Horizontal Flow of Semantic and Phonological Information in Chinese Spoken Sentence Production

Jin-Chen Yang and Yu-Fang Yang

Language and Speech 2008 51: 267
DOI: 10.1177/0023830908098543

Horizontal Flow of Semantic and Phonological Information in Chinese Spoken Sentence Production

Jin-Chen Yang[1,2], **Yu-Fang Yang**[1]

[1] *Institute of Psychology, Chinese Academy of Sciences, Beijing, China*
[2] *Graduate University of Chinese Academy of Sciences, Beijing, China*

Key words

lexical access

phonological facilitation

semantic interference

sentence production

Abstract

A variant of the picture–word interference paradigm was used in three experiments to investigate the horizontal information flow of semantic and phonological information between nouns in spoken Mandarin Chinese sentences. Experiment 1 demonstrated that there is a semantic interference effect when the word in the second phrase (N3) and the first noun in the initial phrase (N1) are semantically related, while there is no effect when N3 and the second noun in the initial phrase (N2) are semantically related. Experiments 2 and 3 showed that there is a phonological facilitation effect only when the two phonologically related words are both in the initial phrase, and there is no effect when they are in different phrases. Reinforcing the findings of an earlier study of horizontal information flow by Smith and Wheeldon (2004), our results indicate that there is a temporal overlap in the access of the nouns in spoken Mandarin Chinese sentences and a flow of semantic and phonological information between these nouns. Moreover, our results are incompatible with a wholly parallel view of horizontal information flow and instead provide support for a view which is partly serial and partly parallel in nature.

1 Introduction

There are two kinds of information flow during speech production: vertical and horizontal information flow (Smith & Wheeldon, 2004). In vertical information flow, information flows across different processing stages within a unit such as a single word and influences the processing at those stages. Many studies of vertical information flow, for instance, have investigated whether the processing of a lemma during the grammatical planning stage is influenced by the selection of the phonemes corresponding to that lemma during phonological planning (e.g., Dell, 1986; Roelofs,

Acknowledgements: This study was supported by Grant 30370481 and 60175013 from the National Natural Science Foundation of China to Yu-Fang Yang. We are extremely grateful to Dr. Mark Smith and the other two anonymous reviewers for their constructive suggestions.

Address for correspondence. Yu-Fang Yang, State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China; e-mail: <yangyf@psych.ac.cn>.

Language and Speech 0023–8309; Vol 51(3): 267–284; 098543; DOI:10.1177/0023830908098543
http://las.sagepub.com

1992). In contrast, horizontal information flow concerns the flow of information between the units of a sentence regardless of whether those elements are drawn from the same or different processing stages. For example, Rapp and Samuel (2002) demonstrated that the selection of a lemma during a sentence completion task is influenced by phonological information flowing from a lexeme at an earlier point in the sentence. As Levelt and Meyer (2000) noted, because studies of horizontal information flow concern the production of multiword utterances such as phrases and sentences, they raise two novel questions which studies of vertical information flow in single words do not. First, does the access of different words in a sentence occur in a parallel or a serial fashion? For instance, in producing the phrase "the book and the pipe," will the time at which "book" is accessed overlap with the time at which "pipe" is accessed? Second, does the access of the different words in a sentence occur in an interactive or a discrete fashion? For instance, in producing the phrase "the book and the pipe," will the processing of "book" interact with and influence the processing of "pipe"? Note that these two questions, while distinct, are interconnected: if there is no temporal overlap in the processing of two words, there cannot be any interaction in their processing either.

Evidence for the discrete and serial view of the production of multiword utterances has been provided by a number of experimental studies. Eye-tracking studies by Meyer et al. (Meyer, Sleiderink, & Levelt, 1998; Meyer & van der Meulen, 2000), for instance, provided support for a serial rather than parallel view of multiple-word access. In these studies, Meyer et al. showed that participants producing phrases such as "arm and boat" begin to process the second word only after the semantic and phonological processing of the first word have been completed. Levelt and Meyer (2000) subsequently proposed that the functional significance of this serial processing is to spread the processing load evenly during the production of a phrase or a sentence, even though it runs the risk of disfluency. However, Meyer and Dobel (2003) provided evidence that people can retrieve an object name's information before fixing upon it. As Smith and Wheeldon (2004) have noted, such a finding indicates that studies such as Meyer et al. (1998, 2000) do not provide unambiguous evidence for a serial view of multiple word access in utterance production such as that proposed by Levelt (2001).

A number of studies have also provided evidence for a parallel and interactive view of multiword production. Martin, Weisberg, and Saffran (1989) asked participants to describe scenes consisting of six object pictures using continuous sentences and showed that there are more substitution errors between two words with both semantic and phonological similarities such as "scarf" and "sweater." This mixed speech error suggests that there is an interaction between semantic and phonological processing of the two nouns within the utterance. Schriefers (1993) reported that if the selection of a sentence-initial determiner within a noun phrase is constrained by the interference between the target word and distractor in a picture–word interference task, its access will be delayed. This result again indicated that the access of a lemma could interact with and be influenced by the access of other lemmas within that sentence. Vigliocco, Vinson, Indefrey, Levelt, and Hellwig (2004) used a continuous naming paradigm and showed that the semantic intruder's grammatical gender is consistent with that of the intended word in producing nouns with determiners marked for gender. This result suggested an interaction between the semantic and grammatical

information of a determiner and a noun. As already noted, Rapp and Samuel (2002) asked participants to complete some printed sentences missing a word and they revealed that lemma access is affected by phonological features of a prior lexeme within the same sentence.

Further evidence for horizontal information flow was provided by a set of four picture–word interference experiments by Smith and Wheeldon (2004), in which subjects were requested to describe the movement of a picture and a word using a sentence. Unlike the standard picture–word interference paradigm, the picture and word in their study were not spatially superposed. When the word and the picture name were semantically related in Experiments 1 and 2, sentence production latencies were longer than those in the unrelated condition. This semantic interference effect was obtained both when the nouns occurred in the same initial phrase of a sentence (e.g., in sentences such as "the book and the pipe move up") and when they occurred in two distinct phrases (e.g., in sentences such as "the book moves above the pipe"). In two further experiments, they showed that only when the two lexemes were in the same phrase would a phonological similarity between two lexemes result in shorter sentence production latencies. Both the semantic interference effect and the phonological facilitation effect provided evidence of temporal overlap and interactive horizontal information flow during sentence production. The results further suggested that there is a different scope to the horizontal flow of semantic and phonological information, with the former occurring between elements within the same sentence, while the latter is restricted to elements drawn from within the same phrase.

In the current set of experiments, we adapt the design employed by Smith and Wheeldon (2004) to further investigate horizontal information flow. Our study differs from that of Smith and Wheeldon (2004) and other studies of horizontal information flow in that we test between two different views of horizontal information flow. On one such view, horizontal information flow is wholly parallel. For instance, if there is a sentence which features a sentence-initial noun (N1), a sentence final noun (N3) and a noun in between these two (N2). According to the wholly parallel view of horizontal information flow, the three lemmas in such a sentence will be accessed simultaneously and information will flow between them. Thus, as N1 is being accessed information from it is flowing into and influencing the access of N2 and N3. At the same time, however, N2 is being accessed and information from it is flowing into and influencing the access of N1 and N3 while N3 is also being accessed and information from it is flowing into and influencing the access of N1 and N2.

A more serial view of horizontal information flow is, however, also possible. It could be, for example, that the access of N1 is initiated prior to and yet nevertheless overlaps with the access of N2 and N3. On such a view, N2 and N3 could be partially activated (perhaps for instance they are activated as concepts rather than as lemmas) while the lemma corresponding to N1 is being accessed. If this were so, semantic information from N2 and N3 could flow into and influence the access of the lemma corresponding to N1. Once the N1 lemma has been accessed, the N2 lemma could subsequently be accessed. At this point, information from the N1 lemma and the partially activated N3 concept could flow into and influence the access of the lemma corresponding to N2. Subsequently, the N3 lemma would be accessed and this in turn would be influenced by information flowing from the N1 and N2 lemmas.

Our study tests between the wholly parallel and partly serial views of horizontal information flow in contrast to previous studies such as Smith and Wheeldon (2004). Because the sentences in Smith and Wheeldon's study featured only two nouns, they did not test between the parallel and serial views of horizontal information flow. Thus, the semantic interference effect they observed could have resulted if semantic information from N2 had disrupted the access of the N1 lemma (i.e., the serial view) but it could also have resulted if both N1 and N2 had interfered with other's access (i.e., the parallel view). In our experiment, we set up a design in which participants produced sentences featuring three nouns corresponding to three elements of a visual display (e.g., "The *peacock* and the *corn* are on the right of the *phoenix*") to test between the serial and parallel views. It was reasoned that if we observed a semantic interference effect between N1 and N3 but no such effect found between N2 and N3, this would be consistent with the serial view but not with the parallel view. Specifically, such a finding would be consistent with the view that, prior to speech onset, semantic information from N3 had influenced the lemma access of N1 but not N2 (i.e., the serial view). However, it would be inconsistent with the view that, prior to speech onset, semantic information from N3 had influenced the lemma access of both N1 and N2 (as required by the parallel view). In contrast, if a semantic interference effect was observed both between N1 and N3 and between N2 and N3, it would be consistent with the parallel view. Specifically, it would be consistent with the view that semantic information from N3 had influenced the lemma access of both N1 and N2 prior to speech onset as the parallel view requires. Effectively, then, the current design allows us to distinguish between the two parallel and interactive views of sentence generation which differ significantly in the extent to which they are parallel and interactive.

2 Experiment 1

Experiment 1 investigated horizontal information flow by manipulating the semantic relationship between three nouns in different positions of Mandarin Chinese spoken sentences. As described above, we aimed to test whether a semantic interference effect would be observed both between N3 and N1 and between N3 and N2 prior to speech onset. To affect this test, two pictures and a two-character Chinese word which served as distractor were presented simultaneously on the computer screen. In the study of Smith and Wheeldon (2004), the elements of their visual array moved. For example, in their Experiment 1, speakers produced sentences such as "the saw and the axe move down" when a picture of a saw and a word "axe" moved vertically in the same direction, and when the two objects moved horizontally in opposite directions speakers produced sentences such as "the saw moves towards the axe". Although they conducted a second experiment which suggested that the interference effect observed in Experiment 1 was not affected by the movement differences, such movement still has the potential to act as a confounding variable. Removing it therefore allows for a cleaner and less ambiguous test of horizontal information flow. So, in our current study, the three objects to be described in one sentence did not move.

In our Experiment 1, the two pictures and the distractor word were on three vertexes of an equilateral triangle whose center was in the middle of the computer

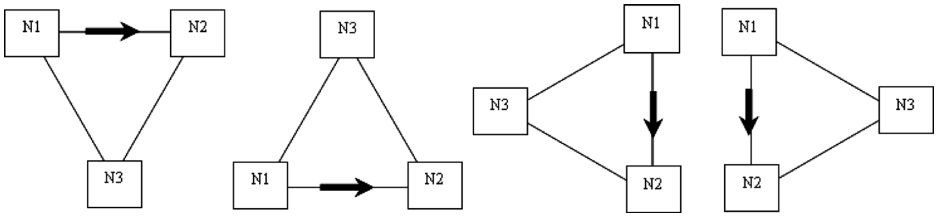
screen (see Figure 1). Four kinds of such equilateral triangles were designed, as shown in Figure 2. Two pictures were always on the two vertexes, which were in the vertical or the horizontal line and the word was on the other vertex. So there were four possible location relationships between the pictures and the word: above, below, right and left. Participants were instructed to describe the location of the two pictures relative to the word in a sentence with identical syntactic form: *N1 and N2 are above (below, on the left or the right of) N3.* Both N1 and N2 were in the initial phrase and N3 was in another phrase.

Figure 1

Example display of three objects to be described with the sentence "孔雀和玉米在凤凰的右边" (The peacock and the corn are on the right of the phoenix) (the background of the scene was black)

Figure 2

The four kinds of location relationships between the two pictures and the distractor word (the pictures were always positioned as shown by the vertical or the horizontal lines): above, below, right, and left. The arrows indicate the directions of description (neither of the boxes, arrows, or lines was provided as part of the visual array)



The distractor word (N3) was semantically related to either the first picture's name (N1) (condition 1), second picture's name (N2) (condition 2) or neither of them (condition 3). For example:

Condition 1: 孔雀和玉米 在凤凰的 右边

(The peacock and the corn are on the right of the phoenix)

Condition 2: 孔雀和玉米 在高粱的 右边

(The peacock and the corn are on the right of the sorghum)

Condition 3: 孔雀和玉米 在牙膏的 右边

(The peacock and the corn are on the right of the toothpaste)

The sentence production latency was defined as the duration from the onset of stimuli to the beginning of the description. Comparing the latencies in three conditions allowed us to test for horizontal information flow between the three nouns in the sentence and thereby between the wholly parallel and partly serial views of horizontal information flow.

2.1 Method

2.1.1 Materials

Sixty pictures were selected from 320 pictures that were mainly from Snodgrass and Vanderwart (1980) and measured with Chinese subjects by Zhang and Yang (2003). All the experimental pictures in the present experiment and the following two experiments had two-character names in Mandarin Chinese because although Chinese characters are basic writing units and are regarded as morphemes, more than 70% of Chinese words are two-character. There is abundant evidence that multimorphemic words in Mandarin Chinese are represented as precompiled entries in mental lexicon (Zhang & Peng, 1992; Zhou & Marslen-Wilson, 1994, 1995; Liu & Peng, 1997; Wei, 2002).

Fifteen pairs of pictures with two-character names were experimental pictures (see Appendix A). Within each pair, there was neither a semantic nor a phonological relationship between the two pictures, and the two-character word was either semantically related to one of the picture's name or to neither of them. There were 45 such two-character words with an average frequency count of 30 occurrences per million. Thirty pictures and 45 words were used as fillers.

2.1.2 Design

There were one practice block and three experimental blocks in the current experiment. Each experimental block consisted of 120 experimental trials and 80 filler trials. Each combination of pictures and word was presented once in the four location relationships

which are shown in Figure 2. The two pictures in each experimental picture pair were presented equally in the positions of N1 and N2. There were three unrelated objects (picture or word) in filler trials. All trials had been pseudo-randomly distributed to reduce the participants' prediction.

2.1.3 Procedures

Before testing began, we had participants learn all the pictures that would be used in the experiment until they could name these pictures smoothly with given names. They were then instructed that they would see two pictures and one word presented simultaneously on the computer screen on each trial, and the task was to describe the position of the two pictures relative to the word. The description should start after speakers had seen all of the three objects and their positions. The order of description was always from left to right or top to bottom (see Figure 2). At the beginning of each trial, a cross appeared in the center of the screen for 600 ms followed by a blank screen for 300 ms. Then two pictures and a word were presented synchronously and lasted 4000 ms. There was a blank screen which was displayed for 2000 ms and which served as an interval before the onset of the next trial. Subjects were tested individually in a quiet room.

2.1.4 Participants

Twenty-five university students were recruited. They were native Mandarin Chinese speakers and were paid for their participation in the experiment.

2.2 Results

Three participants with error rates higher than 25% were excluded from the data. If, on a particular trial, a participant did not use the expected picture names or the expected syntactic structure, or disfluency occurred, the data from the trial was regarded as an error and was excluded. In this way 2.6% of the data was excluded. Data beyond three standard deviations (SD) was also excluded. This accounted for 2.7% of the data. Mean latencies and SD are shown in Table 1.

Table 1

Mean and SD of latencies for Experiment 1

	Mean (ms)	*SD (ms)*
N3 related to N1	1265.4	271.3
N3 related to N2	1236.6	266.6
Unrelated	1229.5	264.6

An ANOVA was carried out on the data. The main effect of the semantic relationship between nouns in different positions was significant, $F_1(2, 42) = 10.7$,

$p < .001$ and $F_2(2, 28) = 11.7$, $p < .001$. Latencies in condition (1) (i.e., the N3 word was semantically related to N1) were longer than those in condition (2) (i.e., the N3 word was semantically related to N2), $F_1(1, 21) = 11.5$, $p < .01$, and $F_2(1, 14) = 7.5$, $p < .05$. The latencies in condition (1) were also significantly longer than those in the unrelated condition, $F_1(1, 21) = 19.3$, $p < .001$, and $F_2(1, 14) = 25.9$, $p < .001$. However, there were no significant differences between latencies in condition (2) and those in the unrelated condition, $F_1(1, 21) = 0.4$, $p > .05$, and $F_2(1, 14) = 3.0$, $p > .05$.

2.3 Discussion

In Experiment 1, it was observed that there is a significant interference effect when the word in the second phrase (i.e., N3) and the first picture name in initial phrase (i.e., N1) are semantically related, while there is no such interference effect when N3 and the second picture name in initial phrase (i.e., N2) are semantically related.

In line with Smith and Wheeldon (2004), our study demonstrated that a semantic interference effect can occur between two words in different phrases of a sentence. This indicates that there is some degree of temporal overlap in the access of several words at different positions in a sentence and that there is an interactive information flow between them.

The absence of semantic interference effect between N2 and N3 demonstrates that semantic information from N3 can influence the lemma access of N1 but not N2 before speech onset. As argued in the introduction, such a result is compatible with a partly serial view of horizontal information flow but not a wholly parallel view.

3 Experiment 2

In Experiment 2, we employed the same paradigm as that used in Experiment 1 to test the phonological facilitation effect between different words in Chinese spoken sentence production. Previous studies (e.g., Smith & Wheeldon, 2004) suggested that the phonological effect can only be obtained within the same phrase, so the distractor word in the current experiment was in the position of the second noun in the initial phrase of a sentence (i.e., N2). The three objects were presented simultaneously on a computer screen as one of the four kinds of equilateral triangles shown in Figure 2. However, the initial picture and the word were always on the two vertexes that were either in the vertical or the horizontal line, and the second picture was on the other vertex. The task was to describe the initial picture and the word's location relative to the final picture. The description directions were the same as those in Figure 2.

Peng et al. (1994) used a repetition priming task and showed that the priming effect of the constituent single character and that of the whole word to a target two-character word are equal. They also proposed a position effect, that is, the priming effect to the initial character in a two-character word is greater than that to the second character. Therefore, the distractor word (N2) in this experiment was a single character, which was phonologically related to either the first character of the first picture's name (N1) (condition 1), second picture's name (N3) (condition 2) or neither of them (condition 3). In the phonologically related conditions, most of the distractor words and the first

character of the target words were homophonic, and the rest had identical syllables but different tones.

Participants were required to describe the location relationship in a sentence with the same definite syntactic structure as that in Experiment 1. For example:

Condition 1: 孔雀(**kong**.que)和恐(**kong**) 在玉米(yu.mi)的 右边

(*The peacock and the kong are on the right of the corn*)

Condition 2: 孔雀(kong.que)和寓(**yu**) 在玉米(**yu**.mi)的 右边

(*The peacock and the yu are on the right of the corn*)

Condition 3: 孔雀(kong.que)和官(guan) 在玉米(yu.mi)的 右

(*The peacock and the guan are on the right of the corn)*

3.1 Method

3.1.1 Materials

Twelve pairs of pictures were selected from those used in Experiment 1 for the current experiment (see Appendix B). Thirty-six single-character words were used as distractors, which had phonological relationships either with the initial character of one of the two pictures' names, or with neither of them. The average frequency count of the words was 32 occurrences per million. Fillers were a further 24 pictures and 36 words which were either single-character, two-character, or three-character.

3.1.2 Design

There were three experimental blocks each with 96 experimental trials and 64 filler trials. The other experimental controls were the same as those in Experiment 1.

3.1.3 Participants

There were 20 paid university students. The procedure was the same as that for Experiment 1.

3.2 Results

Three participants with error rates higher than 25% were excluded from the data. Using the same criteria as in Experiment 1, 3.1% of the data were regarded as errors and excluded. Data beyond three standard deviations (SD) was also excluded. This accounted for 2.7% of the data. Mean latencies and SD are shown in Table 2.

Table 2
Mean and SD of latencies for Experiment 2

	Mean (ms)	*SD (ms)*
N2 related to N1	1223.9	211.5
N2 related to N3	1233.8	212.0
Unrelated	1242.0	225.2

ANOVA showed that the main effect of the phonological relationship between nouns in different positions was significant, $F_1(2, 32) = 2.2$, $p < .05$, and $F_2(2, 22) = 2.3$, $p < .05$. In addition, latencies in condition (1) (i.e., the distractor character was phonologically related to N1) did not show any significant difference from those in condition (2) (i.e., the distractor character was phonologically related to N3), $F_1(1, 16) = .1$, $p > .05$, and $F_2(1, 11) = .6$, $p > .05$. But latencies in condition (1) were shorter than those in the unrelated condition: $F_1(1, 16) = 7.6$, $p < .05$, and $F_2(1, 11) = 10.1$, $p < .05$. Also there were no significant differences between latencies in condition (2) and those in the unrelated condition: $F_1(1, 16) = 1.9$, $p > .05$, and $F_2(1, 11) = 1.0$, $p > .05$.

3.3 Discussion

The result of Experiment 2 demonstrated that there is a significant facilitation effect when the distractor character in the second noun position (N2) is phonologically related to the picture's name in the first noun position (N1). There is no such effect when the distractor character in the second noun position (N2) is phonologically related to the picture's name in the third noun position (N3). The effect between N1 and N2 demonstrates that there is a temporal overlap in the phonological planning of the two nouns within the sentence-initial phrase prior to speech onset and that there is a horizontal flow of phonological information between them. The present experiment also failed to observe a phonological facilitation effect between nouns from different phrases. Consistent with the results of Smith and Wheeldon (2004, Experiments 3 and 4), the current experiment indicates that there is phonological effect only when the related two words occur in the same sentence-initial phrase. Such a finding suggests that, in contrast to the semantic interference effect observed between N3 and N1 in Experiment 1, no phonological facilitation effect would be observed between N1 and N3. We conducted a final experiment to test this directly.

4 Experiment 3

To test whether the initial word's phonological processing can be influenced by a word beyond the first phrase, the same paradigm used in Experiment 2 was employed in this experiment. The distractor word was also a single-character word, but it was in the position of the third noun in the sentence (i.e., N3). The character (N3)

was phonologically related to the initial character of the first picture's names (N1) (condition 1), second picture's name (N2) (condition 2), or neither of them (condition 3). N1 and N2 were in the same initial phrase. In conditions 1 and 2, the distractor character and the first character of the target word were either homophonic or had identical syllables but different tones. There would be three kinds of description sentences:

Condition 1: 孔雀*(**kong**.que)*和玉米*(yu.mi)* 在恐*(**kong**)*的 右边

(*The peacock and the corn are on the right of the kong*)

Condition 2: 孔雀*(kong.que)*和玉米*(**yu**.mi)* 在寓*(**yu**)*的 右边

(*The peacock and the corn are on the right of the yu*)

Condition 3: 孔雀*(kong.que)*和玉米*(yu.mi)* 在官*(guan)*的 右边

(*The peacock and the corn are on the right of the guan*)

4.1 Method

The materials, design and procedures were the same as those in Experiment 2.

4.1.1 Participants

There were 25 paid university students.

4.2 Results

Two participants with error rates higher than 25% were excluded from the data. Using the same criteria as in Experiment 1 and 2, we excluded 1.9% of the data as error trials and 2.5% of the data for being beyond three standard deviations. Mean latencies and SD are shown in Table 3.

Table 3

Mean and SD of latencies for Experiment 3

	Mean (ms)	*SD (ms)*
N3 related to N1	1249.8	315.4
N3 related to N2	1256.3	319.8
Unrelated	1259.1	327.4

An ANOVA showed no significant main effect of the phonological relationship between nouns in different positions, $F_1(2, 44) = .8$, $p > .05$, and $F_2(2, 22) = 0.9$, $p > .05$.

4.3 Discussion

Experiment 3 demonstrated that there is no facilitation effect when the distractor character in the third noun position (N3) is phonologically related to the picture's name in either the first noun position (N1) or in the second noun position (N2). The result of this experiment, together with that of Experiment 2, provides no evidence of a horizontal flow of phonological information between nouns in different phrases. In the current experiment, this failure to observe such an effect is obtained even when the target word is in the initial position of the sentence. As such, it reinforces the results of Experiments 3 and 4 reported by Smith and Wheeldon (2004) in a more complex sentence production task. The results of the current experiment are also consistent with observations of speech errors and experimental studies which have claimed that phonological planning units comprise not more than one or two words within a phrase (e.g., Meyer, 1996).

5 General discussion

The current study was conducted in order to explore how semantic and phonological information flows across a sentence and influences word access. To explore such horizontal information flow we used a variant of the picture–word interference paradigm developed by Smith and Wheeldon (2004). In a number of respects, the results we observed reinforced those obtained by Smith and Wheeldon. Thus, in Experiment 1 we observed, like Smith and Wheeldon (2004, Experiments 1 and 2), a semantic interference effect between words drawn from phrases at the opposite ends of a sentence. Also, in Experiment 2 and 3, we observed a phonological facilitation effect between words within the same phrase but not between words from distinct phrases – a result which again parallels that observed by Smith and Wheeldon (2004, Experiments 3 and 4). As Smith and Wheeldon observed, such findings have a number of implications. First, they indicate that prior to speech onset, phonological planning is confined to the initial phrase of a sentence (cf. also Meyer, 1996) but that some form of higher level planning (which is certainly conceptual but may also be grammatical in nature, see below for further discussion) extends beyond the first phrase across the entire sentence prior to speech onset. Second, such results indicate that there is at least some degree of temporal overlap in the planning of the various words in a sentence. At the level of phonological planning, our results indicate that the words in the initial phrase of a sentence are produced to some extent simultaneously. At a higher planning level (either conceptual or grammatical – it is difficult to be certain on the basis of a semantic interference effect alone), our results indicate that there is some degree of temporal overlap in the planning of the words right across the sentence. Third, our results indicate that there is an interactive flow of information across the sentence. Specifically, prior to speech onset, there is a flow of phonological information between the words in the initial phrase and a flow of semantic information between words from different phrases. Importantly, while our results do reinforce those of Smith and Wheeldon in these respects, they do so in the context of a significantly different design. Thus, our design differed from that of Smith and Wheeldon in removing the potential confound of picture movement.

As well as replicating the data from Smith and Wheeldon's study in these respects, however, the current study also probed an entirely novel issue. As mentioned in the introduction, we modified Smith and Wheeldon's design so that participants were required to name three elements in a visual array (e.g., "The *peacock* and the *corn* are on the right of the *phoenix*") rather than two. Whereas the effects observed by Smith and Wheeldon always involved the first noun in a sentence, our design allowed us to test for effects not involving the first noun in a sentence. Doing so produced some striking results. Thus, in Experiment 1, 2, and 3, we observed semantic interference effects and phonological facilitation effects between N1 and another noun (just like Smith and Wheeldon). However, in all three experiments, we failed to observe any such effects when they did not involve N1 but rather N2 and N3 instead. As argued in the introduction, such a finding is not consistent with a wholly parallel view of horizontal information flow. On such a view, information from all three nouns influences the access not only of N1, but of N2 and N3 also. If this were the case, we would expect effects to be obtained not only between N1 and N3 but also between N2 and N3. The fact that we have observed no effects between N2 and N3 is incompatible with a wholly parallel view of horizontal information flow. It instead suggests a partially serial view of horizontal information flow. In the introduction, we sketched out one such view. On this view, semantic information from the concepts corresponding to N2 and N3 flows into and influences the access of the lemma corresponding to N1 prior to speech onset. However, at this point in speech production, information is not flowing into and influencing the access of the lemmas corresponding to N2 and N3. Rather, on such a partially serial view, while the concepts underlying the three nouns are activated in parallel, the lemmas corresponding to the three nouns are accessed serially with the N2 and N3 lemmas being accessed only after speech onset.

Such a partially serial view is appealingly simple and, broadly speaking, theoretically plausible (it is for instance compatible with studies suggesting that lemma access is incremental whereas conceptual planning has a clausal scope, e.g., Griffin & Bock, 2000; Smith & Wheeldon, 1999). If we assume that semantic interference effects are observed during lemma access (cf. Damian, Vigliocco, & Levelt, 2001, for evidence to this effect), such a view enables us to explain both why an effect is observed between N1 and N3 (i.e., because N1 undergoes lemma access prior to speech onset) but not between N2 and N3 (i.e., because neither N2 nor N3 undergoes lemma access prior to speech onset). However, a number of problems attach to interpreting the current set of results in this way. Thus, although it is reasonable to assume that prior to speech onset lemma access is conducted for N1, we have no direct evidence that prior to speech onset N2 and N3 are only activated as concepts and not as lemmas. Moreover, the view that the second noun in the initial phrase of a sentence is accessed only as a concept prior to speech onset is particularly problematic given studies suggesting that lemma access may be carried out for both nouns in a coordinate noun phrase prior to speech onset (e.g., Smith and Wheeldon, 1999). Such a view is also incompatible with the results of Experiment 2 from the current study. In this experiment, we observed a phonological facilitation effect obtained between N1 and N2 (cf. also Smith & Wheeldon, 2004, Experiments 3 and 4), which indicated that prior to speech onset N2 had to some extent been phonologically planned. Such phonological planning of N2 is clearly incompatible with the view that prior to speech onset N2 is activated

only as a concept and not as a lemma. Such findings, then, work against the version of the partially serial view sketched in the introduction and suggest that we need a different version of this view in which N2 is accessed both as a lemma and as a lexeme prior to speech onset.

Obtaining this modified version of the partially serial view is, however, not without its problems. In particular, if we assume that N2 is activated as a lemma prior to speech onset, it raises the question of why we failed to observe a semantic interference effect between N2 and N3 in Experiment 1. To put it another way, why does N3 interfere with the lemma access of N1 but not N2 prior to speech onset? One (admittedly speculative) possibility is that information from N3 interacts with N1 prior to speech onset but does not interact with N2 until some later point after speech onset. On such a view, we would observe a semantic interference effect between N2 and N3 but only in a design which could track sentence production after speech onset (e.g., an eye-tracking design or a design measuring the time taken to complete the sentence).

This in turn raises the further question of why the information from N3 would bypass N2 prior to speech onset. One possibility is that at this point a speaker is primarily concerned with the selection of the N1 lemma and is using information from N2 and N3 to inform this selection. In selecting a lemma, it is not enough for speakers to ensure that it is compatible with the lexical concept underlying it (i.e., that it expresses the same meaning) and that it is compatible with the syntactic structure in which it is embedded (e.g., that it has the correct grammatical category). Speakers must also check that the lemma fits with other neighboring lemmas. That is to say, lemma selection is determined by semantics, syntax, and collocational structure (Sinclair, 1991). Consider, for instance, the following example from Smith (2000, p. 344):

(1) By night/At night/By day/*At day, Montreal is a thriving city.

In selecting the initial preposition, a speaker must look ahead to the following noun and avoid selecting "at" if the following noun is "day" because the two lemmas do not collocate in English. A failure to check ahead in this way can lead to a variety of speech errors such as grammatical incoherence (Brown, 1980; Smith, 2000) and apokoinu (De Smedt, 1996). The current results are compatible with the view, then, that while selecting N1 the speaker is checking it against the N2 lemma and against the N3 lexical concept. If it checks out, the speaker commits to the articulation of N1 and moves on to the selection of N2. After speech onset, N2 is now checked against its immediate lexical environment just as N1 was. But it is not checked against the members of its immediate lexical environment such as N3 until this point (and hence no semantic interference effect between N2 and N3 is seen prior to speech onset). Presumably carrying out all of this checking prior to speech onset would lead to unacceptable delays in speech onset which the more incremental approach avoids. All of this is, of course, somewhat speculative and other more plausible accounts may be possible. Nevertheless, it does illustrate that versions of the partially serial view of horizontal information flow can be developed which do accord with the results from the current experiment. In contrast, no version of the wholly parallel view is in line with the results of the present study – the current data is simply incompatible with this view in all its forms.

In summary, the current study builds on the work presented in Smith and Wheeldon (2004). Our data replicates their data in respect of issues of scope, temporal overlap, and horizontal information flow in spoken sentence production. It does so, moreover, in the context of an improved design which is not susceptible to a potential movement confound. Moreover, our study also tests between a partially serial and a wholly parallel view of horizontal information flow and finds in favor of the former. Our study also raises a number of interesting questions about the exact nature of this partially serial view of horizontal information flow but, quite clearly, new studies employing new designs will be required to get at these questions.

References

BROWN, E. K. (1980). Grammatical incoherence. In H. W. Dechert & M. Raupach (Eds.), *Temporal variables in speech: Studies in honour of Frieda Goldman-Eisler* (pp. 28–38). The Hague: Mouton.

DAMIAN, M. F., VIGLIOCCO, G., & LEVELT, W. J. M. (2001). Effects of semantic context in the naming of pictures and words. *Cognition*, **81**, B77–B86.

De SMEDT, K. (1996). Computational models of incremental grammatical encoding. In T. Dijkstra and K. de Smedt (Eds.), *Computational Psycholinguistics.* (pp. 279–307). London: Taylor and Francis.

DELL, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review*, **93**, 283–321.

GRIFFIN, Z. M., & BOCK, K. (2000). What the eyes say about speaking. *Psychological Science*, **11**, 274–279.

LEVELT, W. J. M. (2001). Spoken word production: A theory of lexical access. *Proceedings of the National Academy of Sciences*, **98**, 13464–13471.

LEVELT, W. J. M., & MEYER, A. S. (2000). Word for word: Multiple lexical access in speech production. *European Journal of Cognitive Psychology*, **12**, 433–452.

LIU, Y., & PENG, D. (1997). Meaning access of Chinese compounds and its time course. In H. Chen (Ed.), *Cognitive processing of Chinese and related Asian languages* (pp. 219–232). Hong Kong: The Chinese University Press.

MARTIN, N., WEISBERG, R. W., & SAFFRAN, E. M. (1989). Variables influencing the occurrence of naming errors: Implications for models of lexical retrieval. *Journal of Memory and Language*, **28**, 462–485.

MEYER, A. S. (1996). Lexical access in phrase and sentence production: Results from picture–word interference experiments. *Journal of Memory and Language*, **35**, 477–496.

MEYER, A. S., & DOBEL, C. (2003). Application of eyetracking in speech production research. In J. Hyona, R. Radach, & H. Deubel (Eds.), *The mind's eye: Cognitive and applied aspects of eye movement research* (pp. 239–251). Amsterdam: Elsevier.

MEYER, A. S., SLEIDERINK, A. M., & LEVELT, W. J. M. (1998). Viewing and naming objects: Eye movements during noun phrase production. *Cognition*, **66**, B25–B33.

MEYER, A. S., & van der MEULEN, F. F. (2000). Phonological priming effects on speech onset latencies and viewing times in object naming. *Psychonomic Bulletin and Review*, **7**, 314–319.

PENG, D. L., LI, Y. P., & LIU, Z. Z. (1994). Identification of Chinese two-character word under repetition priming condition. *Acta Psychologica Sinica*, **26**, 393–400.

RAPP, D. N., & SAMUEL, A. G. (2002). A reason to rhyme: Phonological and semantic influences on lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **28**, 564–571.

ROELOFS, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition*, **42**, 107–142.

SCHRIEFERS, H. (1993). Syntactic processes in the production of noun phrases. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **19**, 841–850.

SINCLAIR, J. M. (1991). *Corpus, concordance and collocation*. Oxford, UK: Oxford University Press.

SMITH, M. (2000). Conceptual structures in language production. In L. Wheeldon (Ed.), *Aspects of language production* (pp. 331–374). Hove, UK: Psychology Press.

SMITH, M., & WHEELDON, L. (1999). High level processing scope in spoken sentence production. *Cognition*, **73**, 205–246.

SMITH, M., & WHEELDON, L. (2004). Horizontal information flow in spoken sentence production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **30**, 675–686.

SNODGRASS, J. G., & VANDERWART, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity and visual complexity. *Journal of Experiment Psychology: Human learning memory*, **6**, 174–215.

VIGLIOCCO, G., VINSON, D. P., INDEFREY, P., LEVELT, W. J. M., & HELLWIG, F. (2004). Role of grammatical gender and semantics in German word production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **30**, 483–497.

WEI, L. X. (2002). The bilingual mental lexicon and speech production process. *Brain and Language*, **81**, 691–707.

ZHANG, B. Y., & PENG, D. L. (1992). Decomposed storage in the Chinese lexicon. In H. C. Chen, & O. J. L. Tzeng (Eds.), *Language processing in Chinese* (pp. 131–149). The Netherlands: North-Holland, Elsevier.

ZHANG, Q. F., & YANG, Y. F. (2003). The determiners of picture-naming latency. *Acta Psychologica Sinica*, **35**, 447–454.

ZHOU, X. L., & MARSLEN-WILSON, W. (1994). Words, morphemes and syllables in the Chinese mental lexicon. *Language and Cognitive Processes*, **9**, 393–422.

ZHOU, X. L., & MARSLEN-WILSON, W. (1995). Morphological structure in the Chinese mental lexicon. *Language and Cognitive Processes*, **10**, 545–600.

Appendix A: Fifteen picture–word pairs used in Experiment 1

Picture 1	*Picture 2*	*Word 1*	*Word 2*	*Word 3*
梯子 (ladder)	香蕉 (banana)	台阶 (step)	菠萝 (pineapple)	染料 (dyestuff)
帆船 (sailboat)	骆驼 (camel)	游轮 (cruise ship)	牦牛 (yak)	原油 (crude oil)
栅栏 (fence)	燕子 (swallow)	围墙 (wall)	麻雀 (sparrow)	石灰 (lime)
书包 (schoolbag)	靴子 (boot)	钢笔 (pen)	丝袜 (stockings)	山峰 (mountaintop)
孔雀 (peacock)	玉米 (corn)	凤凰 (phoenix)	高粱 (sorghum)	牙膏 (toothpaste)
犀牛 (rhinoceros)	教堂 (church)	大象 (elephant)	寺庙 (temple)	梅花 (plum blossom)
冰箱 (refrigerator)	皮带 (belt)	空调 (air-conditioner)	裤子 (trousers)	陶瓷 (porcelain)
小鸡 (chicken)	拇指 (thumb)	大雁 (wild goose)	手掌 (palm)	波涛 (billow)
毛衣 (sweater)	火柴 (match)	外套 (overcoat)	香烟 (cigarette)	大米 (rice)
窗户 (window)	小号 (trumpet)	门帘 (portiere)	笛子 (flute)	沙滩 (beach)
桌子 (table)	拉链 (zipper)	椅子 (chair)	纽扣 (button)	刊物 (journal)
凳子 (stool)	西瓜 (watermelon)	沙发 (sofa)	荔枝 (lychee)	枕头 (pillow)
眼睛 (eye)	花生 (peanuts)	嘴唇 (lip)	瓜子 (melon seeds)	图纸 (blueprint)
大衣 (coat)	蛋糕 (cake)	衬衫 (shirt)	饼干 (biscuit)	乌鸦 (crow)
南瓜 (pumpkin)	毛笔 (paintbrush)	茄子 (eggplant)	墨水 (ink)	悬崖 (cliff)

Appendix B: Twelve picture–word pairs used in Experiments 2 and 3 (Chinese characters with phonemic notation Pinyin in parentheses)

Picture 1	*Picture 2*	*Character 1*	*Character 2*	*Character 3*
梯子 (ti.zi)	香蕉 (xiang.jiao)	踢 (ti)	厢 (xiang)	针 (zhen)
帆船 (fan.chuan)	骆驼 (luo.tuo)	番 (fan)	锣 (luo)	害 (hai)
栅栏 (zha.lan)	燕子 (yan.zi)	诈 (zha)	宴 (yan)	雾 (wu)
书包 (shu.bao)	靴子 (xue.zi)	舒 (shu)	穴 (xue)	扯 (che)
孔雀 (kong.que)	玉米 (yu.mi)	恐 (kong)	寓 (yu)	官 (guan)
犀牛 (xi.niu)	教堂 (jiao.tang)	溪 (xi)	轿 (jiao)	坡 (po)
冰箱 (bing.xiang)	皮带 (pi.dai)	饼 (bing)	脾 (pi)	球 (qiu)
小鸡 (xiao.ji)	拇指 (mu.zhi)	晓 (xiao)	墓 (mu)	糖 (tang)
桌子 (zhuo.zi)	拉链 (la.lian)	浊 (zhuo)	辣 (la)	碑 (bei)
凳子 (deng.zi)	西瓜 (xi.gua)	邓 (deng)	惜 (xi)	柳 (liu)
眼睛 (yan.jing)	毛笔 (mao.bi)	演 (yan)	矛 (mao)	铜 (tong)
大衣 (da.yi)	蛋糕 (dan.gao)	搭 (da)	旦 (dan)	姓 (xing)