

# How does Prosody Distinguish Wh-question from Wh-declarative in Shanghai Chinese

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## Abstract

Wh-words are ambiguous between interrogative and indefinite interpretations in Shanghai Chinese. This paper compares the prosody of wh-interrogative with wh-indefinite in string-identical wh-questions and wh-declaratives, to further our understanding of the interface between semantics and prosody. Results showed that the semantic distinction is realized through information packaging. The wh-interrogative is by default the focus with prosodic prominence (longer duration, larger f<sub>0</sub> range, and higher f<sub>0</sub>), whereas the wh-indefinitive can never attract focus. Specifically, its following noun is focal and prosodically accented.

**Index Terms:** wh-word, Shanghai Chinese, prosody, focus

## 1. Introduction

It has been widely acknowledged that wh-words are ambiguous between interrogative and indefinite interpretations in many wh-in-situ languages (such as Korean: [1]; Japanese: [2]; Chinese: [3]). Take Korean for example, the wh-word “nwukwu” is ambiguous between an interrogative reading ‘who’ and an indefinite reading ‘someone’. Thus, the sentence in (1) can be interpreted as: i) a wh-declarative with an indefinite reading, and ii) a wh-question with an interrogative reading [1].

- (1) Yuna-ka nwukwu-lul mann-a  
 Yuna-NOM who -ACC meet-INT  
 i) Yuna is seeing someone. [wh-declarative]  
 ii) Who is Yuna seeing? [wh-question]

Therefore, a question is raised about how speakers differentiate this semantic ambiguity (indefinite vs interrogative) when they occur in syntactically identical sentences. Previous studies demonstrated that this semantic ambiguity can be differentiated by prosodic features such as pitch accent, boundary tones, and phonological phrasing.

For instance, Korean utilizes pitch accents and prosodic phrasing to differentiate wh-questions and declaratives containing wh-words: a wh-word bears a high-pitch accent in a wh-question, while it bears a low-pitch accent in wh-declaratives. Furthermore, accentual phrasings are deleted following the wh-interrogatives [1, 4], as illustrated in Figure 1. Similarly, in Japanese, a wh-word displays a sharp rise of f<sub>0</sub> in a wh-question, followed by post-focal reduction which suppresses all lexical accents up to the end. At the end of the wh-question, an interrogative rise intonation is added, terminating post-focal reduction [5], as illustrated in Figure 2.

Different from Korean and Japanese, which are intonation language and pitch accent language respectively, Mandarin Chinese is a tonal language with four lexical tones: High, Rise, Low, and Falling [6]. Since the fundamental frequency in tonal languages carries the function of lexical differentiation in addition to indicating intonation, the study of its prosody is

more complex. So far, there are only three studies investigating the prosody of wh-question and wh-declarative in Mandarin Chinese: [3], [7] and [8]. Results showed that wh-declaratives differ from wh-questions in terms of prosodic properties from the clause onset. (1) Wh-declaratives are longer than wh-questions starting from the subject and the pattern reverses at the wh-word. (2) Wh-declaratives are lower in f<sub>0</sub> and smaller in f<sub>0</sub> range than wh-questions at the wh-word and there is a f<sub>0</sub> range compression in the post-wh-word region in wh-questions. (3) Wh-declaratives show a larger intensity range than wh-questions at the verb and the pattern reverses at the wh-word [3].

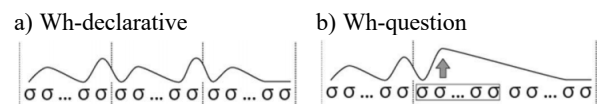


Figure 1: The typical prosody pattern of a wh-declarative (a) and a wh-question (b) in Korean. The vertical dash line indicates the boundary of Accentual Phrases. The syllables surrounded by the box indicate the wh-phrase (cited from [1]).

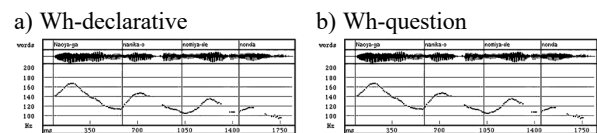


Figure 2: The prosody pattern of the wh-declarative (a) “Naoya-ga nani-o nomiya-de nonda.” (Naoya drank something) and the wh-question (b) “Naoya-ga nani-o nomiya-de nonda no?” (What did Naoya drink). (cited from [5]).

Overall, a general tendency can be summarized from these languages that wh-words are foci in wh-questions and are prosodically accented with raised f<sub>0</sub> and expanded pitch range, but they cannot be foci in wh-declaratives as they are realized with compressed pitch contours. Furthermore, the post-wh-word region adaptations show language-specific features, such as the deletion of accentual phrases in Korean and the compression of the pitch range in Japanese and Mandarin Chinese.

To further our understanding of the interface between semantics and prosody, more cross-linguistic data is needed. Therefore, we take Shanghai Chinese as the object of study to shed some new light.

Shanghai Chinese, a Northern Wu dialect of Chinese, is spoken in the metropolis of Shanghai with a population of 20 million. In contrast to Mandarin Chinese, it has five citation tones [9] and its tonal system can be summarized by three sets

of features (see Table 1): (1) Pitch register: high tones (T1, T2 and T4) with modal phonation and low tones (T3 and T5) with breathy phonation. (2) f0 contour: falling (T1) and rising (T2-T5). (3) Duration: Long tones (T1, T2 and T3), which occur in open or nasal-closed syllables [CV(N)], and short tones (T4 and T5), only occur in syllables closed by a glottal coda [CV?]. Furthermore, when syllables are combined into words, left-dominant tone sandhi rules are applied, which spreads the tonal contour of the initial syllable across the entire word [10, 11]. [12] proposed three types of prosodic units in Shanghai Chinese (prosodic word, prosodic phrase and intonational phrase) and tone sandhi only occurs within the prosodic word.

Table 1. *The value of citation tones and sandhi tones (using Chao's five-level numerical scale, which divides a speakers pitch range into five scales with 5 indicating the highest and 1 the lowest).*

Register	Tone type	Citation tone	Sandhi tone (T+X)
High	T1 [HM]	53	55+31
	T2 [MH]	34	33+44
	T4 [Hq]	55	33+44
Low	T3 [LM]	13	22+44
	T5 [LMq]	12	11+13

All in all, the distinctive prosodic features of Shanghai Chinese make it an intriguing case for investigating the interface between semantics and prosody. Specifically, whether and how do speakers use prosodic cues to distinguish wh-questions from wh-declaratives in Shanghai Chinese when they occur in syntactically identical sentences?

## 2. Methodology

### 2.1. Stimuli

Each stimulus sentence consists of 11 syllables, forming 6 constituents: subject, VP, wh-phrase, object 1, preposition, and object 2, as illustrated in Table 2. Each sentence has both interrogative and indefinite interpretations. Take Stimuli IV for example, it could be interpreted as a wh-declarative “Old Wang bought several pieces of cake for Old Zhang.” or as a wh-question “How many pieces of cake did Old Wang buy for Old Zhang?”. For the speakers to produce sentences with correct semantics and intonation, each stimulus sentence is embedded in two dialogues. The wh-declarative is the answer to the question “What did Old Wang do?”.

Table 2. *Stimulus sentences*

	Subject	VP	Wh-phrase	Object 1	Prep	Object 2
I	老王 /lɑ <sup>22</sup> pɑ <sup>44</sup> / Old Wang	偷了 /tho <sup>55</sup> lɑ <sup>25</sup> / stole	几条 /ci <sup>33</sup> di <sup>34</sup> / how many/several	香烟 /ci <sup>33</sup> ie <sup>51</sup> / Cigarette	给 /pɑ <sup>25</sup> / for	老张 /lɑ <sup>22</sup> tsɑ <sup>44</sup> / Old Zhang
II	老王 /lɑ <sup>22</sup> pɑ <sup>44</sup> / Old Wang	偷了 /tho <sup>55</sup> lɑ <sup>25</sup> / stole	几块 /ci <sup>33</sup> kue <sup>44</sup> / How many/several	蛋糕 /de <sup>22</sup> gɑ <sup>44</sup> / cake	给 /pɑ <sup>25</sup> / for	老张 /lɑ <sup>22</sup> tsɑ <sup>44</sup> / Old Zhang
III	老王 /lɑ <sup>22</sup> pɑ <sup>44</sup> / Old Wang	买了 /mɑ <sup>22</sup> lɑ <sup>24</sup> / bought	几条 /ci <sup>33</sup> di <sup>34</sup> / how many/several	香烟 /ci <sup>33</sup> ie <sup>51</sup> / Cigarette	给 /pɑ <sup>25</sup> / for	老张 /lɑ <sup>22</sup> tsɑ <sup>44</sup> / Old Zhang
IV	老王 /lɑ <sup>22</sup> pɑ <sup>44</sup> / Old Wang	买了 /mɑ <sup>22</sup> lɑ <sup>24</sup> / bought	几块 /ci <sup>33</sup> kue <sup>44</sup> / How many/several	蛋糕 /de <sup>22</sup> gɑ <sup>44</sup> / cake	给 /pɑ <sup>25</sup> / for	老张 /lɑ <sup>22</sup> tsɑ <sup>44</sup> / Old Zhang

### 2.2. Subjects and recording procedures

Five male and five female speakers, between the ages of 25 to 45, participated in the study. Both their parents and they were born and raised in urban areas of Shanghai. They were paid for their participation, and none reported any hearing, vision, or

reading deficiencies. The recording was conducted in the sound booth at Tongji University. Each participant wore a Sennheiser PC 300 high-quality headset microphone that was positioned a constant distance (about 5 cm) from the speaker's mouth.

The sentences were presented in PowerPoint slides in a randomized order. Every participant was required to understand the meaning first and then read the material aloud in a natural way. Following a 5-minute break, the participants read the material again in a different random order. Therefore, we achieved 4 stimulus sentences \* 2 context conditions \* 10 speakers \* 2 times = 160 sentences.

### 2.3. Data analysis

The acoustic analysis was done in Praat [13]. Four layers were manually labeled (see Figure 3): (1) segment; (2) syllable; (3) prosodic word; (4) sentence. Then the Praat script "ProsodyPro" [14] was run, and it automatically provided us with (1) accurate f0 tracks by measuring f0 (Hz) at 10 equidistant points of the vowel; (2) max f0 (Hz), min f0 (Hz) and duration (ms) of each prosodic word; (3) max f0 (Hz), min f0 (Hz) and duration (ms) of the whole sentence.

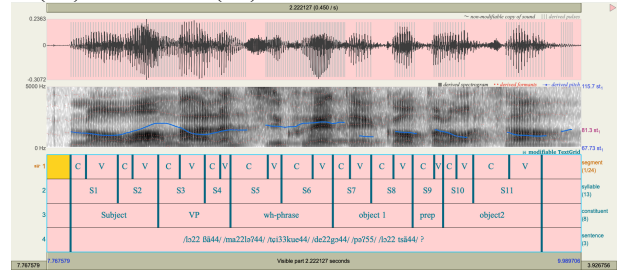


Figure 3. *Spectrogram with superimposed f0 contours of a male speaker.*

Subsequently, the f0 measurements in Hz were converted to semitone relative to 50 Hz using the formula in (1) to better reflect pitch perception [15]. Formula (1) relates frequency in semitones, F, to frequency in Hz, f:

$$F = 12 * \log_2(f/50) \quad (1)$$

Then f0 range of each prosodic word was calculated using the formula in (2):

$$f_0 \text{ range (st)} = \max f_0 \text{ (st)} - \min f_0 \text{ (st)} \quad (2)$$

To eliminate the significant individual differences in duration, the relative duration of each prosodic word was calculated by dividing the absolute value of duration by the average value of each speaker.

Linear mixed-effects models (using lme4 package) were used to investigate how duration and f0 measurements (f0 range, max f0, min f0) were affected by semantic interpretation and sentence intonation. All statistical analyses were carried out in R version 3.3.2 (R Core Team 2016) using the lme4 package version 1.1–12 [16].

## 3. Results

### 3.1. General description

Figure 4 displays the mean f0 contours of each stimulus sentence. These f0 contours were obtained by taking 10 f0 points (in Hz) at proportionally equal time intervals between the acoustic onset and offset of each vowel respectively. These values were then transformed into semitones and then averaged

across speakers and repetitions according to sentence type. There are several things to be noted.

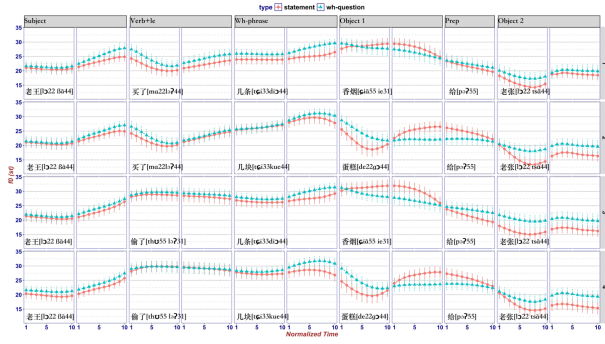


Figure 4: The mean  $f_0$  contours of stimulus sentence. Red lines represent wh-declarative and blue lines represent wh-questions.

The  $f_0$  contours of wh-questions are higher than wh-declaratives starting from the subject and the pattern reverses at object 1. Regarding the part from subject to wh-phrase, the biggest difference between the  $f_0$  contours of wh-questions and wh-declaratives occurs on the second syllable of wh-phrase (i.e. the measure word).

After the wh-phrase, the  $f_0$  curves of the wh-question begin to fall gently until the end of the sentence. In contrast, the  $f_0$  curves of the wh-declaratives show a prosodic accentuation at object 1, which is manifested as high tones higher and low tones lower. Therefore, concerning object 1 “/de<sup>22</sup>go<sup>44</sup>/”, the  $f_0$  curve of the first syllable in the wh-declarative is lower than that in the wh-question, while the curve of the second syllable is higher. Concerning object 1 “/ei<sup>55</sup>ie<sup>31</sup>/”, the  $f_0$  curves of both syllables in the wh-declarative are higher than their counterparts in the wh-question, with the maximum difference occurring on the second syllable. Such phenomenon indicates that object 1 is realized most prosodically prominent in wh-declaratives and it might be the foci.

After object 1, the  $f_0$  curves of the wh-declarative begin to fall sharply until the end of the sentence. Concerning object 2, its  $f_0$  curves in wh-declaratives are much lower than those in wh-questions, which indicates a PFC (post-focus compression) effect. The  $f_0$  contours of the preposition in wh-declarative interpolate between object 1 and object 2, as it is higher than that in wh-question following object 1 “/de<sup>22</sup>go<sup>44</sup>/”, while is lower following object 1 “/ei<sup>55</sup>ie<sup>31</sup>/”.

In sum, the wh-phrase is realized most prominently in wh-questions, while object 1 obtains the prosodical prominence in wh-declarative, which indicates the different focus allocations in two sentence types. Furthermore, the difference between wh-question and wh-declarative starts from the subject, which indicates that the distinction between questions and statements exists at the sentence planning stage.

### 3.2. Quantitative analyses

To verify the above observation, we first selected the relative duration,  $f_0$  range, max  $f_0$ , and min  $f_0$  of the whole sentence as dependent variables. Linear mixed-effects models were conducted on these variables, respectively, with sentence type (wh-declarative vs wh-question) as a fixed factor and with the speaker as a random factor. Results are summarized in Table 3. The duration and  $f_0$  range of the wh-question are significantly smaller than those of the wh-declarative, which is in line with the results of Mandarin Chinese [3]. The min  $f_0$  of

the wh-question is significantly higher, while there is no significant difference in the max  $f_0$ .

Table 3. The effects of sentence type on duration and  $f_0$  measurements of the whole sentence (with wh-declarative as the baseline).

		Estimate	S.E.	t	p
duration	(Intercept)	1.061	0.014	77.725	0.000
	Wh-question	-0.060	0.019	-3.102	0.002
$f_0$ range	(Intercept)	21.626	2.245	9.633	0.000
	Wh-question	-4.456	1.105	-4.032	0.000
max $f_0$	(Intercept)	32.321	2.677	12.074	0.000
	Wh-question	-0.025	0.670	-0.037	0.970
min $f_0$	(Intercept)	10.695	2.460	4.348	0.000
	Wh-question	4.431	0.954	4.645	0.000

Then the same Linear mixed-effects models were conducted on the relative duration,  $f_0$  range, max  $f_0$ , and min  $f_0$  of each prosodic word respectively, with sentence type (wh-declarative vs wh-question) as a fixed factor and with speaker as a random factor.

Concerning the relative duration, the duration of wh-phrase in wh-question (Estimate=0.075, S.E.=0.036,  $t=2.064$ ,  $p=0.039$ ) is significantly longer than that in wh-declarative, while the duration of VP (Estimate=-0.050, S.E.=0.023,  $t=-2.190$ ,  $p=0.029$ ), object 1 (Estimate=-0.202, S.E.=0.028,  $t=-7.276$ ,  $p<0.001$ ) and preposition (Estimate=-0.077, S.E.=0.026,  $t=-2.997$ ,  $p=0.003$ ) in wh-question are all significantly shorter.

Concerning the  $f_0$  range, the  $f_0$  range of wh-phrase in wh-question is significantly larger than that in wh-declarative (Estimate=2.131, S.E.=0.592,  $t=3.599$ ,  $p<0.001$ ), while the  $f_0$  range of preposition (Estimate=-4.408, S.E.=0.691,  $t=-6.380$ ,  $p<0.001$ ) and object 2 (Estimate=-4.436, S.E.=1.032,  $t=-4.297$ ,  $p<0.001$ ) in wh-question are all significantly smaller, as illustrated in Figure 5.

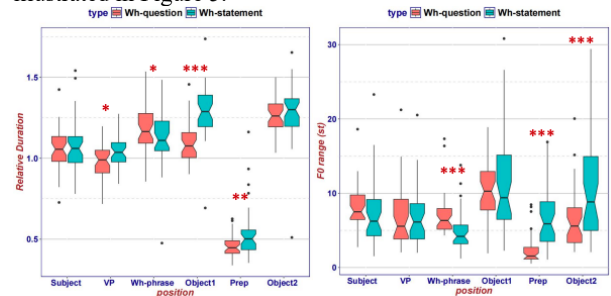


Figure 5: The effects of sentence type on the relative duration (left) and  $f_0$  range (right) of each prosodic word.

Concerning the max  $f_0$  and min  $f_0$ , the max  $f_0$  of subject (Estimate=1.964, S.E.=0.455,  $t=4.320$ ,  $p<0.001$ ), VP (Estimate=1.457, S.E.=0.598,  $t=2.437$ ,  $p=0.015$ ) and wh-phrase (Estimate=2.695, S.E.=0.582,  $t=4.631$ ,  $p<0.001$ ) in wh-question are significantly higher than those in wh-declarative, while the max  $f_0$  of preposition (Estimate=-2.573, S.E.=0.654,  $t=-3.936$ ,  $p<0.001$ ) in wh-question is significantly lower. Meanwhile, the min  $f_0$  of preposition (Estimate=1.835, S.E.=0.910,  $t=2.016$ ,  $p=0.044$ ) and object 2 (Estimate=4.727, S.E.=1.080,  $t=4.375$ ,  $p<0.001$ ) in wh-question are significantly higher than those in wh-declarative, as illustrated in Figure 6.

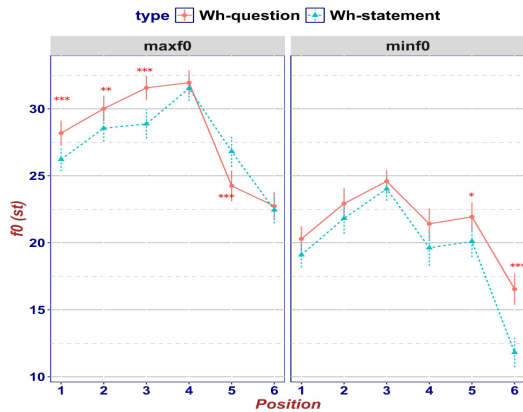


Figure 6: The effects of sentence type on the max f0 (left) and min f0 (right) of each prosodic word. Red lines represent wh-declarative and blue lines represent wh-questions.

#### 4. Discussion

In this paper, we investigated the phonetic realization of wh-word in wh-questions (interrogative reading) and wh-declaratives (indefinite reading), to further our understanding of the interface between semantics and prosody. Our data demonstrated that speakers of Shanghai Chinese do use prosodic features (both global and local ones) to distinguish string-identical wh-declaratives and wh-questions.

The global features include the duration, f0 range, and max f0 of the whole sentence. Specifically, the duration of wh-questions is significantly shorter than that of wh-declaratives. Furthermore, the f0 range of the whole sentence in wh-questions is significantly smaller, which is mainly caused by the raised min f0 in wh-question, as there is no significant difference in the max f0 in the two sentence types, which is consistent with the intonation difference between questions and statements in Mandarin Chinese [17]. In other words, the global features reflect the contrast between interrogative and declarative intonation, rather than the prosodic difference of semantic ambiguity (interrogative vs indefinite).

We further examine the local features of each prosodic word. We found that the max f0 of wh-question is significantly higher than the wh-declarative starting from the subject and the pattern reverses at object 1. In contrast, there is no significant difference in the min f0 in the first half of the sentence until the preposition, where the min f0 of the preposition in the wh-question is significantly higher than that in the wh-declarative. The difference of min f0 between the two sentence types reaches the greatest at the final prosodic word, which indicates that the final prosodic word is the main unit carrying the interrogative intonation.

Furthermore, the local features also reflect the semantic ambiguity (interrogative vs indefinite). In wh-questions, the wh-phrase is realized with significantly longer duration, larger f0 range, and higher max f0, which indicates that the wh-phrase is the most prosodically prominent word. In contrast, the wh-phrase is not accented in wh-declaratives, but its following noun (object 1) is prosodically accented, as evidenced by its significantly longer duration. Although we observed that the f0 contours of object 1 in wh-declarative are realized more distinctively in Figure 4 (i.e. high tones higher and low tones lower), there is no significant difference in f0 range, max f0, and min f0 between the two sentence types. How to explain such a phenomenon? There could be two possibilities. First, the

wh-phrase and its following noun (object 1) form a prosodic phrase. As the wh-phrase is the focus of the wh-question, object 1 is also phonetically enhanced due to the carry-over effect, which caused no significant difference in f0 measurements between object 1 in the two sentence types. Second, it is difficult to prosodically enhance the object as proposed in [18]. Therefore, it relies more on duration adjustments rather than f0 adjustments.

In summary, prosody indeed differentiates wh-declarative from string identical wh-question in Shanghai Chinese. Generally speaking, wh-questions have a shorter duration, a smaller f0 range, and a higher min f0 than wh-declaratives. The max f0 of wh-questions is significantly higher than wh-declaratives starting from the subject and the pattern reverses at object 1. The min f0 of wh-questions is higher than wh-declaratives from the beginning and the difference keeps increasing until it reaches its maximum at the final prosodic word. Two implications can be derived from these results. Firstly, it can be observed that wh-declarative differs from wh-question in terms of prosodic properties from the sentence onset. This indicates that the distinction between question and declarative exists in the sentence planning stage. Secondly, the interrogative intonation is mainly reflected by min f0, especially on the final prosodic word. This is the main unit carrying the interrogative intonation.

Furthermore, the wh-word (interrogative) is the most prominent word in wh-questions, as it has a significantly longer duration, larger f0 range, and higher max f0. In contrast, the wh-word (indefinite) is not accented in wh-declarative, instead, its following noun (object 1) is prosodically accentuated. Such results implicate the different focal status of wh-words in wh-questions and wh-declarative: wh-words are foci in wh-questions but cannot be foci in wh-declarative. In other words, semantics ambiguities (interrogative vs indefinite) are realized through different information packaging, namely the allocation of focus. A questioned constituent (i.e. wh-interrogative in wh-question) is generally assumed to be the focus by default, whereas an indefinite pronoun (i.e. wh-indefinite in wh-declarative) will never attract focus [19]. Such difference could be explained by information load. The questioned constituent carries the most important information in a question and therefore is the information focus. Instead, the indefinite pronoun modifies its following noun and its information load is relatively light, therefore its following noun becomes the information focus.

#### 5. Conclusion

In this paper, we compared the phonetic realization of wh-questions to wh-declaratives, to further our understanding of the relation between semantics and prosody. We found that semantic interpretation is realized through information packaging (specifically focus allocation) and is represented by prosodic features. The wh-word (interrogative reading) in wh-questions is by default the focus with prosodic prominence (i.e. longer duration, larger f0 range, and higher max f0), while the wh-word (indefinite reading) can never attract focus in wh-declaratives. Instead, its following noun (i.e. object 1) is focal and prosodically accented. However, different semantic interpretations cause the string-identical sentences to be wh-question and wh-declarative respectively. It's difficult to say the above prosodic differences are caused by semantic or intonational distinction. Therefore, further investigation is needed, to further our understanding of the interface between semantics and prosody.

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