

Acoustic Correlates of Contrastive Stress in Compound Words versus Verbal Phrase in Mandarin Chinese

Weilin Shen*, Jacqueline Vaissière^{+,#}, and Frédéric Isel^{*,+,#}

Abstract

Duanmu (2000) proposed that tonal languages, such as Chinese, follow the same Compound and Nuclear Stress Rules (Chomsky & Halle, 1968) for phrasal stress as English. This study investigates the acoustic correlates of contrastive stress between compound words and verbal phrases in Mandarin Chinese. We focused on the durational, fundamental frequency, and intensity correlates of stress within minimal pair MN modifier-head compounds and VO verb-object phrases. Our results demonstrated that (1) the final syllable was more lengthened in [VO] than in [MN] and that (2) the F_0 range was larger in [VO] than in [MN]. Moreover, the duration of the pause between the two syllables seems to play a role in distinguishing between [MN] and [VO]. In contrast, we showed that intensity contributed less to this distinction. Our results confirmed the right stress pattern in [VO]; however, we failed to find the lexical stress on the Left syllable we had expected, at least with the speakers we examined. Taken together, the present acoustic study lends support to the hypothesis that principles of stress upward of word level are universal through different languages.

Keywords: Morpholexical Ambiguity, Compounding, Compound versus Nuclear Stress, Acoustic Features.

1. Introduction

In stress languages, such as in English, most words have stable lexical stress patterns and it is often easy to tell which syllables have stress. For a typical tonal language, *e.g.* Mandarin, the word stress is often less obvious. Although, lexical stress has been shown to be highly

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language-dependent, principles of stress upward of word level (*i.e.* compound stress and phrasal stress) are more universal in different languages. Chomsky and Halle (1968) proposed two rules for English compound and phrasal stress.

- **Compound stress rule:** stress is assigned to the leftmost stressable vowel in nouns, verbs, or adjectives, *e.g.* bláckbird.
- **Nuclear stress rule (NSR):** stress is assigned to the rightmost stressable vowel in a major constituent, *e.g.* [the [black bírd]].

It has been proposed that the Compound stress rule and NSR are true for Mandarin Chinese, and they permit one to distinguish between compounds and phrases (Duanmu, 2000). Nevertheless, there is no empirical evidence supporting this hypothesis to date. The first goal of the present study was to understand to what extent morphology affects abstract stress using acoustic-phonetic evidence. Moreover, we were interested in discerning the acoustic phonetic cues, which reflect abstract stress. In Chinese, a V-N construction is sometimes ambiguous, possibly representing both a modifier-head compound [MN] and a verb-object phrase [VO]. For example, a V-N construction ‘chao-fan’ (fry-rice) may be a compound, in which the verbal constituent ‘chao’ (fry) modifies the nominal head ‘fan’ (rice); it may also represent a verb-object relation (to fry rice). The ambiguous pairs have the same segmental characteristics and are assumed to differ from each other only in the stress pattern, showing left stress for compounds and right stress for phrases. There is, however, no phonetic evidence that compound stress and phrasal stress are implemented in [MN] compounds and in [VO] phrases in Mandarin Chinese.

Fraisse (1956) proposed two basic rhythmic tendencies 1) “*rhythmitisation intensive*,” sensitive to strengthening of the initial element, and 2) “*rhythmitisation temporelle*,” building on the lengthening of the final element. The supposed basic rhythmic tendencies predict initial extra loudness and final lengthening. From phonetic studies on the acoustic correlates of stress since the 1950s, researchers have agreed that linguistic stress correlates with a complex configuration of events of increased duration, larger F_0 range, and raised intensity (Lehiste, 1970) and that several cues may be functionally equivalent cross-linguistically (Vaissière, 2004).

Duration

From a series of experiments, Fry (1955, 1958) showed that duration is a consistent correlate of stress at the word level in English and that it is a more effective cue than intensity. Since then, researchers have started to give up the classical view that stress is equated to a higher degree of intensity. Studies on the neutral tone (*i.e.* destressed syllable) in Chinese have confirmed the crucial role of duration on the perception of a destressed syllable for Chinese. Lin (1980, 1990) and Cao (1992) showed that duration of the destressed neutral tone syllable

is systematically shorter (reduced by approximately 50%) than a syllable with full tone.

Fundamental frequency

The F_0 has been showed to be a major acoustic manifestation of suprasegmental structures. It is claimed by some researchers to be the strongest cue of stress for stress languages (Cooper *et al.*, 1985; Lieberman, 1960; Gussenhoven *et al.*, 1997). Nevertheless, others have shown that F_0 is not a necessary cue because stress can be identified on the basis of duration and intensity alone (Cutler & Darwin, 1981). The situation is the same for tonal languages, such as Mandarin. The pitch range has been shown wider when syllables are stressed (Shen, 1985; Liu & Xu, 2005). More specifically, when a 3rd Tone is stressed, it is dipped lower and, when a 4th Tone is stressed, it starts higher and falls lower (Chao, 1968). Moreover, computational corpus studies (Kochanski *et al.*, 2003) have established quantitative F_0 predictions in terms of the lexical tones and the prosodic strength of each word. Shen (1993), however, found that stress in Mandarin could be identified without F_0 information.

Intensity

In literature, the role of intensity for stress is not agreed upon. Fry (1955, 1958) showed that intensity was a less effective cue than duration on the perception of linguistic stress patterns. Nevertheless, some authors have argued that the strongest cue to prominence is intensity for English (*e.g.*, Beckman, 1986; Turk & Sawusch, 1996). For Mandarin Chinese, the effect of the intensity is only secondary. Studies on the neutral tone in Chinese showed that the intensity of the destressed neutral tone is not necessary lower than the one with full tone (Cao, 1986). Moreover, the destressed neutral tone raises its intensity after Tone 3 (Lin, 2006). Phonetic data (Cao, 1992) has illustrated that the destressing of the neutral tone syllable is not related simply to its intensity. The intensity of a neutral tone syllable is lower than that of one with full tone in general, but the situation is reversed when it is preceded by a Tone 3 syllable.

The present study investigates the acoustic correlates of stress between compound and phrase in Mandarin Chinese. We focused on the durational, fundamental frequency, and intensity correlates of stress within minimal pair [MN] modifier-head compound and [VO] verb-object phrase. Our hypotheses were that 1) [MN] modifier-head compound and [VO] phrases differ phonetically with left stress in [MN] modifier-head compounds and right stress in [VO] phrases and that 2) a different prosodic pattern is reflected in acoustic features in F_0 , duration and intensity.

2. Methodology

2.1 Materials

One hundred thirty-five minimal pairs presenting a morpholexical ambiguity (*i.e.* [MN] modifier-head compound vs. [VO] phrases) were selected from the Contemporary Chinese Dictionary 5th edition (Lu & Ding, 2008). Each pair had the same segmental characteristics and was assumed to differ from each other only in the stress pattern. The target words were not recorded in isolation and were embedded in an utterance fragment:

1)我说的不是名词编号而是动词编号.

[I did not say noun “bian-hao” but said verb “bian-hao”.]

The critical words in each pair change their position in the utterance fragment, giving

2)我说的不是动词编号而是名词编号.

[I did not say verb “bian-hao” but said noun “bian-hao”.]

In all, 270 sentences were created. The order of the sentences was randomized.

2.2 Recording Procedure

Before the recording session, the participants were instructed in the goal of the recording and how the recording would proceed. The material was carried out in the laboratory of Phonetics and Phonology of University Sorbonne Nouvelle Paris 3. Speakers were recorded individually in an acoustic chamber, using an attached microphone, placed at a distance of about 5 centimeters from the speaker’s mouth. Speech samples were recorded digitally at 44,100 Hz, 16-bit mono.

2.3 Subjects

Three Mandarin speakers (two females) in Paris participated in the experiment. One female speaker is an international student aged 25 years that was born in Xi’an, China. Her mother tongue and language of schooling is Mandarin. The others speakers are Beijing Mandarin speakers (one female 26 years; one male 32 years).

2.4 Acoustic Measurements

The first syllable, the second syllable, and the pause between them for each critical word were manually marked in Praat, yielding four marks, one at the beginning of the first syllable, a second mark at the offset of the first syllable, a third mark between the offset of the first syllable and the onset of the second syllable, and a fourth one at the offset of the second syllable. A Praat script extracted the duration and intensity value of each segment in msec. F_0 onset and offset were measured at the beginning and at the end of the vowel. In the study, we divided the vowel into ten segments normalized in time, with the mean F_0 of the first segment as F_0 onset and the mean F_0 of the last segment as F_0 offset.

3. Results

Three-way repeated analysis of variance ANOVA tests were performed separately for each acoustic feature (duration, F_0 , and intensity). Word type ([MN] modifier-head compound vs. [VO] verb-object phrase) and syllable position (left syllable: S1 vs. right syllable: S2) were the within groups factors, and word position in the utterance fragment (*i.e.* final vs. non-final) was the between groups factor.

3.1 Duration

3.1.1 Left Syllable vs. Right Syllable

Results of the three-way ANOVA for the duration revealed a significant main effect for word type [$F(1, 134) = 440.8, p < 0.001; \eta_p^2 = 0.77$], a significant main effect for word position [$F(1, 134) = 25.6, p < 0.001; \eta_p^2 = 0.16$], a significant main effect for syllable position [$F(1, 134) = 105.3, p < 0.001; \eta_p^2 = 0.44$], a significant interaction word type x syllable position [$F(1, 134) = 87.4, p < 0.001; \eta_p^2 = 0.40$], and a significant interaction word position x syllable position [$F(1, 134) = 440.8, p < 0.001; \eta_p^2 = 0.77$]. Word position showed no interaction with word type. In order to increase the statistical power, we token the word position out, and ran a two-way ANOVA (word type x syllable position). The two-way ANOVA showed significant main effect for word type [$F(1, 269) = 846.7, p < 0.001; \eta_p^2 = 0.64$] and for syllable position [$F(1, 269) = 166.3, p < 0.001; \eta_p^2 = 0.38$] and a significant interaction word position x syllable position [$F(1, 269) = 217.1, p < 0.001; \eta_p^2 = 0.45$]. *Post hoc* analyses showed a larger effect of syllable position for [VO] [$F(1, 269) = 217.0, p < 0.001; \eta_p^2 = 0.45$] than for [MN] [$F(1, 269) = 28.6, p < 0.001; \eta_p^2 = 0.10$].

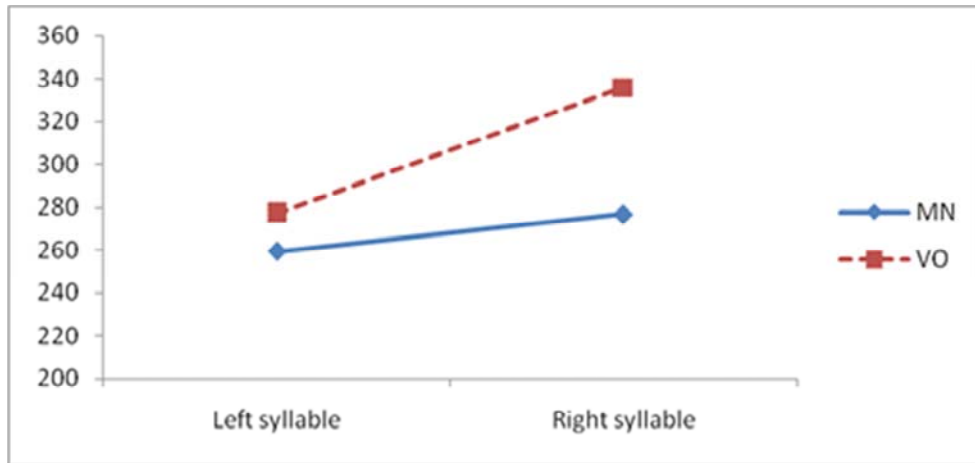


Figure 1. Mean syllable durations in msec for each syllable in [MN] and [VO].

3.1.2 Duration of the Pause

As one can notice a pause between the two syllables in VO, we decided to perform measures of pause duration. The ANOVA on the average pause duration between the syllables showed a significant main effect for word type [$F(1, 269) = 33.5, p < 0.001; \eta_p^2 = 0.11$].

3.2 F₀

The F₀ was analyzed separately for each of the four tones. A three-way ANOVA with word type (MN vs. VO), syllable position (Left syllable vs. Right syllable), and measure point (onset vs. set) was applied to Tone 1 and Tone 4, and a two-way ANOVA with word type (MN vs. VO) and syllable position (Left syllable vs. Right syllable) was calculated on the difference between F_{0max} and F_{0min} for Tone 2 and Tone 3.

3.2.1 Tone 1

Results showed a significant main effect for measure point [$F(1, 45) = 10.7, p < 0.01; \eta_p^2 = 0.19$], a significant interaction between word type and syllable position [$F(1, 45) = 4.7, p < 0.05; \eta_p^2 = 0.10$], and a significant interaction between measure point and syllable position [$F(1, 45) = 6.6, p < 0.05; \eta_p^2 = 0.13$]. Nevertheless, neither significant interaction between word type and measure point [$F < 1$], nor significant interaction between word type, syllable position, and measure point [$F < 1$] was found.

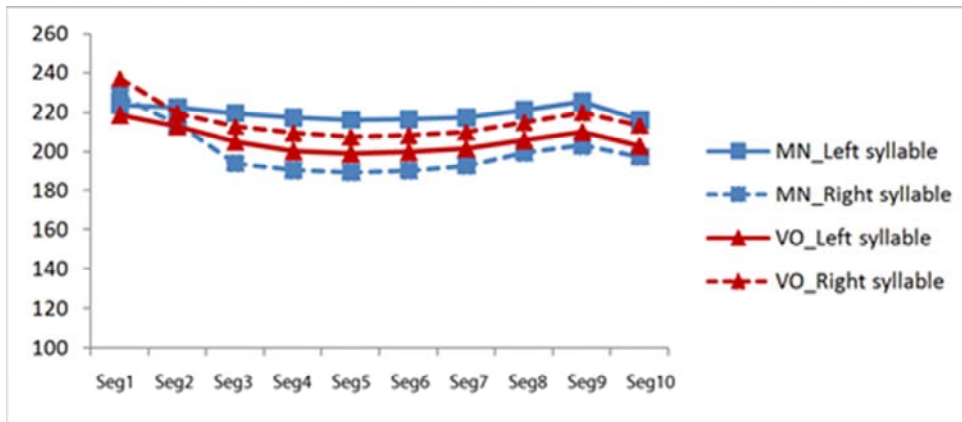


Figure 2. F_0 values on ten segments for Tone 1 for Left and Right syllable in [MN] and [VO].

3.2.2 Tone 2

Neither significant main effect for word type and syllable position [$F < 1$] nor significant interaction [$F < 1$] was found on the difference between F_{0max} and F_{0min} .

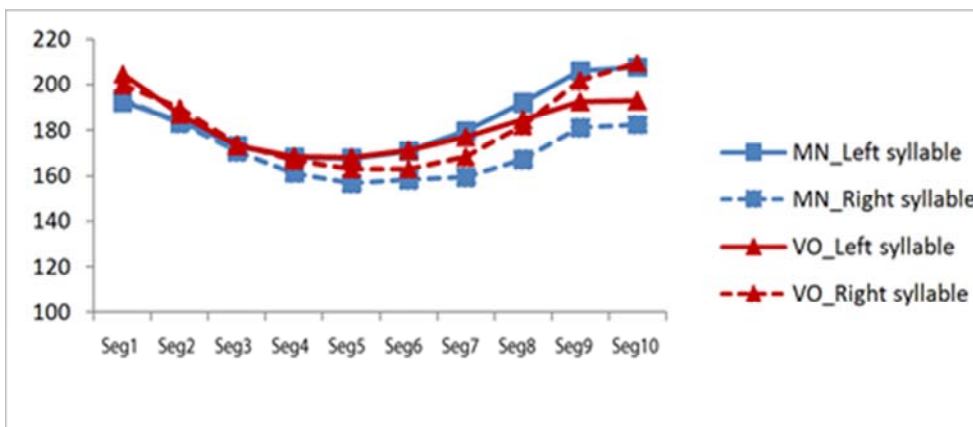


Figure 3. F_0 values on ten segments for Tone 2 for Left and Right syllable in [MN] and [VO].

3.2.3 Tone 3

In order to not confound tone sandhi influence for these analyses, we took out two items in our experimental material with a Tone 3-Tone 3 combination. The two-way ANOVA on the difference between F_{0max} and F_{0min} revealed a significant interaction word type x syllable position [$F(1, 53) = 217.1, p < 0.001; \eta_p^2 = 0.31$]. *Post hoc* analyses showed a larger effect of syllable position for [VO] [$F(1, 53) = 37.9, p < 0.001; \eta_p^2 = 0.42$] than for [MN] [$F(1, 53) = 37.9, p < 0.05; \eta_p^2 = 0.80$].

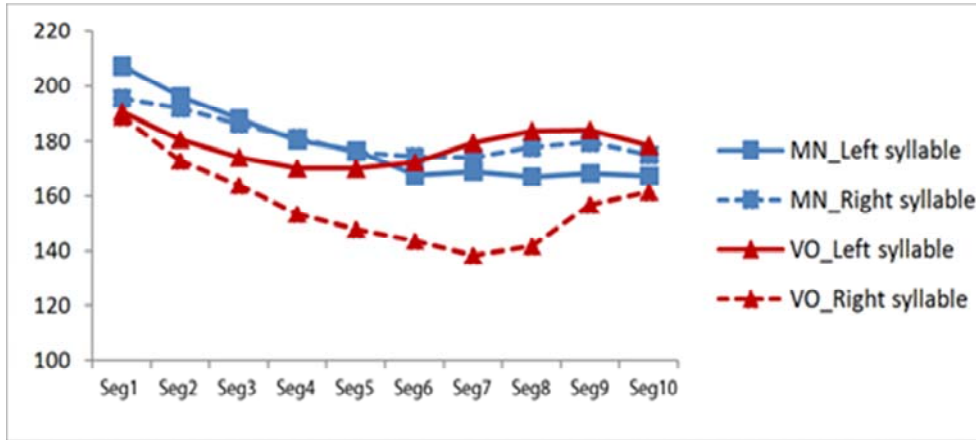


Figure 4. F_0 values on ten segments for Tone 3 for Left and Right syllable in [MN] and [VO].

3.2.4 Tone 4

Results showed a significant main effect for measure point [$F(1, 91) = 339.1, p < 0.001; \eta_p^2 = 0.79$] and for syllable position [$F(1, 91) = 14.0, p < 0.001; \eta_p^2 = 0.13$], a significant interaction between word type and syllable position [$F(1, 91) = 23.5, p < 0.001; \eta_p^2 = 0.21$], a significant interaction between measure point and syllable position [$F(1, 91) = 14.4, p < 0.001; \eta_p^2 = 0.14$], and a significant interaction of word type x measure point x syllable position [$F(1, 91) = 6.8, p < 0.05; \eta_p^2 = 0.07$]. *Post hoc* analyses showed a main effect of syllable position for the Left syllable of [VO] [$F(1, 91) = 36.8, p < 0.001; \eta_p^2 = 0.29$], however, there was no main effect of syllable position for the Left syllable of [MN] [$F < 1$].

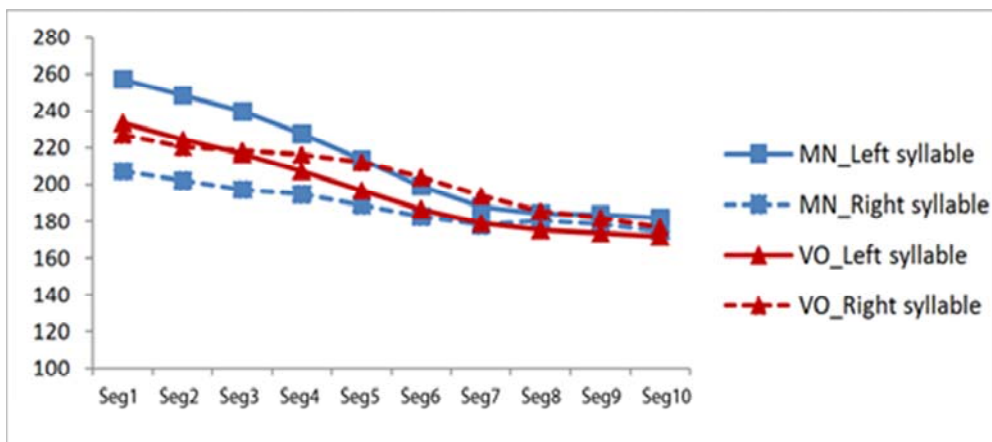


Figure 5. F_0 values on ten segments for Tone 4 for Left and Right syllable in [MN] and [VO].

3.3 Intensity

A three-way ANOVA with repeated measure was performed on the average intensity. Results showed a significant main effect for word type [$F(1, 134) = 139.0, p < 0.001; \eta_p^2 = 0.64$], a significant main effect for word position [$F(1, 134) = 234.8, p < 0.001; \eta_p^2 = 0.16$], a significant main effect for syllable position [$F(1, 134) = 58.9, p < 0.001; \eta_p^2 = 0.31$], a significant interaction word type x syllable position [$F(1, 134) = 87.4, p < 0.001; \eta_p^2 = 0.40$], and a significant interaction word position x syllable position [$F(1, 134) = 440.8, p < 0.001; \eta_p^2 = 0.77$]. No interaction was found.

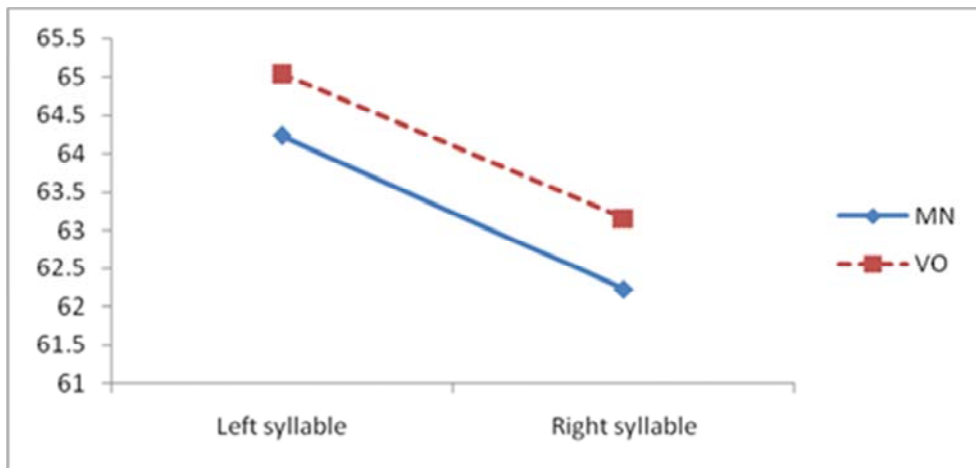


Figure 6. Mean intensity (dB) for each syllable in [MN] and [VO].

4. Discussion

This article investigated the acoustic correlates of linguistic stress on the ambiguous structure Verb-Noun (*i.e.* [MN] vs. [VO]) in Mandarin Chinese. Moreover, the acoustic feature associated with this stress pattern was analyzed. As explained in the introduction, duration, F_0 , and intensity are the main correlates of stress. Results showed the implication of duration, F_0 , and intensity in the production of compound and phrasal stress in Mandarin.

Our preliminary data showed that the duration was longer for the right syllable in [VO], which was consistent with previous studies on the acoustic correlates of linguistic stress for stress languages and for tone languages, such as Mandarin. Nevertheless, the ‘assumed stressed’ left syllable in [MN] was not longer than the Right syllable. We also performed measures of pause duration, and the results on the average pause duration between the Left and Right syllables showed that average pause duration is longer in [VO] than in [MN]. Nevertheless, we considered that this larger pause duration was not an acoustic manifestation of stress but a mark of the syntactic boundary in the verb-object phrase.

Despite the fact that, in tone languages, F_0 information should be attributed to its lexical

usage, our results showed that F_0 would be a reliable cue for the stress pattern in [MN] and [VO]. The F_0 range was shown to link to the stress for Tone 3 and Tone 4, which was in line with the predictions (Chao, 1968) that pitch range is wider for stressed syllables, specifically, when a 3rd Tone is stressed, it dips lower, and, when a 4th Tone is stressed, it starts higher. Our results showed that, for Tone 3 the right syllable in [VO] had a larger F_0 range than the left syllable. For Tone 4 the left syllable in [MN] showed higher onset F_0 than the right one.

The analyses on the intensity were in line with previous studies, which showed a less important role of the intensity for stress. In our preliminary data, the intensity was shown to have larger amplitude in [VO] than in [MN] for the two syllables. Nevertheless, we failed to find the strengthening of the Left syllable in [MN], as proposed by Fraise, that left-headed feet should show extra loudness on the initial syllable than the second initial. Our results showed the same pattern of intensity between [VO] and [MN]. Therefore, we considered that, unless the [VO] and [MN] were presented together, the intensity was not an effective cue for distinguishing between [VO] and [MN].

In sum, our preliminary data suggested an implementation of the final lengthening for the stressed syllable in [VO], but no initial extra loudness in [MN]. The F_0 information suggested that, for Tone 3, the Right syllable was stressed in [VO] and, for Tone 4, the Left syllable was stressed in [MN]. The results confirmed the right stress pattern in [VO]; however, with the only support in Tone 4, we did not consider a lexical stress on the Left syllable in [MN].

The prosodic information, such as stress, duration, and pause was shown to be critical for the processing of the compound words (Isel *et al.*, 2003). Once we have shown that compound word and verbal phrase present different acoustic patterns with respect to the position of stress, the next step would be to verify whether this stress pattern is used by the listeners to differentiate the two forms in cases of segmental ambiguities. For this purpose, we plan to conduct different perception and categorization experiments. At the same time, more speakers would be added to the production study.

5. Conclusion

Our results showed a right stress pattern in [VO] with longer duration in the Right syllable, larger range F_0 , and longer pause duration between the syllables; in contrast, no initial strengthening in [MN] was found. Only the F_0 range information in Tone 4 supported a lexical stress on the Left syllable in [MN].

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Appendix

Table 1. One hundred thirty-five minimal pairs [MN] [VO] selected in the Contemporary Chinese Dictionary 5th edition (Lu & Ding, 2008).

	Verb	Noun		Verb	Noun	
1	帮工	help w ith farm w ork	helper	71 讲话	speak	speech
2	报价	to quote	a quote	72 剪影	to sketch	a sketch
3	爆料	reveal a new s	new s	73 兼职	hold tw o or more posts concurrently	concurrent post
4	保险	to assure	insurance	74 剪纸	cut paper	paper-cut
5	备份	to backup	backups	75 结晶	crystallize	crystal
6	备料	to stock	stock preparation	76 借款	to loan	a loan
7	编号	to number	a number	77 结尾	to end	ending
8	编剧	w rite a play	playw right	78 进口	to import	importation
9	编码	encoded	code	79 进账	register an income	income
10	标价	mark the price	price	80 纪实	to record actual events	record of actual events
11	表情	express one's feelings	expression	81 记事	to record	a record
12	比价	compare the price	price parity	82 捐款	contribute money	donation
13	拨款	allocate funds	Appropriation	83 决策	make a strategic decision	a strategic decision
14	补液	supply w ater	fluid supplementation	84 开局	to open	opening
15	补益	to benefit	benefits	85 开头	make a start	beginning period
16	藏书	collect books	a collection of books	86 考绩	check achievement	merit of professional performance
17	插话	interpose	episode	87 理事	to manage	member of a council
18	超人	exceed	superman	88 留言	leave a message	a message
19	成人	grow up	adult	89 留影	take a photo as a memento	photograph
20	成文	become official dispatch	existing writings	90 满堂	fill the hall	w hole hall
21	喝水	absorb w ater	drinking w ater	91 满月	complete the first month of life	full moon
22	创意	create	originality	92 逆流	against the flow	backset
23	创作	create	creation	93 配方	make up a prescription	a prescription
24	传人	teach	successor	94 平价	stabilize the price	fair price
25	传闻	to rumour	a rumour	95 评价	evaluate	evaluation
26	传言	pass on a message	hearsay	96 品味	to taste	taste
27	出口	to export	exports	97 欠款	owe e	debt
28	存货	to stock	a stock	98 欠债	run into debt	amount due
29	存粮	store up grain	grain in stock	99 欠账	to debit	debit
30	出身	come from	class origin	100 签证	to visa	a visa
31	出账	enter an item of expenditure in the accounts	payment	101 签字	to sign	signature
32	存款	to deposit	a deposit	102 起价	make a price	starting price
33	代表	to delegate	a delegate	103 起头	to start	beginning
34	答卷	answ er questions in an examination paper	answ er sheet	104 融资	to finance	a finance
35	倒账	repudiate a debt	bad debts	105 说理	argue	argument
36	得分	to score	a score	106 谈话	to talk	a talk
37	定案	decide on a verdict	verdict	107 提包	carry a bag	handbag
38	订单	to order	an order	108 题词	w rite an inscription	an inscription
39	顶风	against the w ind	head w ind	109 贴息	pay interest	interest so deducted
40	定稿	finalize a manuscript	final version	110 替工	w ork as a substitute	temporary w orker
41	定价	make a price	fixed price	111 投资	invest	investment
42	定量	to quantify	norm	112 限价	limit the price	limited price
43	定时	define a time	definite time	113 限量	limit the quantity of	limited quantity
44	定义	to define	definition	114 限令	order sb. to do sth. w ithin a certain time	an order
45	定员	designate members	fixed number of staff members	115 限期	set a time limit	deadline
46	定址	select a venue	permanent venue	116 显效	take effect	effect
47	断层	fault	faultage	117 选项	delect an option	option
48	对话	have a dialogue	dialogue	118 续约	renew a contract	renewal term
49	罚金	to fine	a fine	119 押款	borrow money on security	a loan on security
50	罚款	impose a fine	a fine	120 演义	explain some reason or fact	historical novel
51	发面	leaven dough	leavened dough	121 议价	negotiate a price	negotiated price
52	返程	to return	return	122 引例	to cite	citation
53	返利	to rebate	a rebate	123 用语	choose w ords	choice of w ords
54	发言	speak	speech	124 约期	fix a date	date of appointment
55	封口	to seal	seal	125 渔利	reap unfair gains	easy gains
56	分界	have as the boundary	boundary	126 造型	to model	modelling
57	耕地	to plough	cultivated land	127 摘要	make a summary	summary
58	管家	manage	manager	128 掌舵	steer a boat	the man w ho steers a boat
59	鼓包	to lump	a lump	129 征文	solicit articles	essay w riting
60	雇工	hire labour	hired labourer	130 转机	transfer	a favourable turn
61	耗材	consume	consumptive material	131 转年	pass to the coming year	the coming year
62	合力	join forces	resultant	132 铸币	to coin	coined money
63	护法	defend	custodian	133 驻军	to garrison	garrison
64	回话	to reply	a reply	134 作文	w rite a composition	composition
65	汇款	make a remittance	remittance	135 作业	to operate	a job
66	回礼	present a gift in return	a gift in return			
67	回味	recollect the pleasant flavour of ...	aftertaste			
68	寄语	send w ord	message			
69	剪报	cut new spaper	cuttings			
70	兼差	w ork part-time	part-time jobs			

