Research Article

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To stress or not to stress: what can Mandarin pronouns inform us of the accessibility of topic and focus?

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Abstract: Referents with a topical or focused status have been shown to be preferable antecedents in real-time resolution of pronouns. However, it remains unclear regarding whether topicality and focus compete for prominence when co-present in the same narrative, and if so, how differential prominence affects prosodic realization of a subsequent pronoun. Building upon the general understanding that stress on pronouns signals an unusual, less accessible interpretation, we take advantage of the conditional bi-clausal construction in conjunction with homophonic 3rd person pronouns in Chinese. We manipulated the information status of two referents that were introduced into a six-clause narrative in succession, specifically (i) Topic and (ii) Focus, and also (iii) the Reference of the Pronoun (either the first or second referent). Our acoustic analyses showed that pronouns were produced with higher F0s when the first referent was topicalized than when it was not topicalized under conditions where the second referent was focused. Pronouns referring back to the first referent were uttered longer when the referent was not topicalized than when it was topicalized. These results suggest accessibility statuses of referents vary dynamically in response to different prominence-lending cues, and these variations can be captured by the prosodic features of a following pronoun.

Keywords: pronoun; topic; focus; speech production; referential shift

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1 Introduction

Personal pronouns, as a form of anaphora, refer to highly accessible entities in discourse. Upon seeing a pronoun, comprehenders need to search among referential candidates for an appropriate antecedent that it co-refers with in their mental representations of prior discourse. While computing long-distance dependencies is rather taxing, comprehenders can resolve pronoun-antecedent relationship fairly rapidly in real time (e.g., Arnold et al. 2000; Kaiser 2011; Vogelzang et al. 2016), as guided by certain parsing heuristics. For instance, the default interpretation of a pronoun is a highly accessible referent (Ariel 1988, 2001). In sentence processing literature, a referent with either a topical or focused status has been shown to have elevated accessibility, hence a preferable antecedent for a subsequent pronoun (Colonna et al. 2015; Cowles et al. 2007; Kaiser 2011; Rohde and Kehler 2014). However, few studies have investigated cases where both topical and focused referents are present in the same discourse competing for prominence (cf. Arnold 1999; Kaiser 2011), and the results are rather inconsistent, particularly regarding the effect of focus. Thus, it remains unclear how they interact and which referent is preferred by an upcoming pronoun.

One way to address this issue is to investigate the prosodic form of the pronoun. In spoken discourse, pronouns are generally assumed to be unstressed by default (Ariel 1988:79; Gleitman 1965:280; Reinhart 2006:144). But when they get stressed, accentuation signals unusual interpretation (Akmajian and Jackendoff 1970; Gleitman 1965; Kameyama 1999). In other words, only when a pronoun has a non-default interpretation will it receive an accentuation. Built upon these general rules, the current study set out to examine prosodic realizations of pronouns in short Chinese narratives containing topical and focused referents, using prosodic features as a window to evaluating the differential prominence of these two discourse referents.

1.1 Pronoun resolution and the Accessibility Theory

Real-time interpretation of a pronoun, also known as pronoun resolution, can be influenced by a number of factors, including first mention, recency, implicit causality of the verb, syntactic parallelism, thematic role or event structure, and information structure (e.g., Arnold 2001; Caramazza et al. 1977; Colonna et al. 2015; Cowles et al. 2007; Foraker and McElree 2007; Gernsbacher et al. 1989; Gibson et al. 1996; Koornneef and Sanders 2013; Rohde and Kehler 2014; Schumacher et al. 2016). Most of these factors affect pronoun resolution by elevating the accessibility of certain discourse referents and therefore, they can be well captured by the Accessibility Theory

(Ariel 1988). Following von Heusinger and Schumacher (2019), we term such factors as "prominence-lending cues". The stronger and/or larger number of cues a referent contains, the more prominent this referent gets, and hence easier/more accessible for subsequent retrieval.

According to the Accessibility Theory (Ariel 1988:68), "Referring expressions are no more than guidelines for retrievals." Highly accessible entities, when re-mentioned in subsequent discourse, require less lexical information, typically taking shortened or reduced forms such as pronouns or demonstratives. In contrast, full proper names and definite descriptions are reserved for less accessible entities, especially when newly introduced into the discourse. Thus, more attenuated forms of reference – as measured by the amount of lexical information and/or phonological size – mark higher accessibility of its referent (Ariel 1988: 82). Adopting this theory, we assume throughout the current paper that the default interpretation of an unstressed pronoun is the most accessible entity in the discourse.

1.2 Topic and focus in pronoun resolution

As a pair of concepts in the Information Structure Theory (Lambrecht 1994), topic and focus are invested with high accessibility. Topic is defined as what a sentence or discourse is "about" (Gundel and Fretheim 2004:176; Lambrecht 1994), and a topic typically denotes discourse-old information (Chafe 1976; Gundel 1974). In discourse models (e.g., Givón 1983), pronouns are often analyzed as a device for topic continuity because topic is the most accessible referent in interlocutors' minds (Ariel 1988, 2001; Givón 1983; Kaiser 2011). In contrast to the discourse-old topic, focus encodes emphasized, discourse-new information (Jackendoff 1972; Lambrecht 1994) that can be expressed prosodically (Breen et al. 2010; Xu and Xu 2005), or syntactically via 'it'-clefts or *wh*-questions targeting to-be-focused elements (Beier and Ferreira 2022; Cutler and Fodor 1979; Kiss 1998). Compared to non-focused forms, focused information attracts more attention, is more prominent in the mental representation, and hence is better retained in memory for later retrieval (Birch and Garnsey 1995; Káldi and Babarczy 2021). Given its high level of activation and accessibility, a focused item should preferably be the antecedent of a subsequent pronoun. In short, both topical and focused entities are good candidates for antecedents of pronominal forms.

Indeed, evidence from a fair amount of empirical research has shown that topic or focusing can facilitate pronoun resolution. Studies on the effect of topic have been careful to tease apart topicality from subjecthood, as subjecthood is also a prominence-lending cue for candidate antecedents of a pronoun, and tends to co-occur with topicality (Crawley and Stevenson 1990; Järvikivi et al. 2005; Kaiser 2006, 2011). Once disentangled from subjecthood, topic is found to have a facilitative effect

on pronoun resolution independent of subject preference (Rohde and Kehler 2014; Xu 2003; X. Xu 2013). Using a story continuation task, Rohde and Kehler (2014) found that compared to non-topical subjects, topical subjects are more likely to be the antecedent of an upcoming pronoun. This effect of topic on pronoun resolution is found cross-linguistically from corpus distributions or fragment completion (Chinese: Xu 2003; English: Arnold 1999; German: Colonna et al. 2012) and online experiments (Chinese: X. Xu 2013; English: Cowles et al. 2007; Kaiser 2011). However, the effect of focus is not consistent across real-time processing experiments. While some studies found a preference for pronouns to co-refer to focused referents (Blything et al. 2021; Kaiser 2011), others showed an absence of focusing effects when foci are realized as objects rather than subjects (X. Xu 2013), and still others found that focused referents are dispreferred by pronouns occurring in the same sentence (Colonna et al. 2015). These results suggest that the facilitative effect of focus on pronoun resolution is highly susceptible to grammatical role and its position relative to the pronoun.

It is worth noting that few studies have evaluated the strength of both topic and focus, and results are also rather inconsistent. Using cross-model priming, Cowles et al. (2007) found that naming latencies are shorter for both topical referents and focused referents, suggesting a similar psychological effect of topicality and focusing. Using questionnaires,[1] Colonna et al. (2012) found that topicality facilitates pronoun resolution, but contrastive foci are dispreferred by pronouns. The inconsistency in focusing between these two studies might in part be due to inhibitory effects of foci on intra-sentential pronouns, given that foci are preferred by inter-sentential pronouns (Colonna et al. 2015). However, these works remain silent on the issue of possible interaction of topic and focus, as both factors were examined in separate experiments. To our knowledge, only two studies manipulated topic and focus in the same discourse. Arnold (1999) constructed stories containing both discourse topic and contrastive focus, and asked participants to continue the stories. She found that participants tended to use pronouns to refer to discourse topics, and full names to the focused objects, indicative of boosted salience only for topic but not for focus. As noted earlier, the lack of focusing effect is probably due to the regulation of grammatical role: focused antecedents occupying the object position may not be influential enough to impact pronoun resolution. Using visual-world eye-tracking, Kaiser (2011, Experiment 2) investigated potential competitions between topicality and

1 In the target sentences of questionnaires, Colonna et al. (2012) constructed a main clause that contained topic (e.g., '*As for Peter, he has slapped John*') or focus (e.g., '*It is Peter who has slapped John*'), and a subordinate clause containing an ambiguous pronoun (e.g., '*when he was young*'). Then in a following paraphrase of the subordinate clause starting with a gap, participants were asked to fill in the gap that necessitated the resolution of the ambiguous pronoun.

contrastive focusing in dialogues, as in (1) below. Critically in (1b), focus was created by a corrective statement in different syntactic forms (standard SVO or *it*-cleft), and topicality was established by pronominalization (*he/him*) of a discourse-old NP referent introduced earlier uttered by Speaker A – either the subject *Greg* in (i & iii) or the object *Mike* in (ii & iv).

(1) Speaker A: *I heard that Greg congratulated Mike enthusiastically yesterday.*
Speaker B:
a. No, that's not quite right.
b. (i) He congratulated John. [SVO, focus = Object]
(ii) John congratulated him. [SVO, focus = Subject]
(iii) It was John that he congratulated. [Cleft, focus = Object]
(iv) It was John who congratulated him. [Cleft, focus = Subject]
c. The prizes for the best-ranked tennis players were about to be announced, and
d. he was holding a new yellow tennis racket. (Test sentence)
e. Everyone was in a good mood that day.

(from Kaiser 2011: 1648)

Kaiser (2011) found that upon hearing the ambiguous pronoun in the test sentence (1d), participants showed a subject preference in all conditions, regardless of whether contrastive focusing (conveyed in SVO or cleft constructions) was on the subject or object. We note, however, the prominence lending cues are unbalanced for the two referents in (1b). As illustrated in Table 1, the first referent always has two cues (i.e., subjecthood in conjunction with either pronominalized topicality or focusing), whereas the second referent has one cue only (i.e., either focusing or pronominalized topicality). Thus, to compare the relative weight of topicality versus focusing, it is necessary to create a design where topical and/or focused referents are both placed in the subject position.

Table 1: Distribution of prominence-lending cues for the two referents in Exp 2. of Kaiser (2011).

Word order	Grammatical role of focus	Cues for the 1st referent in (1b)	Cues for the 2nd referent in (1b)
SVO	Object	Subject + pronominalized topicality	Focusing
SVO	Subject	Subject + focusing	Pronominalized topicality
Cleft	Object	Subject + pronominalized topicality	Focusing
Cleft	Subject	Subject + focusing	Pronominalized topicality

To sum up, existing research has shown that topicality facilitates pronoun interpretation, and that focusing can have a similar effect only when inter-sentential pronouns are co-referential with subject NPs. However, it remains unclear whether topic and focus – when co-present in a narrative – similarly affect the accessibility of their corresponding referents, and if not, what is their relative weight/strength as prominence-lending cues.

1.3 Stressed pronouns

Apart from psycholinguistic work on real-time pronoun resolution, there has been a long-standing line of research interfacing with acoustic phonetics. Specifically, the prosodic realization of a pronoun can also reveal whether its associated antecedent is the default interpretation or not, because stressed pronouns imply a different interpretation from unstressed counterparts. This generalization has been articulated in different formulations by many researchers. Akmajian and Jackendoff (1970: 124) observed that contrastive stress on nouns or pronouns can each render a different interpretation for subsequent pronouns. Kameyama (1999: 12) posits the Complementary Preference Hypothesis that "a focused pronoun takes the complementary preference of the unstressed counterpart". This hypothesis predicts that when a pronoun is stressed, its antecedent shifts from its default interpretation (i.e., when unstressed), and falls on an alternative NP. A repetition-based account (Gleitman 1965) makes similar predictions: while repeated material is typically left out (i.e., deleted) or unstressed, increase in stress is an indication of non-repetition or contrast. Likewise, the Accessibility Hierarchy (Ariel 1988: 79) also states that when a pronoun is stressed, it is no longer a marker for high accessibility, but rather a marker for mid accessibility. Therefore, if a pronoun is co-referential with an NP whose accessibility is lower than another NP, it receives accentuation.

Predictions of these hypotheses are borne out in empirical studies. In a speech production experiment on Spanish, Rello and Llisterri (2012) found that a pronoun is uttered with prosodic prominence in the presence of an intervenor that competes with its default interpretation for prominence. Gargiulo et al. (2019) investigated pronoun production in languages allowing (Italian) or not allowing (Swedish) null pronouns. They found that regardless of typological distinctions, pronouns in both languages received stressing when referring to non-default interpretations. Similarly, converging evidence from speech production and interpretation in Italian (Goad et al. 2018) and Chinese (Hou et al. 2017) has also shown a correlation between referential shift and the stressing of a pronoun.

Assuming that this correlation indeed exists, it is possible to use prosodic features of pronouns as an indicator for the varying accessibility status of their

antecedents. Topic and focus both have a facilitative effect on pronoun resolution as they increase the accessibility of their corresponding referents. But when both are present in the same discourse, no consensus has reached regarding which is more accessible. To further address this question, we investigate prosodic realizations of Chinese pronouns in narratives with the two salient NPs. Below we first provide a brief background of Chinese pronouns, before presenting bi-clausal constructions that are suitable to examine the issue. Then we outline our experimental design and research hypotheses.

1.4 The Chinese language

In Mandarin Chinese, the third-person singular pronouns 她/他 'she/he' are monomorphemic and more crucially, both are pronounced as [t^ha] in speech, regardless of gender. Thus, these homophonic pronouns provide an excellent opportunity for us to further examine whether and how they are uttered differently when Chinese speakers read them (i.e., disambiguated by their orthographic information in print) out loud, and thus gaining insight into varying accessibility levels of referents that they are associated with.

Chinese pronouns are found to conform to the predictions of the Complementary Preference Hypothesis (see Section 1.3). In a speech production experiment, Hou et al. (2017) manipulated the ambiguity of pronoun (same vs. different gender) and the referential consistency (unchanged vs. switched) to examine their roles in prosodic realization of Chinese anaphors. They found that the subject pronoun *ta* 'he' received more stress (i.e., a higher F0 and longer duration) when referring to the object NP ('Xiao Gang') in the preceding clause, as in (2), than when referring to the subject NP ('Xiao Dang'), which was the default interpretation. Clearly, Chinese speakers are sensitive to referential shift, and they do vary accordingly prosodic forms of shifted elements.

(2) *Kaishi Xiao Dang bei le Xiao Gang, ranhou TA bei le*
first Xiao Dang carry PERF Xiao Gang, then HE carry PERF
XIAO DANG.
XIAO DANG
'First, Xiao Dang carried Xiao Gang, and then he carried Xiao Dang.'
(Hou et al. 2017: 1394)

In Mandarin, sentence topic can be syntactically marked using the so-called bi-clausal (复句 *fuju*) structure, where a pair of conjunctions (e.g., *yinwei…suoyi* 'because…so') occur in two separate clauses. When an NP is placed before a conjunction, it acquires the status of topic. Consider a pair of examples from Xu

(2003) below. The NP '*Xiao Li*' can either (i) precede the conjunction 'because' – resulting in a topic-comment construction as in (3a), or (ii) follow the conjunction, and therefore is not topic marked – resulting in a subject-predicate construction as in (3b).

(3) a. Topic-NP preceding conjunction
Xiao Li yinwei ø bing le, suoyi ta
Xiao Li CONJ-because ZERO-(he) ill ASP so he
buneng lai.
cannot come.
'Xiao Li(topic), because (he) was ill, he couldn't come.'

b. Subject-NP following conjunction
Yinwei Xiao Li bing le, suoyi ta buneng lai.
CONJ-because Xiao Li ill aspect so he cannot come.
'Because Xiao Li was ill, he couldn't come.'
(Xu 2003: 98)

Focusing on cause-effect bi-clausal constructions in the *Corpus of Chinese Newspapers and Periodicals*, Xu (2003) found that pronouns in the second clause are significantly more likely to be coreferential with the topicalized NP (i.e., preceding the conjunction 'because') than with the subject NP (i.e., following the conjunction 'because'). This distributional or interpretation bias is found to guide Chinese comprehenders to process pronouns in cause-effect bi-clausal constructions, as revealed by event-related potentials in X. Xu (2013), where pronouns induced a larger P600 that indexes integration difficulties when referring to non-topic referents than when referring to topic referents, but no effect was found in the subject-predicate structure.

Subsequent corpus investigation on the distributions of different types of Chinese bi-clausal constructions has largely confirmed that such a bias for the coreferential relation exists between the topic NP and the pronoun, except for conditional bi-clausal sentences (i.e., *ruguo…name* 'if…then'), where only a weak topic-pronoun coreference is found (Chen 2012). Thus, this construction provides a good syntactic template for us to further check the strength of topic versus focus in pronoun resolution.

1.5 The current study: an overview

In the present study, we created two narratives, each consisting of four sentences. As each narrative goes, two referents – one with the status of sentence topic (NP1) and the other informational focus (NP2) – are introduced in succession into the discourse as the two salient entities. These two referents have typical names of distinct genders

(e.g., *Lin Xue* as a female; *Zhang Chao* as a male) selected from a list of Chinese names with genders normed by Chang et al. (2020). The final, critical sentence has the above-mentioned *conditional* bi-clausal construction, where we manipulated the information status of Topic by placing the NP1 before or after the conditional conjunction *ruguo* 'if', as shown in (4a–b).

(4) a. Topic-NP1 preceding the conjunction
Lin Xue ruguo zhuyidao zhangmu de quelou, name ta
Lin Xue if noticed account NOM loophole then she
henkuai hui zuo-hao jilu bing yaoqiu zhenggai.
very-quickly will do-well record and request rectification
'Lin Xue, if she noticed loopholes of the account, then she would quickly make a record and request rectification.'

b. Non-topic NP1 following the conjunction
Ruguo Lin Xue zhuyidao zhangmu de quelou, name
if Lin Xue noticed account NOM loophole then
ta henkuai hui zuohao jilu bing yaoqiu zhenggai.
she very-quickly will do-well record and request rectification
'If Lin Xue noticed loopholes of the account, then she would quickly make a record and request rectification.'

Focus is induced by a narrow interrogative question in the preceding discourse, as in (5a), with *shei* 'who' targeting a specific human referent. In the subsequent sentence (6), the NP2 'Assistant Zhang Chao' as a natural response to (5a) provides new information, hence is focused. However, when preceded by a declarative statement as in (5b), the same NP2 in (6) is not focused.

(5) a. Focus-inducing narrow question
shei fuze jiedai gongzuo a?
who responsible reception task Q
'Who is in charge of reception?'

b. Non-focus declarative
xia zhouyi zhiqian yao wancheng jiesuan
next Monday before need finish accounting
'Accounting should be done by next Monday.'

(6) Varying status of the NP2 depending on the preceding clause (5a–b)
Zhuli Zhang Chao fuze jiedai gongzuo. Ta shuxi
assistant Zhang Chao responsible reception task he familiar
liucheng.
process
'Assistant Zhang Chao is in charge of reception. He is familiar with the processes.'

Table 2: Sample item set in English translation (original texts were in Chinese).

	Condition	Example sentence
(1)		Finance Bureau Commissioner Lin-Xue (NP1) went to the insurance company to audit at noon.
(2)	a. Focus	Who is in charge of reception?
	b. Non-focus	The accounting work should be finished by next Monday.
(3)		Assistant Zhang-Chao (NP2) is in charge of reception; he (*ta1*) is familiar with the processes.
(4)	a. Topic	(i) Lin-Xue, if noticed the gaps and omissions of accounting items,
	b. Non-topic	If Lin-Xue noticed the gaps and omissions of accounting items,
	a. pronoun = NP1	(ii) then she (*ta2*) will soon make a record and ask for rectification.
	b. pronoun = NP2	then he (*ta2*) will search through the files and fill in the gaps soon.

A sample narrative is provided in Table 2 (see Section 2.2 for detailed explanation, and Appendix for full sets of experimental conditions). These sentences were to be read out loud by native speakers of Mandarin Chinese who were told to have a listener in mind. Note that for both speakers and listeners, the pronoun in the 3rd sentence (hereafter *ta*1) is unambiguously referring back to *Zhang Chao*. But the target pronoun (hereafter *ta2*) in the critical 4th sentence, though visually gender-marked, is (temporarily) ambiguous for listeners because the orthographic information is unavailable to them (but referential ambiguity will be fully resolved as the narrative comes to an end). Seeing pronominal forms in print (with disambiguating gender), the speakers might utter pronouns differently depending on varying conditions, to help listeners with pronoun resolution (Gargiulo et al. 2019).

1.6 Predictions

Assuming that Chinese speakers are sensitive to explicit gender-marked pronominal forms in varying contexts, we predict that these pronouns will be uttered differently when co-referential with specific NPs in different discourse contexts. Specifically, we expect that when the NP1 is topicalized (e.g. (4a–i) in Table 2), the target pronoun *not* referring back to it will receive stress, and the same should hold true for focusing (e.g., (2a) & (3) in Table 2). In the conditions involving both topicalization and focusing, we expect the two NPs to compete for prominence, and thus the pronoun co-referring with the less prominent NP will receive accentuation. Simply put, we expect to see interactions of various kinds.

To verify that there is indeed competition between topic and focus that leads to stressing of the target pronoun, we also planned to compare the prosodic features of the (temporarily ambiguous) target pronoun to those of the unambiguous pronoun (i.e., ex.[6]), which should be most reduced/unstressed and may serve as a baseline. Following Ariel (1988), in the presence of two referents competing for discourse prominence, regardless of which referent is ultimately resolved as the appropriate antecedent of the pronoun, lower accessibility markers will be employed, rendering the pronoun referring to either of them to be more stressed than unambiguous pronouns. Thus, we expect to see high prosodic prominence for the target pronouns compared to the baseline of unambiguous pronouns.

2 Methods

2.1 Participants

Eighteen native speakers of Mandarin Chinese participated in the experiment, all born and raised in Beijing. They were nine females and nine males aged between 18 and 26 (M = 22, SD = 2.39). No speech or hearing impairments were reported and they received monetary compensation after finishing the experiment.

2.2 Materials

Our experimental stimulus is a narrative consisted of four sentences, where two referents (NP1 and NP2) are introduced in succession. We manipulated three factors: Focus, Topic and Reference Choice. The factor of Focus has two levels: in the Focus condition, the sentence containing the NP2 (e.g., *Zhang Chao* in ex. [6]) is preceded by a narrow interrogative question (ex. [5a]), such that the NP2 as the answer to the question is the focus (see similar designs in Beier and Ferreira 2022; Cutler and Fodor 1979). In the non-Focus condition, the sentence containing the NP2 remains the same (ex. [6]), but it functions as a natural continuation of the preceding declarative statement (ex. [5b]) that does not bias comprehenders' attention or heighten their expectations for the NP2. The factor of Topic, also having two levels, involves manipulation of the position of the NP1 (e.g., *Lin Xue*) in the conditional bi-clausal construction: in the Topic condition, the NP1 precedes the conjunction (*ruguo* 'if'); in the non-Topic condition, the NP1 follows the conjunction. The factor of Reference Choice involves the ultimate resolution of the target pronoun in the conditional construction: the pronoun refers to either NP1 (*Lin Xue*) or NP2 (*Zhang Chao*). Thus, the $2 \times 2 \times 2$ factorial design yields 8 conditions (see Table 2).

As shown in Table 2, the 1st sentence is an introductory sentence, where the NP1 (*Lin Xue*) is introduced in order to fulfil the 'givenness' requirement for Topic. The 2nd and 3rd sentences form a pair to differentiate the Focus/non-Focus conditions. The 3rd sentence always consists of two clauses, with the first one introducing the NP2, and the second containing a pronoun (i.e., *ta1*) that invariably co-refers with NP2. The critical 4th sentence is cast in the conditional bi-clausal construction: the first clause differentiates Topic/non-Topic conditions, while the second clause differentiates the resolution of the target pronoun (i.e., *ta2*), co-referential with either NP1 or NP2.

Two sets of experimental stimuli were created. Thus, there were 2 (topic) × 2 (focus) × 2 (reference) × 2 (sets of material) = 16 narratives. Each of the eighteen speakers uttered 3 repetitions of these narratives. All together there were 16 × 18 × 3 = 864 utterances for analysis.

2.3 Recording procedure

Recording was done individually in a soundproof phonetics laboratory at Shanghai Jiao Tong University, China. Participants were seated in front of a 13.3-in. Mac laptop, wearing a Beyerdynamic NMX 300 headset microphone. Their task was to read aloud the sentences displayed on the computer screen (one narrative on each screen). The microphone was placed approximately 2 in. away from the left side of participants' lips. All utterances were recorded using Praat (ver. 6.1.38, by Boersma & Weenink) and digitized into the Mac computer as mono channel WAV files at 44.1 kHz sampling rate with 16-bit amplitude resolution, following Liu and Xu (2005: 70–87).

Prior to recording, participants were instructed that they should pay attention to both the words and the punctuations. They were also told that the recordings of their utterances would be used for a language comprehension experiment, so that they might want to imagine a listener while reading each narrative. During the recording, participants were required to reread the whole trial whenever the experimenter noticed mispronunciation or disfluency, following Wang et al. (2017: 24–56). Breaks were scheduled after every 8 narratives, but the participants were encouraged to take a break whenever needed. All versions of the narratives were randomized, with 3 practice trials (simple daily conversations in different scenarios) at the beginning. The recording took around 40 min for each participant.

2.4 Measurement and analysis

All utterances were extracted and saved as separate WAV files. We used ProsodyPro (Y. Xu 2013) to obtain the phonetic features of the Chinese third-person pronouns *ta1* and *ta2*. Following Hou and Jia (2013) and Hou et al. (2017), we focused on the vowel. Hence, we extracted maximum F0, average F0 and F0 range of the pronouns. All F0 values were then transferred to semitone F0 (calculated by 12 log2[F0]). These, together with durations, are taken as measures of stressing in Chinese (Liu and Xu 2005; Wang and Xu 2011; Wang et al. 2017). Although amplitude/intensity is reportedly also indicative of stress, it is not analyzed here because its results highly resemble the results of F0 (Xu et al. 2012).

When comparing between *ta1* and *ta2*, we only used the duration measure because F0 measures are known to be affected by differences in phonological environments, specifically, the positions in which *ta1* and *ta2* occur. In addition, given that F0 tends to rise up in post clause-boundary positions (Wang et al. 2017), the clause-initial *ta1* should always have a higher F0 than the clause-internal post-conjunction *ta2*.[2] All these aspects of variations might attribute to the differences in F0, if any. Note, however, Chinese character is morpheme-based, each corresponding to exactly one syllable. Thus, it is plausible to compare the durations of the two pronouns, with their difference as an indicator for stressing.

The two sets of experimental items were analyzed separately, because the target pronoun was followed by [hʏn] in item 1 but by [mɑ] in item two. Existing work has shown that when uttering a vowel-consonant-vowel sequence, the tongue movement of the second vowel starts before the consonant offset, and the tongue movement of the first vowel continues after the consonant onset (Butcher and Weiher 1976; Kent 1972; Recasens 1987; Whalen 1990). This vowel-to-vowel coarticulation may extend beyond syllable boundary (Magen 1997).

All statistical analyses were conducted under R (4.1.3) environment (R Core Team, Urbanek & Bibiko, R Foundation for Statistical Computing, 2022). We used the lme4 package for analyses with linear mixed effects (LME) model. For each item, we examined main effects of Topic (Topic coded as 0.5, non-Topic as −0.5), Focus (Focus coded as 0.5, non-Focus as −0.5), Reference (NP1 coded as 0.5, NP2 as −0.5) and their interactions. All significant interactions were unpacked with the *probe_interaction()*-function in the *interactions* package. For all the models, we began with a maximal random effect structure with random intercepts and slopes for participants, and simplified it to address convergence failure or singularity. All final models, along with model R^2s, are provided in the tables presenting statistical analyses in the Results section.

2 For checking purposes, *ta1* indeed has higher F0 values than *ta2*, as confirmed by our analysis.

2.5 Results

All the 864 utterances were included in the analyses. The descriptive and statistical results are presented in Tables 3–13. Below we focus on the results that showed significant effects. We first present the differential results for the baseline *ta1* and the target pronoun *ta2* in duration, and then report the analyses of *ta2* under different experimental conditions.

Table 3: F0 measures of the target pronoun *ta2* in item 1.

Topic	Focus	max F0 (st)		F0 range (st)		ave F0 (st)	
		NP1	NP2	NP1	NP2	NP1	NP2
+	+	90.32 (6.04)	90.68 (6.05)	0.68 (0.44)	1.30 (2.95)	89.97 (6.02)	89.91 (5.79)
−	+	89.66 (5.98)	89.77 (5.82)	0.79 (0.61)	0.78 (0.70)	89.22 (5.95)	89.33 (5.78)
+	−	89.84 (5.82)	89.70 (5.93)	0.75 (0.58)	0.84 (1.33)	89.46 (5.83)	89.24 (5.92)
−	−	89.84 (5.82)	90.15 (5.94)	0.91 (1.78)	1.05 (2.27)	89.43 (5.72)	89.53 (5.67)

Table 4: F0 measures of the target pronoun *ta2* in item 2.

Topic	Focus	max F0 (st)		F0 range (st)		ave F0 (st)	
		NP1	NP2	NP1	NP2	NP1	NP2
+	+	89.90 (5.90)	89.60 (5.82)	0.83 (1.44)	0.59 (0.40)	89.43 (5.69)	89.28 (5.79)
−	+	89.68 (6.30)	89.78 (5.83)	0.72 (0.70)	0.79 (0.90)	89.27 (6.17)	89.28 (5.63)
+	−	89.20 (5.91)	89.55 (5.63)	0.52 (0.53)	0.81 (0.95)	88.93 (5.85)	89.07 (5.62)
−	−	89.52 (6.01)	90.15 (6.53)	0.99 (1.56)	1.17 (2.38)	88.97 (5.85)	89.41 (5.81)

Table 5: Statistical analysis of F0 range of the target pronoun *ta2* in item 1.

Fixed effects	Estimate	SE	*t*	*p*
Topic × focus × reference				
(Intercept)	0.786	0.222	3.539	<0.001
Topic	−0.104	0.302	−0.346	0.73
Focus	0.126	0.302	0.417	0.677
Reference	−0.002	0.302	−0.006	0.995
Topic × focus	−0.061	0.427	−0.144	0.886
Topic × reference	0.616	0.427	1.443	0.15
Focus × reference	0.143	0.427	0.335	0.738
Topic × focus × reference	−0.659	0.603	−1.092	0.275

Model = lmer(f0range ~ topic * focus * reference + (1|subject)). Model R^2 = 0.04. Significance codes: 0 <= '***' < 0.001 < '**' < 0.01 < '*' < 0.05.

Table 6: Statistical analysis of maximum F0 of the target pronoun *ta2* in item 1.

Fixed effects	Estimate	SE	*t*	*p*
Topic × focus × reference				
(Intercept)	89.995	1.333	67.514	<0.001
Topic	0.277	0.285	0.97	0.346
Focus	0.226	0.201	1.125	0.261
Reference	−0.160	0.201	−0.795	0.427
Topic × focus	1.007	0.402	2.508	0.013*
Topic × reference	0.103	0.402	0.257	0.797
Focus × reference	−0.157	0.402	−0.39	0.697
Topic × focus × reference	−0.700	0.803	−0.871	0.384
Topic × focus				
NP2 = Focus				
Topic	0.39	0.174	2.236	0.031*
NP2 = Non-Focus				
Topic	-0.113	0.174	-0.783	0.519

Model = lmer(maximumf0 ~ topic * focus * reference + (1+topic|subject). Model R^2 = 0.88.

Table 7: Statistical analysis of average F0 of the target pronoun *ta2* in item 1.

Fixed effects	Estimate	SE	*t*	*p*
Topic × focus × reference				
(Intercept)	89.513	1.335	67.047	<0.001
Topic	0.266	0.173	1.542	0.124
Focus	0.189	0.219	0.864	0.4
Reference	0.019	0.173	0.112	0.911
Topic × focus	0.795	0.346	2.3	0.022*
Topic × reference	0.244	0.346	0.707	0.48
Focus × reference	−0.081	0.346	−0.234	0.815
Topic × focus × reference	−0.146	0.691	−0.211	0.833
Topic × focus				
NP2 = Focus				
Topic	0.332	0.122	2.717	0.007**
NP2 = Non-Focus				
Topic	−0.066	0.122	−0.536	0.592

Model = lmer(averagef0 ~ topic * focus * reference + (1+focus|subject). Model R^2 = 0.91.

Table 8: Statistical analysis of F0 range of the target pronoun *ta2* in item 2.

Fixed effects	Estimate	SE	*t*	*p*
Topic × focus × reference				
(Intercept)	0.803	0.132	6.063	<0.001
Topic	−0.229	0.112	−2.052	0.041*
Focus	−0.141	0.112	−1.258	0.209
Reference	−0.074	0.112	−0.661	0.509
Topic × focus	0.374	0.224	1.671	0.096
Topic × reference	0.098	0.224	0.439	0.661
Focus × reference	0.328	0.224	1.465	0.144
Topic × focus × reference	0.417	0.447	0.933	0.352

Model = lmer(f0range ~ topic * focus * reference + (1|subject)). Model R^2 = 0.18.

Table 9: Statistical analysis of maximum F0 of the target pronoun *ta2* in item 2.

Fixed effects	Estimate	SE	*t*	*p*
Topic × focus × reference				
(Intercept)	89.673	1.389	64.547	<0.001
Topic	−0.216	0.156	−1.39	0.165
Focus	0.137	0.163	0.843	0.408
Reference	−0.195	0.161	−1.213	0.23
Topic × focus	0.478	0.311	1.537	0.125
Topic × reference	0.342	0.311	1.1	0.272
Focus × reference	0.582	0.311	1.872	0.062
Topic × focus × reference	0.121	0.622	0.195	0.846

Model = lmer(maximumf0 ~ topic * focus * reference + (1 + focus + reference|subject)). Model R^2 = 0.93.

Table 10: Statistical analysis of average F0 of the target pronoun *ta2* in item 2.

Fixed effects	Estimate	Standard error	Statistic	*p*-value
Topic × focus × reference				
(Intercept)	89.206	1.364	65.4	<0.001
Topic	−0.055	0.12	−0.462	0.645
Focus	0.221	0.119	1.854	0.065
Reference	−0.110	0.129	−0.851	0.406
Topic × focus	0.263	0.239	1.101	0.272
Topic × reference	0.237	0.239	0.992	0.322
Focus × reference	0.365	0.239	1.53	0.127
Topic × focus × reference	−0.141	0.478	−0.296	0.767

Model = lmer(averagef0 ~ topic * focus * reference + (1 + topic + reference|subject)). Model R^2 = 0.96.

Table 11: Duration of the target pronoun *ta2* in item 1 and item 2.

Topic	Focus	Duration (ms) – item 1		Duration (ms) – item 2	
		NP1	NP2	NP1	NP2
+	+	94.1 (26.1)	98.2 (31.9)	70.5 (28.1)	69.8 (25.1)
−	+	94.0 (28.5)	88.9 (25.6)	78.0 (31.6)	71.7 (25.3)
+	−	92.3 (29.4)	98.3 (31.4)	74.8 (32.6)	86.6 (36.6)
−	−	95.1 (30.1)	90.4 (26.2)	91.2 (37.6)	71.6 (28.7)

Table 12: Statistical analysis of the duration of the target pronoun *ta2* in item 1.

Fixed effects	Estimate	SE	*t*	*p*
Topic × focus × reference				
(Intercept)	93.702	4.431	21.145	<0.001
Topic	3.183	2.196	1.45	0.148
Focus	−0.683	2.196	−0.311	0.756
Reference	−0.533	2.42	−0.22	0.828
Topic × focus	1.335	4.391	0.304	0.761
Topic × reference	−10.824	4.391	−2.465	0.014*
Focus × reference	0.22	4.411	0.05	0.96
Topic × focus × reference	−0.353	8.782	−0.04	0.968
Topic × reference				
Reference = NP1				
Topic	−1.114	1.553	−0.718	0.473
Reference = NP2				
Topic	4.297	1.553	2.768	0.006**

Model = lmer(duration ~ topic * focus * reference + (1 + reference|subject)). Model R^2 = 0.40.

Table 13: Statistical analysis of the duration of the target pronoun *ta2* in item 2.

Fixed effects	Estimate	SE	*t*	*p*
Topic × focus × reference				
(Intercept)	76.215	4.948	15.402	<0.001
Topic	−3.847	2.279	−1.688	0.092
Focus	−7.383	3.246	−2.275	0.036*
Reference	4.155	2.705	1.536	0.143
Topic × focus	−1.714	4.558	−0.376	0.707
Topic × reference	−17.668	4.558	−3.876	<0.001***
Focus × reference	−1.306	5.072	−0.258	0.798
Topic × focus × reference	24.053	9.117	2.638	0.009**

Table 13: (continued)

Fixed effects	Estimate	SE	*t*	*p*
Focus				
Reference = NP1				
Topic	−3.763	2.279	−1.651	0.1
Reference = NP2				
Topic	−0.942	2.279	−0.413	0.68
Non-focus				
Reference = NP1				
Topic	−8.919	2.279	−3.913	<0.001***
Reference = NP2				
Topic	5.928	2.279	2.515	0.01*
Topic × reference				
Reference = NP1				
Topic	−6.341	1.612	−3.934	<0.001***
Reference = NP2				
Topic	2.493	1.612	1.547	0.123

Model = lmer(duration ~ topic * focus * reference + (1 + reference * focus|subject)). Model R^2 = 0.47.

2.5.1 Comparing *ta1* and *ta2*

To check whether the target pronoun was deviated from the canonical, reduced pronoun (in the 4th clause), we conducted paired-sample *t*-test for both items. Indeed, the mean duration of *ta2*s was significantly longer than that of *ta1*s, for both item 1 (93.70 ms vs. 68.31 ms, t (143) = –17.158, $p < 0.001$) and item 2 (76.22 ms vs. 58.63 ms, t (143) = –10.333, $p < 0.001$), as shown in Figure 1.

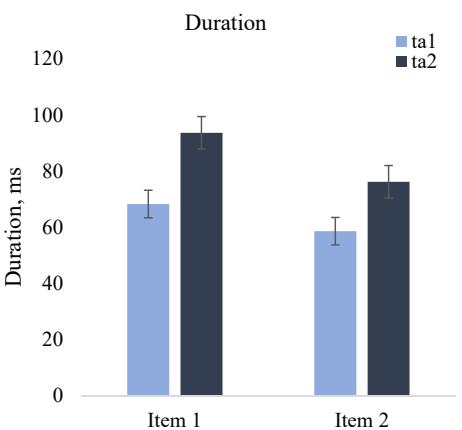

Figure 1: Duration of *ta1* and *ta2* in two item sets. Error bars represent 95 % confidence intervals (±1.97 standard error).

2.5.2 F0 analyses of the target pronoun *ta2*

Tables 3 and 4 present the F0 semitone (st) measures of the target pronoun *ta2* as a function of conditions for items 1 and 2, respectively. Tables 5–7 report the results of statistical analyses of the F0 (st) measures with the linear mixed effect model for item 1, and Tables 8–10 report the results of statistical analyses of the F0 (st) measures with the linear mixed effect model for item 2.

In the case of the target pronoun *ta* 'he/she' in item 1, there was an interaction of Topic and Focus on the measures of maximum F0 (β = 1.007, SE = 0.402, t = 2.508, p = 0.013) and average F0 (β = 0.795, SE = 0.346, t = 2.3, p = 0.022), but no other main effect or interactions were found.

Follow-up comparisons showed that under conditions where the NP2 was focused, the target pronoun *ta* had a significantly higher maximum F0 (β = 0.39, SE = 0.174, t = 2.36, p = 0.031) and a significantly higher average F0 (β = 0.332, SE = 0.122, t = 2.717, p = 0.007) when the NP1 *Lin Xue* was topicalized than when the NP1 was not topicalized. Conversely, under conditions where the NP2 was non-focused, these two F0 measures of the target pronoun appeared to be higher with non-topicalized NP1 than with topicalized NP1, though neither reached statistical significance (see Figure 2).

In the case of the target pronoun in item 2, there was a main effect of Topic on the measure of F0 range (β = –0.229, SE = 0.112, t = –2.052, p = 0.041): the F0 range was significantly smaller when the NP1 was topicalized than when the NP1 was not topicalized (see Figure 3). No other main effect or interactions were found.

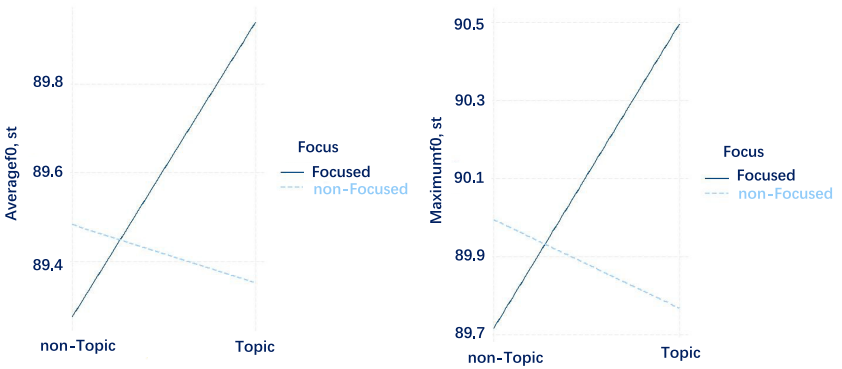

Figure 2: Interaction of topic and focus on average F0 (left) and maximum F0 (right) measures of the target pronoun *ta2* in item 1.

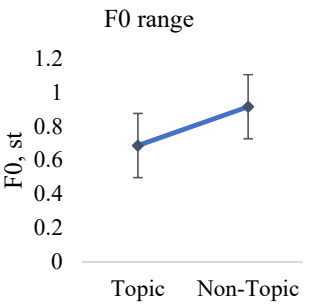

Figure 3: Main effect of topic on F0 range of the target pronoun *ta2* in item 2. Error bars represent 95 % confidence intervals (±1.97 standard error).

2.5.3 Duration analysis of the target pronoun *ta2*

Table 11 shows the durations of the target pronoun *ta2* in two item sets. Tables 12 and 13 present the results of statistical analyses of the durations for item 1 and item 2, respectively.

For the duration of the target pronoun in item 1, there was only an interaction between Topic and Reference (β = –10.824, SE = 4.391, t = –2.465, p = 0.014), but no other main effect or interactions. Unpacking this interaction showed that target pronouns referring to the NP2 *Zhang Chao* were uttered significantly longer when the NP1 *Lin Xue* was topicalized than when the NP1 was not topicalized (β = 4.297, SE = 1.553, t = 2.768, p = 0.006). Conversely, target pronouns referring to the NP1 appeared to be numerically longer with non-topicalized NP1 than with topicalized NP1, though the difference failed to reach significance (see Figure 4).

In the case of the target pronoun in item 2, there was a main effect of Focus (β = –7.383, SE = 3.246, t = –2.275, p = 0.036), a two-way interaction between Topic and Reference (β = –17.668, SE = 4.558, t = –3.876, p < 0.001), a three-way interaction between Topic, Focus and Reference (β = 24.053, SE = 9.117, t = 2.638, p = 0.009), but no other effects. Unpacking the Topic × Reference interaction showed similar patterns as items 1 (see Figure 5), except that now the significant topicalization effect was found with pronouns referring to the NP1 (β = –6.341, SE = 1.612, t = –3.934, p < 0.001), but not with pronouns referring to the NP2.

Unpacking the three-way interaction revealed (see Figure 6) that under non-Focus conditions, there was an interaction of Topic and Reference: when the pronoun referred back to the NP1 *Li Mei* its duration was shorter for a topicalized NP1 than for a non-topicalized NP1 (β = –6.341, SE = 2.279, t = –3.913, p < 0.001); when the pronoun referred back to the NP2 *Zhang Liang*, its duration was longer for a

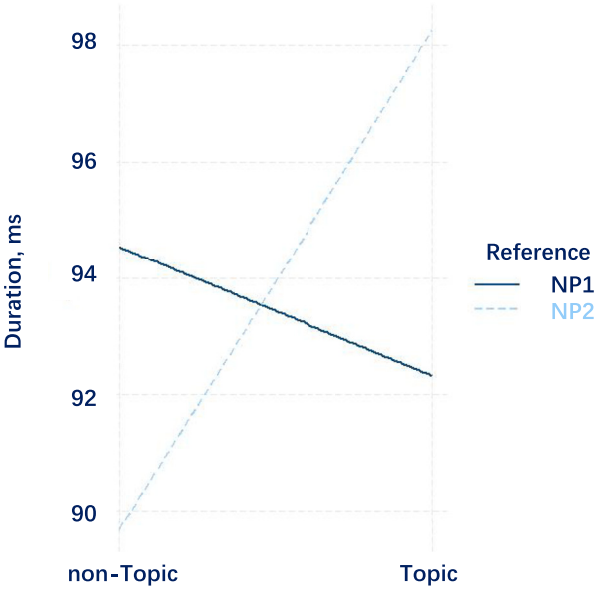

Figure 4: Interaction of topic and reference on the duration of the target pronoun in item 1.

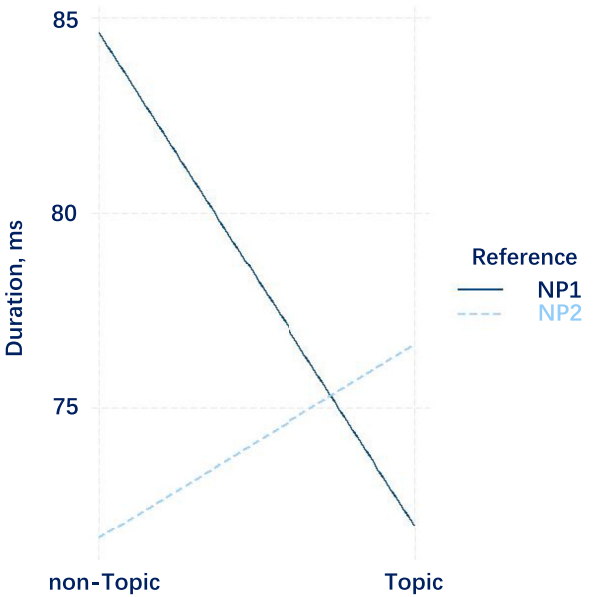

Figure 5: Interaction of topic and reference on the duration of the target pronoun in item 2.

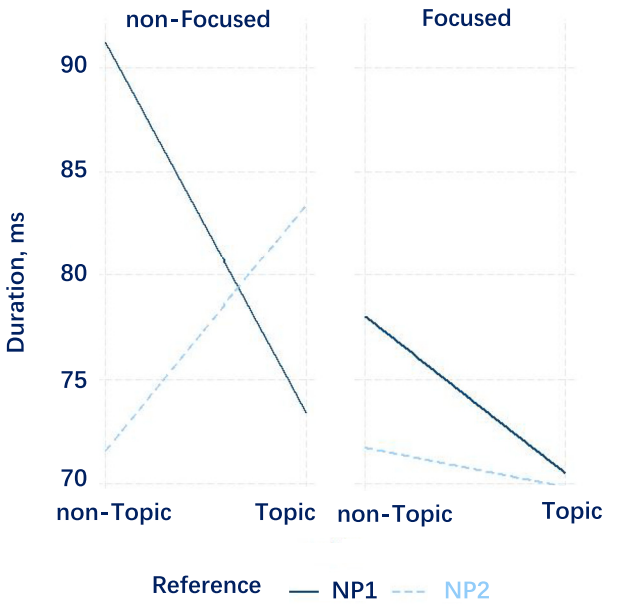

Figure 6: Interaction of topic, focus, and reference on the duration of the target pronoun in item 2.

topicalized NP1 than for a non-topicalized NP1 (β = 5.928, SE = 2.279, t = 2.515, p = 0.01). Under Focus conditions, there was no interaction of Topic and Reference, though there appeared to be a numeric trend for pronouns referring to the NP1 to be uttered shorter when the NP1 was topicalized than when the NP1 was non-topicalized.

2.5.4 Post-hoc power analyses

Following one reviewer's suggestion, we also conducted post-hoc simulation-based power analyses for the effects detected by our final LME models, using the *mixed-power()*-function of the *mixedpower* package (Kumle et al. 2018, 2021). For each analysis, we included the fixed factors and the random variable "subject" in the simulations, with a sample size of 18 and a critical t value of 2. By default, each analysis was based on 1000 simulations. The statistical power of our detected significant effects ranges from 0.54 to 0.97. Assuming that the effect sizes observed in the current study are appropriate estimates of the true effect sizes, a prospective study with a sample size of 37 will have its power values larger than 0.8.

3 Discussion

In this production study, we investigated how Chinese third-person pronouns were phonetically realized in mini-narratives where topic and focus as potential antecedents competed for accessibility and retrieval, in order to further evaluate the differential prominence of the two discourse referents. Consistent with our expectations, Chinese speakers were indeed sensitive to the varying information statuses of the NPs (i.e., Topic and Focus) as the narrative unfolded clause by clause, and such sensitivity in turn affected the way they uttered the subsequent pronoun, as evidenced by distinct F0s and durations across conditions. These prosodic variations of the pronouns observed in the current study are as predicted by the Accessibility Theory (Ariel 1988, 2001), and importantly, the distinct acoustic properties revealed by stressed pronouns are consistent with the referential shift accounts (Akmajian and Jackendoff 1970; Gleitman 1965; Kameyama 1999). In what follows, we discuss our major findings and their implications, address potential issues and point out future directions.

3.1 Interactive effects of topic, focus, and pronoun resolution

One major finding of the current study is that on the duration measure of the pronoun, both items showed an interaction between Topic and Reference. Specifically, when resolved as coreferential with the NP1 (item 2, Figure 5), pronouns were uttered with more prominence (i.e., longer) under conditions with non-topicalized NP1 than under conditions with topicalized NP1; when resolved as coreferential with the NP2 (item 1, Figure 4), pronouns were uttered with more prominence under conditions with topicalized NP1 than under conditions with non-topicalized NP1. In other words, pronouns tended to refer back to the NP1 under Topic conditions, but to the NP2 under non-Topic conditions. Overall, this finding is in line with previous studies showing a facilitative effect of topic on pronoun resolution (Arnold et al. 2000; Crawley and Stevenson 1990; Kaiser 2011; Rohde and Kehler 2014; Xu 2003, X. Xu 2013), providing further evidence for pronouns to prefer topicalized NPs that have elevated accessibility relative to non-topicalized counterparts.

It is worth noting that for item 2, the interaction of Topic and Reference was further moderated by the factor of Focus (manifested as a three-way interaction): Topic-preferring pronouns were only observable when the NP2 was not focused, but not when the NP2 was focused. The modulation of Focus suggests that the focused referent can compete with the topicalized referent for discourse prominence as it becomes the preferable antecedent of a following pronoun, to the

extent that the effect of Focus can even mask the effect of Topic on pronoun interpretation.

The competition between Topic and Focus can be further evidenced by an interaction of Topic and Focus on the maximum F0 and the average F0 of the target pronoun for item 1, which is the second major finding of the current study. Before discussing these results, it is important to note that the Topic × Focus interaction without modulation of Reference should be interpreted with caution, because they do not reflect any interpretational bias for pronoun resolution. Rather, such effects should be interpreted as prosodic prominence induced by *increased ambiguity* of the pronoun. Suppose that the existence of one prominent referent (e.g., focus) creates a strong bias for the subsequent pronoun, thus decreasing its level of referential ambiguity. But adding another prominent referent (e.g., topic) increases the ambiguity level of the pronoun, now that the two prominent referents are both highly preferable candidates to be chosen as the antecedent. In light of our stimulus design, that is exactly what we found: in the presence of a focused NP2 '*Zhang Chao*' and a non-topicalized/subject NP1 '*If Lin Xue*…', there was a clear interpretational bias towards the NP2 and therefore the target pronoun *ta* was not stressed. But in the presence of a focused NP2 and a topicalized NP1 '*Lin Xue, if* …', the target pronoun was more stressed (compared to a non-topicalized NP1 in conjunction with a focused NP2). Therefore, this interaction provides additional support that Topic and Focus, when co-present in the same discourse, compete for prominence such that they both are highly probable antecedents.

We hereby propose that referential ambiguity is a continuum, instead of a binary opposition, ranging from a strong interpretational bias (unambiguous) to an interpretational dilemma where both or multiple referents are equally preferable (highly ambiguous, i.e., the reference of the pronoun is highly uncertain). The earlier assertion that ambiguous pronouns are more stressed than unambiguous pronouns (Ariel 1988) is now extended accordingly: more ambiguous pronouns are more stressed than less ambiguous pronouns. In short, the Topic × Focus effect on pronoun stressing without interacting with Reference reflects their joint contributions to increasing/decreasing the ambiguity level of the pronoun.

3.2 Strong referential bias for the NP2 in item 2

Interestingly for item 2, but not for item 1, target pronouns were uttered with a smaller F0 range under the Topic conditions relative to the non-Topic conditions, as shown in Figure 3. This pattern of F0 range compression might initially appear puzzling, but here we should note that in Mandarin Chinese, stressing leads to an

expansion of the F0 range for Tone 2, Tone 3, and Tone 4 (e.g., Wang et al. 2002), but to a compression of the F0 range for Tone 1 (Li 2002, p. 532, Figure 6). The third-person pronoun *ta* in Chinese has the level tone (Tone 1) and thus, the smaller F0 range under the Topic conditions means that in item 2, the pronoun was stressed in the presence of the topicalized NP1. In light of our experimental design, this may, again, reflect the competition between the topicalized NP1 and a referential bias of the target pronoun towards the NP2 *Zhang Liang*: the topicalized NP1 competes with the biased NP2, rendering the following pronoun more ambiguous and therefore was stressed. Recall that we also found a main effect of Focus on the duration of the pronoun for item 2. The overall shorter duration of the pronoun under the Focused conditions compared to non-Focused conditions suggests that the focusing of the NP2 increased its accessibility and referential bias, and therefore reducing the ambiguity of the following pronoun. In a nutshell, these findings (i.e., the smaller F0 range given the topicalized-NP1 and the shorter duration given the focused-NP2) are two sides of the same coin, showcasing an NP2 bias in item 2.

But why, then, did the NP2 in item 2 trigger a much stronger referential bias than that in item 1? We speculate that the prolonged process of encoding might be the source of the NP2 bias in item 2. Close examination of the items showed that compared to the 4-character NP2 (*zhu li Zhang Chao* 'Assistant Zhang Chao') in item 1, the NP2 in item 2 was two-syllable longer, with a four-character professional title *hai wai xue zhe* 'overseas scholar' and a two-character proper name *Zhang Liang*. This elaboration or detailed characterization (of a newly introduced referent in the 3rd clause) might raise the NP2 to an even higher activation level than that of a shorter title in item 1, because the longer the encoding stage was, the better retrieval it enabled (Káldi and Babarczy 2021). While the explanation we offered here appears rather speculative, we note that the different referential biases of the two items indicate that the accessibility of NPs in multi-clause narratives is dynamically changing, and can be influenced by a range of factors including their places in the discourse, syntactic position, informational statuses, and possibly even the length of the NPs.

3.3 Audience design

One thing worth noting is that the pronouns here, though occurring in different discourse contexts, were unambiguous to our participants as the speakers, because the person, number, and gender features encoded in the orthography of the pronouns were available in print. Nevertheless, the target pronouns were produced differently across conditions. Recall that according to the Accessibility Theory (Ariel 1988, 2001), stressing of pronouns functions as an indicator for the listeners to

consider less accessible entities. The differences detected in the current study might be attributed to audience design (e.g., Brennan and Clark 1996; Clark and Murphy 1982; Snedeker and Trueswell 2003), that is, our participants deliberately provided prosodic cues even to imaginary listeners (as they were instructed prior to the production experiment).

Note, however, our production task might not be deemed ideal to elicit natural utterances, since participants were tested individually in the lab reading aloud by themselves the experimental stimuli that were designed to be dialogues. Given that audience design should be more easily detectable in highly interactive tasks (e.g., Demberg et al. 2023, p. 16), future studies might employ an interactive scenario that encourages naturalistic productions, as in Breen et al. (2010) and Hou et al. (2017), to replicate the current results or test for even stronger effects.

3.4 Potential concerns and future directions

Our study has some remaining issues or limitations. One potential concern raised by a reviewer is that our analyses included different speakers that vary in socio-linguistic backgrounds and idiosyncratic features, whereas inter-speaker variation might be a potential confound (e.g., Johnson et al. 1993; Sorensen et al. 2016; Weirich and Fuchs 2013). Yet we do not think inter-speaker variation should undermine our results mainly for three reasons. First, our speakers' individual differences, including age, gender, and even the districts where they come from, were balanced or controlled for. Second, by-participant random intercepts were included in the random-effects structures of all final models, some of which also included by-participant random slopes. Third, the within-subject design was used in the current study, to capture the acoustic differences of the target pronoun *ta* produced by the same speaker across all conditions. As inter-speaker variability is more related to 'the intrinsic size and shape of the speech articulators irrespective of the articulatory tasks' (Serrurier et al. 2019, p. 2149), our within-subject design should not be confounded by the anatomical variations, and hence is minimally subjective to inter-speaker variations.

Another potential issue raised by a reviewer is ecological validity. Specifically, while we constructed richly contextualized narratives, our production task was not highly interactive and contained repetitive materials. The increasing fatigue along the experiment might have induced what has been found as the "erosion effects". To address this concern, we conducted comparative analyses of items from the beginning to the end of the list (i.e., number 8–16 vs. 40–48 per speaker). The results

showed no difference between the beginning and the end of the list on any of the F0 measures or the duration of the target pronoun, as presented in Table 14. In addition, to facilitate further examination by interested researchers, we provide two sample audio files produced by a female speaker: one occurred early (Num. 8), and the other late (Num. 40).

Table 14: Comparative analyses of utterances from the beginning and end of the list.

Fixed effects	Estimate	SE	*t*	*p*
Maximum F0 – Item1				
(Intercept)	90.413	1.464	61.761	<0.001
Round3	0.071	0.399	0.178	0.859
F0 range – Item1				
(Intercept)	0.983	0.234	4.200	<0.001
Round3	−0.147	0.330	−0.446	0.656
Average F0 – Item1				
(Intercept)	89.879	1.461	61.510	<0.001
Round3	0.188	0.315	0.596	0.552
Maximum F0 – Item2				
(Intercept)	90.120	1.487	60.618	<0.001
Round3	0.350	0.481	0.727	0.482
F0 range – Item2				
(Intercept)	0.583	0.237	2.461	0.023
Round3	0.225	0.242	0.929	0.355
Average F0 – Item2				
(Intercept)	89.797	1.462	61.435	<0.001
Round3	0.183	0.276	0.663	0.521
Duration – Item1				
(Intercept)	0.092	0.008	11.303	<0.001
round3	−0.008	0.007	−1.204	0.254
Duration – Item2				
(Intercept)	0.070	0.006	11.178	<0.001
round3	−0.005	0.004	−1.511	0.134

Last but not the least, one remaining issue that needs to be addressed is the relationship between overt pronouns and zero pronouns in Chinese. In the current study we assumed pronouns to refer back to the most accessible entities in the discourses, yet Chinese allows zero anaphora, which presumably is ranked higher on the accessibility hierarchy than pronouns (Ariel 1988). Most existing work has indicated that Chinese pronouns and zero pronouns are at the same level of accessibility, such that they are interchangeable without causing interpretational difficulty (Yang et al. 1999, 2021). Yet Lam and Hwang (2022) found that topicality only increased the use of null pronouns but decreased the use of overt pronouns. Assuming there is division of labour between overt and null pronouns in Chinese, future work might examine whether our finding with pronouns as a referential form indicative of high accessibility of its antecedent could be extended to zero anaphora.

4 Conclusions

The current study investigated prosodic realizations of Chinese third-person pronouns in discourse with co-presence of topic and focus. It was found that when a pronoun referred back to a less accessible antecedent or when its referential interpretation was rendered more ambiguous by competitive antecedent candidates, Chinese speakers tended to raise its F0 and lengthen the duration. Our results suggest different referential patterns for stressed and unstressed pronouns due to the interplay of prominence-lending cues, including topicalization, focusing, recency, first mention primacy, and the NP length.

The current study exemplifies how prosodic features of pronouns could be used to deepen our understanding of cognitive status of discourse referents with a production task. These findings can be further extended to real-time processing research regarding whether acoustic differences indicative of referent accessibility are perceptually significant as to facilitate comprehension, hence deepening our understanding of the role of information structure on pronoun resolution.

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Author contributions: FW and CZ designed the experiments. CZ collected the data and carried out the acoustic analyses. The co-authors developed the model code

together and CZ performed the statistical analyses. The manuscript was prepared with contributions from both co-authors. FW supervised the project. Both authors have read and agreed to the submitted version of the manuscript. The authors applied the SDC approach for the sequence of authors.

Ethics statement: The research was conducted in accordance with the Declaration of Helsinki, and was approved (IRB No. 1909S2102) by the Ethics Review Committee of the School of Foreign Languages, Shanghai Jiao Tong University.

Conflict of interest statement: The authors have no conflicts of interest to declare.

Appendix

Item 1

Condition number	Condition type	Item 1 narratives
1	Topic × Focus × NP1	A: 财政局专员林雪(NP1)中午去保险公司审计了。 'Finance Bureau Commissioner Lin Xue (NP1) went to the insurance company to audit at noon.' B: 谁负责接待工作呢? 'Who is in charge of reception?' A: 助理张超(NP2)负责接待工作, 他很熟悉各项流程。 'Assistant Zhang Chao (NP2) is in charge of reception, he is familiar with the process.' 林雪如果注意到账目的缺漏, 那么她(NP1)很快就会做好记录并要求整改。 'Lin-Xue, if noticed the gaps and omissions of accounting items, then she will soon make a record and ask for rectification.'
2	nonTopic × Focus × NP1	A: 财政局专员林雪(NP1)中午去保险公司审计了。 'Finance Bureau Commissioner Lin Xue (NP1) went to the insurance company to audit at noon.' B: 谁负责接待工作呢? 'Who is in charge of reception?' A: 助理张超(NP2)负责接待工作, 他很熟悉各项流程。 'Assistant Zhang Chao (NP2) is in charge of reception, he is familiar with the process.' 如果林雪注意到账目的缺漏, 那么她(NP1)很快就会做好记录并要求整改。 'If Lin-Xue noticed the gaps and omissions of accounting items, then she will soon make a record and ask for rectification.'

(continued)

Condition number	Condition type	Item 1 narratives
3	Topic × nonFocus × NP1	A: 财政局专员林雪(NP1)中午去保险公司审计了。 'Finance Bureau Commissioner Lin Xue (NP1) went to the insurance company to audit at noon.' B: 下周一之前要完成结算。 'The accounting work should be finished by next Monday.' A: 助理张超(NP2)负责接待工作, 他很熟悉各项流程。 'Assistant Zhang Chao (NP2) is in charge of reception, he is familiar with the process.' 林雪如果注意到账目的缺漏, 那么她(NP1)很快就会做好记录并要求整改。 'Lin-Xue, if noticed the gaps and omissions of accounting items, then she will soon make a record and ask for rectification.'
4	nonTopic × nonFocus × NP1	A: 财政局专员林雪(NP1)中午去保险公司审计了。 'Finance Bureau Commissioner Lin Xue (NP1) went to the insurance company to audit at noon.' B: 下周一之前要完成结算。 'The accounting work should be finished by next Monday.' A: 助理张超(NP2)负责接待工作, 他很熟悉各项流程。 'Assistant Zhang Chao (NP2) is in charge of reception, he is familiar with the process.' 如果林雪注意到账目的缺漏, 那么她(NP1)很快就会做好记录并要求整改。 'If Lin-Xue noticed the gaps and omissions of accounting items, then she will soon make a record and ask for rectification.'
5	Topic × Focus × NP2	A: 财政局专员林雪(NP1)中午去保险公司审计了。 'Finance Bureau Commissioner Lin Xue (NP1) went to the insurance company to audit at noon.' B: 谁负责接待工作呢? 'Who is in charge of reception?' A: 助理张超(NP2)负责接待工作, 他很熟悉各项流程。 'Assistant Zhang Chao (NP2) is in charge of reception, he is familiar with the process.' 林雪如果注意到账目的缺漏, 那么他(NP2)很快会翻找档案补齐票据。 'Lin-Xue, if noticed the gaps and omissions of accounting items, then he'll search through the files and fill in the gaps soon.'

(continued)

Condition number	Condition type	Item 1 narratives
6	nonTopic × Focus × NP2	A: 财政局专员林雪(NP1)中午去保险公司审计了。 'Finance Bureau Commissioner Lin Xue (NP1) went to the insurance company to audit at noon.' B: 谁负责接待工作呢? 'Who is in charge of reception?' A: 助理张超(NP2)负责接待工作, 他很熟悉各项流程。 'Assistant Zhang Chao (NP2) is in charge of reception, he is familiar with the process.' 如果林雪注意到账目的缺漏, 那么他(NP2)很快会翻找档案补齐票据。 'If Lin-Xue noticed the gaps and omissions of accounting items, then he'll search through the files and fill in the gaps soon.'
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Item 2

Condition number	Condition type	Item 2 narratives
1	Topic × Focus × NP1	A: 司长李梅(NP1)应邀参加一个政府会议。 'Director Li Mei was invited to attend a government meeting.' B: 谁正在发言啊? 'Who is giving a speech now?' A: 海外学者张亮 (NP2)正在发言, 他在讲解关于生态保护的提案。 'Zhang Liang, an overseas scholar, is giving a speech, he is talking about the proposal of ecological protection.' 李梅如果有任何疑惑, 那么她(NP1)马上会举起手提问。 'Li Mei, if has any doubts, then she'll raise her hand immediately and ask questions.'
2	nonTopic × Focus × NP1	A: 司长李梅(NP1)应邀参加一个政府会议。 'Director Li Mei was invited to attend a government meeting.' B: 谁正在发言啊? 'Who is giving a speech now?' A: 海外学者张亮 (NP2)正在发言, 他在讲解关于生态保护的提案。 'Zhang Liang, an overseas scholar, is giving a speech, he is talking about the proposal of ecological protection.' 如果李梅有任何疑惑, 那么她(NP1)马上会举起手提问。 'If Li Mei has any doubts, then she'll raise her hand immediately and ask questions.'
3	Topic × nonFocus × NP1	A: 司长李梅(NP1)应邀参加一个政府会议。 'Director Li Mei was invited to attend a government meeting.' B: 与会者多是重量级专家。 'Most of the participants were heavyweight experts.' A: 海外学者张亮 (NP2)正在发言, 他在讲解关于生态保护的提案。 'Zhang Liang, an overseas scholar, is giving a speech, he is talking about the proposal of ecological protection.' 李梅如果有任何疑惑, 那么她(NP1)马上会举起手提问。 'Li Mei, if has any doubts, then she'll raise her hand immediately and ask questions.'

(continued)

Condition number	Condition type	Item 2 narratives
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5	Topic × Focus × NP2	A: 司长李梅(NP1)应邀参加一个政府会议。 'Director Li Mei was invited to attend a government meeting.' B: 谁正在发言啊? 'Who is giving a speech now?' A: 海外学者张亮 (NP2)正在发言, 他在讲解关于生态保护的提案。 'Zhang Liang, an overseas scholar, is giving a speech, he is talking about the proposal of ecological protection.' 李梅如果有任何疑惑, 那么他(NP2)马上会暂停讲话解答问题。 'Li Mei, if has any doubts, then he'll pause immediately to answer questions.'
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(continued)

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