences were recorded by a male speaker to the hard drive of an IBM-compatible Pentium computer with the aid of the Creative Wave sound card using the Creative Wave audio program. These sentences varied from approximately 60 to 80 characters in length. The time from the beginning of the sentence to the onset of the ambiguity was measured using the same program. A control list linked the characters of the visual target and the time of the visual target presentation for each sentence.

At the time of the onset of the ambiguity, a visual target was flashed on the screen for 300 milliseconds. An internal dedicated CPU in the button box measured the time from the presentation of the visual target until a response was made on the button box or 2000 milliseconds had passed, whichever was earlier. The program controlled for timing problems in video

display, such as raster position. The measurements of the dedicated CPU are accurate to the thousandths of a millisecond (0.001ms). The measurements themselves were made to the nearest millisecond. The sentences occurred in random order (i.e., the order of presentation of the sentences was different for each subject, which has the advantage of counteracting ordering effects), and there was a 5-second delay between sentences. Non-words were presented 50% of the time (i.e., each subject saw 21 words and 21 non-words). Non-words were composed of two possible characters in Mandarin that did not have an associated semantic representation (i.e., 路裙).

5.6. Procedure

Subjects sat in front of a computer monitor in a sound-attenuated booth and were told that they had two tasks. The first task was to listen and understand the sentences that they heard. They were told that they would be tested on the comprehension of the sentences at the end of the experiment. They were also told that they had a second task: to watch the computer screen and, when they saw characters appear on the screen, to decide whether the characters made up a word or not. They were told to press the right-hand button (marked *ci* 'word') as fast as possible if they thought it was a word and to press the left-hand button (marked *feici* 'non-word') if they did not think it was a word. They were asked to keep their fingers directly on the buttons at all times.

The auditory sentence continued without interruption even when the visual probe was being presented and the subjects were making their decision. Each subject's attention was focused on the middle of the screen by means of a black mask that allowed only a small word-sized area of the screen to be visible. At the end of the cross-modal portion of the experiment, the subjects were given 10 sentences printed on a sheet of paper and asked to mark which sentences they had just heard. These ten sentences varied as to whether they were completely the same as heard in the experiment, or whether they were only partly the same.¹⁶

5.7. Results

Subjects were screened for errors on an individual basis. Subjects with errors greater than 15% on the lexical decision task (i.e., more than 6 wrong) and those with errors above 20% on the comprehension test (i.e., more than 2 wrong) were dropped from the analysis. After screening for errors, there were 40 subjects with reliable data.¹⁷ Table 1 presents the mean

Table 1. Mean reaction times (in milliseconds) for related and control probes for both primary and secondary meanings of the ambiguity

Meaning of the ambiguity	Probe type	
	Related	Control
Primary	618*	660
Secondary	635*	668

* Significant difference between related and control contrast.

reaction times of correct responses in each condition. An ANOVA was run on the data of individual subjects employing Lists (4) as a between-subjects factor (materials counterbalancing factors) and Ambiguity Meaning (Primary and Secondary) and Probe Type (Related and Control) as within subjects factors. An overall significant main effect of Probe Type ($F(1,36) = 7.657$, $p < 0.01$) was found.

These effects were further examined via *a priori* planned (1-tailed) comparisons of the Probe Type condition (Related vs. Control Probes) for each of the Ambiguity Meaning Conditions (Primary and Secondary). There was significant priming for the related (compared to control) probes for the Primary meaning ($F(1,36) = 5.708$, $p < 0.012$), as well as for the Secondary meaning ($F(1,36) = 4.930$, $p < 0.017$).

5.8. Discussion

These results demonstrate that when an ambiguity with two salient meanings occurs in a context that is biased towards the subordinate (or secondary) meaning, both the primary and secondary meanings of the ambiguity are primed relative to their respective control words at the onset of the ambiguity. This finding supports a context-independent model of lexical access and provides evidence against the context dependent model. In addition, the data above again show that although context may play a very important role in propositional interpretation in Mandarin, the language processor does not give to special priority context in determining the meaning of an ambiguous word. Thus the language-driven hypothesis has not received support from this experiment.

Lastly, even though verbs are found to be susceptible to meaning changes in coercive contexts in off-line experiments, context alone cannot influence access of a verb's meaning in on-line sentence comprehension. The evidence found in the above experiment suggests that the category-driven hypothesis does not hold in its current form.

Note that although I didn't find evidence for either the context-dependent model, the language-driven hypothesis, or category-driven hypothesis, the fact that I didn't *cannot* be attributed to lack of sensitivity in the experimental methodology. There are four conditions in this experiment: (1) the experimental word related to the primary meaning, (2) the control word for the primary meaning experimental word, (3) the experimental word related to the secondary meaning, and (4) the control word for the secondary meaning experimental word. The context-dependent model, the language-driven hypothesis, and the category-driven hypothesis all predicted that *only* the experimental word related to the secondary meaning would be faster than its control word. If this had been found, then it would be necessary to ask whether the experiment had been sensitive enough to measure the lexical access effects for the primary meaning relative to its control word. However, what I found was that both the primary meaning and the secondary meaning was available at the offset of the ambiguous word, even when the context was strongly biased towards the secondary meaning of the ambiguity. The fact that both experimental groups were facilitated relative to their respective control groups indicates that the experiment was sensitive enough to capture this facilitation.

6. CONCLUSION

The experimental evidence presented here demonstrates that both meanings of an ambiguity are accessed at the onset of the ambiguity when the context is biased towards the secondary meaning. This evidence does not support the context-dependent model, which says that contextual bias should aid the processor in selecting a meaning. The data presented here do support an account within a context-independent model.

There are, however, additional questions that may be asked. Although the context-independent and context-dependent models make different predictions, some researchers have argued that the evidence which would seem to support an ordered-access account, which is an account within the context-independent model, is evidence instead for a context-dependent model. For example, Tabossi and colleagues (Tabossi et al. (1987), Tabossi (1988), Tabossi and Zardon (1993)) find that only the contextually appropriate meaning is accessed when the preceding sentential context is biased towards the most frequent meaning of the word, but both meanings are accessed when the context is biased towards the subordinate meaning (which is what the ordered-access account predicts). They argue that this is an instance of the context of the sentence and the frequency of the meaning combining to influence lexical access. Thus, since context is

influencing lexical access at least for the dominant meaning, the data support a context-dependent model. However, as Ahrens (1998) points out, no conclusion can be reached until an experiment is run where the sentence is biased towards the fourth meaning of a word. The ordered-access account says that if any subordinate meaning is selected, all the more dominant meanings must also be accessed. But if context and frequency in combination are the critical factor, then the fourth meaning and the first meanings should be accessed (that is, only the contextually appropriate meaning and the most frequent meaning). This latter case, called the frequency and context account, would be evidence for a context-dependent model of language processing.¹⁸

Thus, in order to determine whether the multiple-access account or the ordered-access account is the correct one, the sentential context must be biased towards the primary meaning. If only the contextually appropriate meaning is obtained, that would be evidence for an ordered-access model, and then a further experiment would need to be run to distinguish between the ordered-access account and the frequency and context account. If, however, both meanings are primed, that would be evidence for the multiple-access account. I am currently running experiments designed to answer these questions.

The data found here refute several hypotheses. The first is the interactionist account of lexical ambiguity resolution in natural speech comprehension. It has been argued both here and elsewhere (Ahrens (1998)) that there is no on-line natural speech comprehension evidence for interactive lexical ambiguity resolution. Whenever the bias is towards the secondary meaning of the ambiguity, both meanings are always primed relative to their controls. This holds for English, Italian, Cantonese, and Mandarin.¹⁹ There is also no evidence that the context-prominence of a language allows context to access only the contextually appropriate meaning (i.e., the language-driven hypothesis). Finally, there is no evidence that the lexical category of the ambiguous word allows context to influence which meaning will be accessed (i.e., the category-driven hypothesis). In sum, all work to date argues for a context-independent, modular model of lexical access in on-going speech comprehension.

There are, however, issues concerning lexical ambiguity resolution that still need to be investigated. First, as I mentioned above, there is the issue of which account within the context-independent model is more appropriate. Second, there is the issue of the speed of lexical ambiguity resolution. Ahrens (1998) postulates that the context-prominence of a language might allow the processor to select the contextually appropriate meaning faster, *after* all meanings have been accessed, as compared with languages which

rely less heavily on context for interpretation (i.e., the Speeded-selection hypothesis). This hypothesis explains why, for example, Li and Yip (1996) find that lexical ambiguity resolution has occurred as early as the offset of the ambiguous word for Cantonese but that in English both meanings are still accessed at the offset (Swinney (1979), Onifer and Swinney (1981), Love and Swinney (1996)). Third, there is the issue of timing concerning not only the position of the probe point but also the length of presentation of the visual probe. Most studies that have argued for a multiple-access account presented the probe for 1000ms or less. However, studies that have argued for a modified selective-access account have all had the visual probe presented for 1500ms or longer. These timing issues are critical to understanding the time course of lexical ambiguity resolution. My hypothesis is that the differing position on modularity and interaction will be resolved once these time course issues are clarified. I am currently running studies designed to examine these issues related to timing. (See also Ahrens (1999b)).

Lastly, there is one caveat. Even if the lexical ambiguity resolution data turns out to be conclusively on the side of the modularity hypothesis for natural speech comprehension, it does not necessarily mean that all cognitive processing, or even all language processing, is carried out in a modular fashion. Tanenhaus and Lucas (1987) review experiments that test the modularity hypothesis at several different levels and tentatively conclude that modularity (or interactiveness) is not necessarily a design characteristic of the language-processing system but instead may result from the relationship among representations. However, finding that lexical access occurs independently of context suggests that the benefits of a modular architecture are enough that this type of architecture is used to keep the discourse and lexical levels distinct in the case of speech comprehension.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the support of research grants from National Chung Cheng University during 1995–1996, from National Taiwan University during 1996–1997, and from the National Science Council during 1998–1999 (#87-2411-H-002-030-M7) and during 1999–2000 (#88-2411-H-002-051-M8). I would also like to thank the International Association of Chinese Linguistics for providing me with a travel grant to present my work at the Seventh International Conference of Chinese Linguistics at Stanford University in June 1998. Thanks also go to Jean Hsu and Douglas Chiu for their assistance in collecting the data presented here. I am grateful to Chu-Ren Huang, Tracy Love, and Dave Swinney, and three anonymous

reviewers for their comments on the work presented here. I would also like to thank Gu-Jing Lin, Vicky Tzuyin Lai, and Dora Lu for their help in formatting the final version of this manuscript. Remaining errors are my sole responsibility.

NOTES

¹ For discussion of differing accounts within a context-dependent model, please refer to section 6 of this paper and to Ahrens (1998, 1999b).

² Scholars who have reviewed the findings on lexical ambiguity resolution, such as Simpson (1994), or who have performed a meta-analysis on previous lexical ambiguity resolution data (Lucas (1999)) have conflated the two modalities, which has led them to conclude that the data support an interactionist account. However, Ahrens (1998) argues that it is inappropriate to conflate the modalities because "(a) there are different areas in the brain that deal with auditory and visual stimuli; (b) speech (or sign language) production and comprehension is learned earlier than reading; and (c) that speech (or sign language) is the basis for learning how to read." An additional reason has to do with the time course of reading comprehension, which is carried out at slower speed than listening comprehension. Thus, the time course of lexical ambiguity resolution in reading comprehension is a different question from that of speech comprehension and should be examined separately.

³ Subjects on average press the word or non-word button (or say the word in a naming task) 550–650ms after seeing the visual probe while listening to an on-going sentence, and a disyllabic word is, on average, 400–600ms long.

⁴ The fact that only the contextually appropriate meaning was available at the offset of the ambiguity might be due to sentential wrap-up effects, as the ambiguity was positioned at the last word of each sentence. However, as an anonymous reviewer points out, Seidenberg et al. (1982) did find evidence for multiple access in a cross-modal naming task in English at the sentence-final position. One, perhaps crucial, difference between these two experiments is that Seidenberg et al.'s presentation time of the visual target was either a maximum of 1000 ms or 700 ms while Li and Yip's visual target presentation time was a maximum of 2000 ms. Ahrens (1999b) postulates that the length of visual target presentation in the Li and Yip experiment might be so long that what is being measured are post-lexical effects.

⁵ Li (1998) argues that using a cross-modal naming task interfered with listening to the ambiguous word when the visual target presentation occurred at the onset of the ambiguous word and so discounts the results at the onset. However, interference should mean that the reaction times slowed, but Li and Yip's (1996) results show that the naming times were faster at the onset than the control words. See Ahrens (1999b) for further discussion.

⁶ Li and Yip (1998) have used a cross-modal gating task to look at whether context can influence the interpretation of a gated homophone. A gated naming task is an on-line task, but since the sentence stops at the gated word, it is not considered to be an on-going sentence comprehension task. Furthermore, the task requires subjects to guess the gated word. This integration task is different from the cross-modal lexical decision or naming task, which is a priming task. A gating task requires subjects to be consciously aware of the stimulus they are guessing at. But subjects are not required to be aware of the priming relationship between the auditory ambiguity and the visual target in a cross-modal priming task. In fact, when the visual target presentation time is 300 milliseconds (as in Ahrens (1999b) and the current experiment), it is highly unlikely that the subjects notice such a priming relationship. See Ahrens (1999b) and Hillert (1998) for further discussion.

⁷ See Ahrens (1998, 1999b) for a different interpretation of the Italian results.

⁸ Bates et al. (1991) use the data they obtain from aphasic speakers of Mandarin Chinese to propose that the action naming deficits in Broca's aphasics and the object naming deficits

in Wernicke's aphasics are better explained by a lexical categorical account than by the traditional grammatical account (i.e., that Broca's aphasics have trouble naming open-class words, and Wernicke's aphasics have trouble naming closed-class words.)

⁹ "Off-line" refers to the fact that the experiment is carried out without timing measurements and that the subjects can finish comprehending the stimuli before providing a response. The order of the two possible meanings was randomly presented so as to avoid ordering effects. See Ahrens (1999a) experiment 2b for further details.

¹⁰ Both Bernard Victorin (p.c.) and an anonymous reviewer point out that the types of meaning changes inherent in (3b) and (3c) are different (i.e., (3b) involves a metaphorical meaning change of the subject, and (3c) involves a non-canonical but literal interpretation of the verb). They suggest that it is not surprising that the subjects choose the non-canonical but literal interpretation. However, there is no evidence in the literature that suggests that a literal, non-canonical interpretation should be preferred over a metaphorical interpretation (see Gibbs (1994) for further discussion of how metaphors are interpreted with respect to literal language). In addition, there was no preference for (3b) or (3c) found in a separate ratings task, which indicates that the preference for either interpretation is roughly the same when the subjects are not forced to make a decision. What is important for the discussion here is that the subjects choose the interpretation where verb meaning changed when they were forced to do so. Since this experiment was modeled on Gentner and France (1988), similar sentence types were used. Future work can explore the coercion effect with different sentence types.

¹¹ Mandarin Chinese is the official language that is spoken throughout China and Taiwan by the majority of speakers, who may in addition speak another regional dialect. In this paper, I focus on the Mandarin Chinese that is spoken in Taiwan.

¹² This means that 40% of the subjects gave a different meaning for their first choice response (i.e., they gave either the secondary meaning or an entirely different meaning), and 50% of the subjects gave a different meaning for their second choice response (i.e., they gave either the primary meaning or an entirely different meaning). The critical point for this experiment, however, is that 60% of the subjects listed the same meaning first, and 50% listed the same meaning second.

¹³ The verbs are more equi-biased in their meanings than the nouns used in Tabossi et al. (1987), for example, where both the primary and secondary meanings were given by 75% of the subjects.

¹⁴ Tabossi et al. (1987) first used this completion criterion in order to ensure that the preceding sentential context was biased enough to potentially influence lexical access.

¹⁵ Space considerations preclude publication of all the experimental stimuli. However, interested readers may request a copy from the author.

¹⁶ The assumption is that the subjects could not score 80% or above on this test unless they were listening carefully to the content of all 42 sentences, especially since these sentences were approximately 60–80 characters in length.

¹⁷ In addition, example number 12 was also screened from the data because during the running of the experiment, it came to my attention that the word *bishi* 'test' was used as a control word when the context of the sentence had to do with teachers and classmates encouraging another student to do well in a competition.

¹⁸ Please see Ahrens (1999b) for further discussion of the possible accounts within the context-dependent model. Note that it is also possible to use words with three meanings as well to distinguish between these two hypotheses.

¹⁹ In the case of Cantonese, Li and Yip (1996) found that both meanings were accessed at the onset of the ambiguity, but only the contextually appropriate meaning was accessed at the offset. As discussed in endnote 5, Li and Yip (1998) emphasize the result at the offset while I am referring to their results at the onset.

REFERENCES

- Ahrens, Kathleen (1998) "Lexical Ambiguity Resolution: Languages, Tasks and Timing," in D. Hillert (ed.), *Sentence Processing: A Cross-linguistic Perspective*, Academic Press, pp. 11-31.
- Ahrens, Kathleen (1999a) "The Mutability of Noun and Verb Meaning," in *Chinese Languages and Linguistics V: Symposium Series of the Institute of Linguistics* (Preparatory Office), Number 2, Academia Sinica, Taipei, pp. 335-371.
- Ahrens, Kathleen (1999b) "Timing Issues in Lexical Ambiguity Resolution," paper presented at the International East Asian Psycholinguistics Workshop, Ohio State University, to appear in M. Nakayama (ed.), *Sentence Processing in East Asian Languages*, CSLI, Stanford.
- Bates, Elizabeth, Sylvia Chen, Quid Tzeng, Ping Li and Meiti Opie (1991) "The Noun-Verb Problem in Chinese Aphasia," *Brain and Language* 41, 203-233.
- Bates, Elizabeth, Antonella Devescovi and Simona D'Amico (1999) "Processing Complex Sentences: A Cross-linguistic Study," *Language and Cognitive Processes* 14(1), 69-123.
- Bates, Elizabeth, Sandra McNew, Brian Machinney, Antonella Devescovi, and Stan Smith (1982) "Functional Constraints on Sentence Processing: A Cross-linguistic Study," *Cognition* 11, 245-299.
- CKIP (1993) *Corpus-Based Frequency Count of Words in Journal Chinese*, Academia Sinica, Chinese Knowledge Information Processing Group, Taipei.
- Fodor, Jerry (1983) *Modularity of the Mind*, MIT Press, Cambridge.
- Gentner, Dedre (1982) "Why Nouns are Learned before Verbs: Linguistic Relativity Versus Natural Partitioning," in S. A. Kuczaj (ed.), *Language Development: Volume 2, Language, Thought and Culture*, Lawrence Earlbaum Associates, Hillsdale, NJ, pp. 301-334.
- Gentner, Dedre and Irene France (1988) "The Verb Mutability Effect," in S. Small et al. (eds.), *Lexical Ambiguity Resolution*, Morgan Kaufmann Publishers, San Mateo, pp. 343-382.
- Gibbs, Raymond (1994) *The Poetics of the Mind: Figurative Thought, Language and Understanding*, Cambridge University Press, Cambridge.
- Gopnik, Alison and Soonja Choi (1995) "Names, Relational Words and Cognitive Development in English and Korean Speakers: Nouns are not Always Learned Before Verbs," in M. Tomasello and W. E. Merriam (eds.), *Beyond Names for Things: Young Children's Acquisition of Verbs*, Lawrence Earlbaum Associates, Hillsdale, NJ, pp. 63-80.
- Hillert, Dieter (1998) "Verb Processing in German and English: Ambiguity, Discontinuous Forms, and Thematic Complicity," in D. Hillert (ed.), *Sentence Processing: A Cross-Linguistic Perspective*, Academic Press, San Diego, pp. 247-263.
- Hogaboam, T. and Charles A. Perfetti (1975) "Lexical Ambiguity and Sentence Comprehension," *Journal of Verbal Learning and Verbal Behavior* 14, 265-274.
- Huang, C.-T. James (1984) "On the Distribution and Reference of Empty Pronouns," *Linguistic Inquiry* 15.4, 531-574.
- Li, Ping and Michael Yip (1996) "Lexical Ambiguity and Context Effects in Spoken Word Recognition: Evidence from Chinese," in G. Cottrell (ed.), *Proceedings of the 18th Annual Meeting of the Cognitive Science Society*, Lawrence Earlbaum Associates, Hillsdale, NJ, pp. 228-232.
- Li, Ping (1998) "Crosslinguistic Variation and Sentence Processing: The Case of Chinese," in D. Hillert (ed.), *Sentence processing: A Cross-linguistic Perspective*, Academic Press, San Diego.
- Li, Ping and Michael Yip (1998) "Context Effects and Processing of Spoken Homophones," in C. K. Leong and K. Tamaoka (eds.), *Reading and Writing: An Interdisciplinary Journal* 10, 223-243.
- Love, Tracy and David Swinney (1996) "Co-reference Processing and Levels of Analysis

- in Object-relative Constructions: Demonstration of Antecedent Reactivation with the Cross-modal Priming Paradigm," *Journal of Psycholinguistic Research* 25(1), 5–24.
- Lucas, Margery (1999) "Context Effects in Lexical Access: A Meta-analysis," *Memory and Cognition* 27(3), 385–398.
- MacWhinney, Brian, Elizabeth Bates, and Reinhold Kliegel (1984) "Cue Validity and Sentence Interpretation in English, German and Italian," *Journal of Verbal Learning and Verbal Behavior* 23, 127–150.
- Marslen-Wilson, William and Lorraine Tyler (1980) "The Temporal Structure of Spoken Language Understanding," *Cognition* 8, 1–71.
- McClelland, James L. and David E. Rumelhart (1981) "An Interactive Model of Context Effects in Letter Perception, Part I. An Account of Basic Findings," *Psychological Review* 88, 375–405.
- McClelland, James L. (1987) "The Case for Interactionism in Language Processing," in M. Coltheart (ed.), *Attention and Performance XII: The Psychology of Reading*, Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 3–36.
- Nicol, Janet, Janet Fodor and David Swinney (1994) "Using Cross-modal Lexical Decision Tasks to Investigate Sentence Processing," *Journal of Experimental Psychology: Learning, Memory and Cognition* 20(5), 1229–1238.
- Onifer, William and David Swinney (1981) "Accessing Lexical Ambiguities during Sentence Comprehension: Effects of Frequency of Meaning and Contextual Bias," *Memory and Cognition* 15, 225–236.
- Ross, John R. (1982) "Pronoun Deleting Processes in German," paper presented at the Annual Meeting of the Linguistic Society of America, San Diego.
- Seidenberg, Mark, Michael Tanenhaus, James Leiman and Marie Bienkowski (1982) "Automatic Access of the Meanings of Ambiguous Words in Context: Some Limitations of Knowledge-based Processing," *Cognitive Psychology* 14, 489–537.
- Simpson, Greg (1981) "Meaning Dominance and Semantic Context in the Processing of Lexical Ambiguity," *Journal of Verbal Learning and Verbal Behavior* 20, 120–136.
- Simpson, Greg (1994) "Context and the Processing of Ambiguous Words," in M. Gernsbacher (ed.), *Handbook of Psycholinguistics*, Academic Press, San Diego, pp. 359–374.
- Swinney, David (1979) "Lexical Access during Sentence Comprehension: (Re)consideration of Context Effects," *Journal of Verbal Learning and Verbal Behavior* 18, 645–660.
- Tabossi, Patrizia (1988) "Accessing Lexical Ambiguity in Different Types of Sentential Context," *Journal of Memory and Language* 27, 324–340.
- Tabossi, Patrizia, Lucia Colombo and Remo Job (1987) "Accessing Lexical Ambiguity: Effects of Context and Dominance," *Psychological Research* 49, 161–167.
- Tabossi, Patrizia and Francesco Zardoni (1993) "Processing Ambiguous Words in Context," *Journal of Memory and Language* 32, 359–372.
- Tanenhaus, Michael and Margery Lucas (1987) "Context Effects in Lexical Processing," *Cognition* 25, 213–234.

Received: May 27, 1998

Revised: March 20, 2001

Graduate Institute of Linguistics
National Taiwan University
1 Roosevelt Road, Section 4
Taipei 106, Taiwan
E-mail: ahrens@ms.cc.ntu.edu.tw