The time course of intersyllabic junctures in Standard Chinese

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普通话音节间音联的时域特性

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[摘要] 所谓音联(juncture)，就是语音的相邻音段之间的连接和分界现象。它既可发生在音节内部，也可发生在音节之间。音联现象是由于不同音段之间的协同发音作用而引起的，它既涉及语音特性的频域变化，又涉及这种变化的时域分布。本文集中考察普通话两音节结构中音节间音联的时域分布特性。具体说，就是考察前音节的韵母跟后音节的声母之间的连接和分界问题。

本研究的基本实验材料由 386 个(C1)V1-(C2)V2 型两音节结构组成，其中正常重音型 319 个，轻声型 67 个，由一个男发音人以正常速度说出。在这些两音节结构中，C1 和 C2 可能是零声母，也可能是不同的辅音声母；V1 和 V2 可能以元音结尾，也可能以鼻音结尾。通过对这些语音材料进行声学分析和测量，对音节间音联作了以下几个方面的考察：(1) 音节间发音态势套叠(overlap)的大致过程及音节之间的分界信息；(2) 音节间发音态势套叠的时域范围；(3) 套叠的时域范围跟语音结构特点之间的关系。

根据现有的实验结果，对普通话音节间音联的时域特性有如下几点看法：

1. 在时间域里，音节之间的连接关系可以通过发生在音节边界上不同音段发音态势之间的转变过程来加以说明，兹以 C1V1-C2V2 型结构为例，边界上的声学信息表明，这个过程大致经历以下几个基本阶段：(1) V1 发音过程中的 C2 作势阶段，那就是，在 V1 的发音期间，发音器官就开始逐渐趋向于 C2 的成阻态势。这是一个量变的过程，在生理上对应于先期协同发音，在这个过程中，仍然以 V1 的发音态势为主，尽管它已经受到 C2 准备态势的干扰；(2) 发音器官实行 V1 态势到 C2 态势的转折，这是一个质的变化。在这个转折点上，V1 的发音已经基本完成，而 C2 正式成阻并开始发音，而且，这个转折点是可以通过边界上的声学信息大致界定的，所以，这个转折点可以看作两个音节的分界点，根据本研究观察到的信息，它就是前一音节第二共振峰的末尾；(3) C2 发音过程中 V1 态势的收尾阶段，那就是，从 V1 跟 C2 的转折点起，V1 的发音虽然已经基本结束，但由于惯性的作用，某些器官的发音态势会保留一段时间，直到逐渐被下一个音段的发音态势完全取代为止。这也是一个量变过程，在生理上对应于遗留的协同发音，在这个过程中，C2 的发音态势尽管也受到 V1 遗留态势的干扰，但它已经占了统治地位。

上述过程是根据音节边界上的声学效应，并参考国外关于发音过程的 X 光研究资料所作的一种推测。假如这个假设确实有道理的话，那么，它将在音节的感知机制方面给我们以某种启示，有助于我们了解为什么从发音上及其声学效应上看音节之间是彼此套叠的，而且其时域范围甚广，而在听感上却能把两个音节分开。这起码暗示着以下几种可能性：(1) 的确

存在着音节的感知中心；(2) 音节之间的确存在着分界信息，尽管它们在发音态势上相互套叠，但所涉及的不过是前一音节的收尾阶段和后一音节的准备阶段，对于音节的感知来说，它们并不是关键部位，并没有落在音节的感知中心；(3) 这或许正好反映了汉语不同于其它语言的一个特点。因为汉语是个典型的声调语言，每个音节都有固定的、具有区别意义功能的声调。就多音节结构而言，也都具有一定的、取决于各音节调类的连读变调格式。因此，在连续话语里，除了儿化这样的特殊情况以外，音节之间的发音态势套叠一般不会抹煞掉音节与音节的分界。至于儿化，它不仅涉及语音上的协同发音，而且涉及语法形态的变化，应该另文讨论。

2. 音节之间发音态势套叠的时域范围大致有定，就本文研究的这个发音人的情况而言，正常型音节间态势叠接区间的平均时长在 130-140 毫秒之间，约占整个词长的 17%左右。而且，发生在音节边界上的先期协同发音和遗留协同发音的时程大致相当，也就是说，前音节韵母的后过渡跟后音节声母的前过渡大致等长，其平均值在 60-70 毫秒之间。但是，由于各种因素的影响，个体之间的内部差异比较大。这不但表现为过渡段绝对时长方面的差异，同时也表现为过渡段跟整个韵母或声母时长比例分布上的相对离散性。就前音节的后过渡跟整个韵母的时长比而言，从 10%到 35%不等，虽然绝大多数分布在 20-25%之间；就后音节声母的前过渡跟整个声母的时长比来看，从 20%到 90%不等，尽管多数分布在 40-50%之间。这些内部差异看来主要跟音节的重音地位以及音节的结构特点有关。

3. 影响音节间音联时域特性的主要因素：(1) 音节间音联的时域特性同音节的重音地位具有密切关系。在轻声型两音节结构中，由于后音节为轻声音节，其声母的前过渡明显缩短，它同正常重读情况下声母前过渡之间的时长差异是一种系统差异，相关的变量分析结果表明，这种来自重音地位的影响是十分显著的；(2) 前音节韵尾的性质影响音节间过渡音的时长分布，当前音节以鼻音结尾时，其后过渡段比以元音结尾时要短，与之相应的后音节声母前过渡段也比元音结尾情况下的短，这种差异也是十分显著的；(3) 后音节声母发音方法的不同对音节间过渡音的时长分布具有一定影响，主要表现在后音节以鼻音、边音或浊擦音作声母时，前音节后过渡和后音节前过渡都比以清擦音为声母时要短，但是，这种差异并不明显；(4) 后音节声母发音部位的不同一般不影响音节间过渡时长的分布。不过，在带“子尾”的轻声词中，后音节声母[ts]的闭塞段特别短，有时甚至根本观察不到。这种情况比较特殊，或许涉及语法形态问题，本文暂不讨论。

Abstract

This paper reports a preliminary investigation on the time course of intersyllabic junctures in Standard Chinese. As the basis of this study, durational measurements for relevant events in some 400 disyllabic words were made, that is based on a close obsevation to the acoustic effect of temporal overlap between neighboring segments across syllable boundaries. The process of gestural overlap between syllables is described, the corresponding overlap extent is presented, and the rough boundary marker between syllables is estimated as well.

I. Introduction

Just like tone, stress and intonation, juncture between different speech units is partial

manifestations of the prosodic features in speech production(Chao,1980). It is related to the pheno-menon of connexion and segmentation at the boundary of neighboring segments(Xu, 1989) due to coarticulation, and it can take place in either case of intra- and inter-syllables(Ohman, 1966). In essence, "coarticulation refers to overlap of articulatory gestures associated with separate speech segments, and by extension to its acoustic effects"(Keating, 1988:1). So this phenomenon is physiologically referred to articulatory gesture coodination involving both spatial and temporal domains(Browman & Goldstein, 1989). In this study, the main attention is paid to the temporal phasing of intersyllabic case.

Generally, the temporal phasing of articulatory gestures is defined as "an abstract characterization of coordinated task-directed movements of articulators within the vocal tract"(Browman & Goldstein, 1989:206). Therefore, the fundamental task involved here is to inquire into the process of articulatory movements and the extent of gestural overlap. According to Browman and Goldstein(1989:211), "the pattern of organization, or constellation, of gesture corresponding to a given utterance is embodied in a set of phasing principles ...that specify the spatiotemporal coordina-tion of the gestures". However, the x-ray data on articulatory process (Wood, 1991) indicate that, the extent of articulatory gesture overlap is variable, usually there were two even three phonemes produced in parallel, in some case, the articulatory gestures for two different phonemes even active at the same moment. Consequently, such a process is hard to be defined, and the exact extent of this overlapping is difficult to be estimated, especially in the case where only the acoustic information is available. Nevertheless, from the point of view of practice in speech processing or of underlying approach in speech production, to observe such overlapping process and search for a rough extent may be necessary.

The present investigation is concentrated on the intersyllabic junctures in Standard Chinese (hereafter SC). The main purpose is to test: (1) how the articulators move from one syllable to the next and whether there exist any information that can mark the syllable boundary? (2) what is the extent to which the neighboring segments overlap and does the difference in syllable structure affect the extent of temporal overlap?

2. Materials and methods

Test materials involved in this investigation consist of two groups of (C1)V1-(C2)V2 type disyllabic words. The first group contains 319 normal (NM)stress type words, in which 79 is duplicated ones designed for the convenience of a comparitive observation to their spectrograms. In this subgroup, the final (hereafter V1) of the first syllable can be closed by a nasal or a vowel, and the initial (hereafter C2) of the second syllable is selected from various consonants differing either in place or manner of articulation so as to examine possible effect to the manifestation of temporal overlap across syllable boundaries; The second group includes 67 words in neutral(NT) type stress, i.e., the first syllable in the word is normally stressed while the second one is neutralized with weaked stress(Cao, 1992). This group of words is designed to test if different stress types have any influence upon temporal characteristics of gestural overlap. All these

materials were read in moderate speed by a native male speaker of SC, and analyzed by using Key Mode 5500 Spectrogragh.

The basis of this study is a careful observation and durational measurements to relevant events through spectrograms, but these events and some related criterion obviousely have to be defined before any measurements can be conducted. First, the intersyllabic junctures involved here is represented by V1's offglide tranfsition, C2's(or V2's) onglide transition, and the boundary marker between V1 and C2 or V2. In the case of C2 is voiceless stops or affricates, the C2's onglide is impossible to be observed, so we just take the interval of their closure(gap) as the correlate. Second, as what has been mentioned above, it is difficult to define where is the exact beginning or ending point of an articulation from the acoustic signal, so here we just roughly estimate their locations with reference to observable variation of the formant transitions. In other words, the durational data obtained here can only reflect the elemental extent of temporal overlapping between V1 and C2 or V2. And thirdly, the ending point of V1's offglide, which should also be regarded as the starting point of C2 or V2 onglide, is defined in terms of the energy end of the second formant and the higher. The reason will be specified below in section 3.1.1.

3. Observation and analysis

3.1. *Observation to the acoustic effect*

3.1.1. *Boundary information and measure criterion*

Speech production involves complex motor control. Some previous approaches have claimed that different kinds of segments may go on simultaneously, and thus there are no borders perpendicular to the time axis in an articulatory or acoustic record to separate one segment from another(Fowler, 1980; Wood, 1991). It may be common in all languages. Thus, with respect to intersyllabic juncture in the SC, a fundamental question facing us is that how to bound the periods of V1 offglide and C2 or V2 onglide. To determine the measure points, we have closely examined the spectral effect across syllable boundary in all the test materials, and found that the junture patterns can be classified in terms of different intersyllabic structures. The examples are shown in Fig. 1, from which we can see that, when V1 is any vowel and C2 is nasal, lateral or voiced fricative(e.g. Fig 1.a), the transitions including V1's offglide and C2's onglide is observable and the measure points are easier to be located. Otherwise, especially when V1 is a nasal and C2 is a voiceless stop or affricate, either the V1 offglide or C2 onglide is difficult to be observed . The most ambiguous situation occurs in V1-V2 structure, with V1, V2 being the same phoneme, where the formant trajectories of V1 and V2 are usually connected smoothly without marked boundary information. So in this case, where is the ending point for V1 offglide is the crux of the matter, i.e., should it locate at the end of the first formant(F1) or that of the second formant(F2) and the higher?

To overcome this difficulty, let us have a further observation of the case where V1 is a vowel and C2 is nasal or lateral. As what can be seen from Fig. 1.a, an evident fault block exists between /o/ of the1st /lao/ and /l/ of the 2nd /lao/, and the formant patterns of transitions are quite

different one side from the other of the fault block. Obviously, this fault block is the mirror of a rapid change in articulatory movement, It indicates a qualitative variation from /o/ turnning to /I. Consequently, this point should be regarded as the acoustic evidence for the border between the two syllables. A similar evidence is also found from the example shown in Fig.1.b, where the word is duplicated by two zero-initial syllables, and /u/ of the 1st /iou/ is followed by vowel /i/ of 2nd /iou/, a turning marker between the two syllables also can be seen with reference to their formant patterns. Since in both cases, the border occurs right at the F2 end of V1 and the F2 begining of C2 or V2, it is reasonable to take this point as the ending point of V1's offglide and the starting point of C2 or V2's onglide.

3.1.2. *Overlap process*

The process for temporal overlapping between the two syllables also can be specified through the acoustic effects described above. Take Fig. 1.a as an example, from which we can see that, in the left wing of the fault block between /o/ and /l/, the F2 of /o/ is rising and the F3 is falling from their target values. It can be observed by comparing the formant patterns of their finals in the two syllables. It indicates a spatiotemporal coordination of gestural overlap, i.e., an articulator movement directed towards /l/ has started when the /o/ articulation is on going, so it is a kind of anticipatory coarticulation by overlapping the articulatory tendency of /l/ onto the gestures of /o/. Obviously, this is only a preparing period for /l/, during which the /o/ gesture is still dominant, though it has been interpolated. Therefore, the period before the fault block is actually a process of quantitative variation from the /o/ towards the /l/. On the other hand, in the right wing of the fault block, the formant pattern is essencially belonging to the /l/, but its former portion clearly deviates from its target value, It can be seen by comparing the formant patterns of the initials in the two syllables. This phenomenon is caused by a carryover coarticulation. It shows that, from the moment of the fault block, the gestures of /l/ have been the dominant, but still to be interpolated by the reminder gesture of /o/, because the gestures of /o/ can not stop at once but withdrow gradually. This kind of mechanism has been revealed by an x-ray approach (Wood. 1991:286) that provides evidence that:

"...the typical utilization of any articulator was that there were brief of movement, and longer periods of inactivity. ...The overall impression is one of the articulators being mashalled momentarily as needed and left alone when not needed, until ..."

According to the proof quoted above, there must be a withdrowal process for the articulators involved in the articulation of /o/. This is also a process of quantitative change taken place during the former portion of /l/.

Generally, the mechanism of speech production for various structures must be identical in the same language. Therefore, it is quite reasonable to assume that, the process of temporal overlapping observed from the examples of /lao-lao/ or /iou-iou/ should also be true for the cases other than them.

3.2. *The extent of temporal overlapping*

3.2.1. *General impression*

Durational measurements for relevant events are summarized in the Tables I and II. Table I gives an outline of the extent of temporal overlap taken place both in NM and NT type words. The figures specified under the columns of mean, sd and ratio represent mean duration, standard deviation and durational ratio of the offglide to V1 and the onglide to C2 or V2 respectively. In addition, for the purpose of comparison, the minimal and maximal values occuring among individual tokens are listed here, too. The data given in Table II represent only the mean duration and standard deviation in the NM type of duplicated words, but the situations are specified in 8 subgroups, in order to observe whether the phonetic difference of V1 or C2 affects temporal overlap between V1 and C2.

Table I. The mean duration, sd, durational ratio(to V1 in the 1st sylla. and to C2 or V2 in 2nd sylla.) and the minimal - maximal value of the offglide and onglide in NM type(group one) and NT type (group two)words: (1) in the case of C2 is zero initial; (2) in the case of C2 is various consonant initial.

groups		tokens.	offglide of V1				onglide of C2 or V2			
			mean(ms)	sd	ratio(%)	min-max(ms)	mean	sd	ratio(%)	min-max
group one	(1)	38	69	18	21	45 - 98	66	19	18	38 - 102
	(2)	281	71	15	24	31 - 120	68	17	51	31 - 138
group two	(1)	9	60	43	25	46 - 95	32	22	23	13 - 55
	(2)	58	71	16	25	46 -104	30	15	38	0 - 74

Taking an overview to the data shown in Table I, a general impression is that, on the one hand, in respect of absolute duration, the mean value for V1 offglide or C2 onglide is quite close to each other in the NM type words, no matter whether C2 is a zero initial or consonant initial. This phenomenon seems to show that, the extent of temporal overlapping between syllables does follow a rough constant, and in the NM type of disyllabic structure, the interval of anticipatory coarticulation is approximated to that of carryover coarticulation. At least, it is true for the situation with respect to the same speaker. On the other hand, however, there is some difference between the figures of group one and group two. Besides, a tremendous difference between the minimal and maximal values listed in Table I indicates that, there also exists considerable difference among the individual tokens. Moreover, from Fig.3, we find that, the distribution of durational ratios for individual tokens is quite dispersed, though most of the tokens for V1 offglide locate between 20-25%, and those for C2 onglide locate between 40-50%. These internal diferences seem to be caused by multiple factors, which will be specified in 3.2.2.

Table II. The mean duration and sd of V1's offglide and C2's onglide in duplicated NM type word: (1) in the case of 1st syllable with a nasal ending; (2) in the case of 1st syllable with a vowel ending; (3) when C2 is unaspirated stops; (4) C2 is aspirated stops; (5) C2 is nasal, lateral or voiced fricative; (6) C2 is voiceless fricative; (7) C2 is unaspirated affricative and (8) C2 is aspirated affricative.

	V1's offglide			C2's onglide		
	tokens	mean(ms)	sd	tokens	mean(ms)	sd
(1)	30	55	12	30	52	12
(2)	49	70	12	49	70	16
(3)	9	63	24	9	75	33
(4)	9	62	24	9	63	24
(5)	12	52	20	12	47	18
(6)	15	64	21	15	64	22
(7)	9	66	14	9	62	11
(8)	9	53	15	9	50	15

3.2.2. *Internal difference and influence factors*

According to the limited materials tested here, the main influence factors seem to be related to the phonetic characteristics of V1 and C2 or V2.

First, as what can be seen from the data of group two listed in Table I, the situation in the NT type of disyllabic words is different from that in NM type words, i. e., in NT type ones, the interval for V1 offglide is somewhat equal to, while that of C2 onglide is obviously shorter than their partners in NM type words. Fig. 2 provides a more imaged description about this situation, and the result from the analysis of variance also indicates that, this difference is highly significant [$F(1,131)=167.46$; $P<0.001$]. It is obvious that this defference is caused by stress contrast of the syllables. Since in NT type words, the second syllable is neutralized and shortened greatly(Cao, 1992), so the duration of C2 onglide is shortened correspondingly. This phenomenon may agree with such a suggestion that "the movements of gestures are not timed with respect to an external clock but only with respect to the internal stages of some other gesture." (Zsiga, 1991:122).

Second, if we compare the mean value in the the first two lines of Table II, a systematic distinction between the two sets of data can be observed. It shows an influence of the V1 type upon the manifestation of temporal overlapping between V1 and C2. Specifically, in the case where V1 is a nasal ending, both the offglide and onglide is considerablly shorter than that for the case where V1 is a vowel, and this kind of influence is statistically significant[for V1 offglide, $F(1, 77)=30.72$, $P<0.001$; for C2 onglide, $F(1,77)=29.53$, $P<0.001$].

Thirdly, the influence from the difference on articulation manner of C2 is also existed. For

example, comparing the mean durations listed in lines (3) to (8) of Table II, a slight difference can be observed between the cases where C2 is nasal, lateral or voiced fricative and where C2 is voiceless fricative, as well as between the cases where C2 is aspirated and unaspirated stop or affricates, but no significance has been found here. As for the situations between the cases of (3)(4)(7)(8) vs. that of (5)(6) are not comparable, because here the means of onglide in the cases of (3)(4)(7)(8) actually represent the gap duration of C2, instead of the exact onglide.

So far, no clear influence has been found from the difference of articulation place upon the manifestation of temporal overlapping, but a special situation may be worth to be mentioned. That is, a particular shortemning for the gap of C2 in NT type words occurs when the C2 is the consonant [ts], where even no gap could be observed in a few cases. Of course, this phenomenon is so-called "/ts13 uei3/" that may be due to some other morphological effects, which are beyond the scope of the present paper.

5. Conclusion

The experimental data and related acoustic observation lead to the following suggestions:

(1) Articulatory movement from one syllable to the next seems to execute through the steps as follows: at the first stage, preparing the articulation of C2 during the latter portion of V1. Specifically, during the articulation of V1, the articulators move gradually towards the obstruction of C2 by overlapping the tendency of C2 gesture onto V1, the gesture of V1 thus to be interpolated, but still being dominant. After that, there is a turning point, at that moment, the articulation of V1 has finished and the gesture of C2 has been built up formally; at the second stage, whithdrawing the articulation of V1 during the foermer portion of C2, i.e., the gesture of V1 doesn't withdrow suddenly from the turning point, but get off gradually by overlapping its remainder onto the former portion of C2, so the gesture of C2 is interpolated, but has being the dominant already.

(2) The extent of gestural overlapping between syllables does follow a rough constant, and the interval of anticipatory coarticulation is close to that of carryover coarticulation. However, there exists great internal difference among the individual tokens due to the influence coming from multiple factors. The main influence comes from stress contrast of the syllables, and different coda types of the first syllables.

The process of temporal overlapping between syllables in SC described above is assumed according to the limited investigation conducted in this study with reference to some previous researches related to speech production. If this assumption is reasonable, then it may give us some insight on the mechanism of syllable perception . Specifically, how can people distinguish individual syllable from connected speech, though the syllables are evidently overlapped. At least, some impression or possiblilities can be drawn: (1) There does exist boundary marker between syllables; (2) The perception center does exist in each syllable; and (3) It may be related to such a characteristics that, Chinese is a typical tone language, in which, each syllable must have an inherent tone pattern with the function of distinguishing lexical meaning. Also, each

polysyllabic structure has its own regular tone sandhi pattern, therefore, the boundary marker between syllables is impossible to be obliterated. The gestural overlapping occurred between syllables seems only involve in the period of preparing or withdrowing for a syllable articulation, instead of the perception center. Cosequently, temporal overlap of intersyllabic gestures generally does not affect the perception of individual syllables from connected Chinese speech, except for the particular case of the so-called retroflexion, while that phenomenon may be not only referred to the phonetic coarticulation, but also related to some aspects of gramma. Therefore, it ties outside of the purview of this study.

References

Browman, C. P., & Goldstein, L. (1989) Articulatory gestures as phonological units, *Phonology*, **6**, 201-251.

Cao, Jianfen (1992) On neutral-tone syllables in Mandarin Chinese, *Canadian Acoustics*, **20:3**, 49-50.

Chao, Yuanren (1980) *Language and Symbolic System*. Beijing:Commercial Press.

Fowler, C. (1980) Coarticulation and theories of extrinsic timing, *Journal of Phonetics*, **8**,113-133.

Keating, P. (1988) Coarticulation and timing, In *UCLA Working Papers*, **69**, 1-2.

Ohman, S. (1966) Coarticulation in VCV utterances: spectrographic measurements, *J. Acoust. Sco. Am.* **39**, 151-168.

Wood, S. A. J. (1991) X-ray data on the temporal coordination of speech gestures, *Journal of Phonetics*, **19**, 281-292.

Xu, Yi (1989) Syllables and junctures. In *An Outline of Experimental Phonetics*(Wu, Zongji & Lin, Maocan, editors), pp. 193-249. Beijing: Higher Education Press.

Zsiga, E. C. (1994) Acoustic evidence for gestural overlap in consonant sequences, *Journal of Phonetics*, **22**, 121-140.

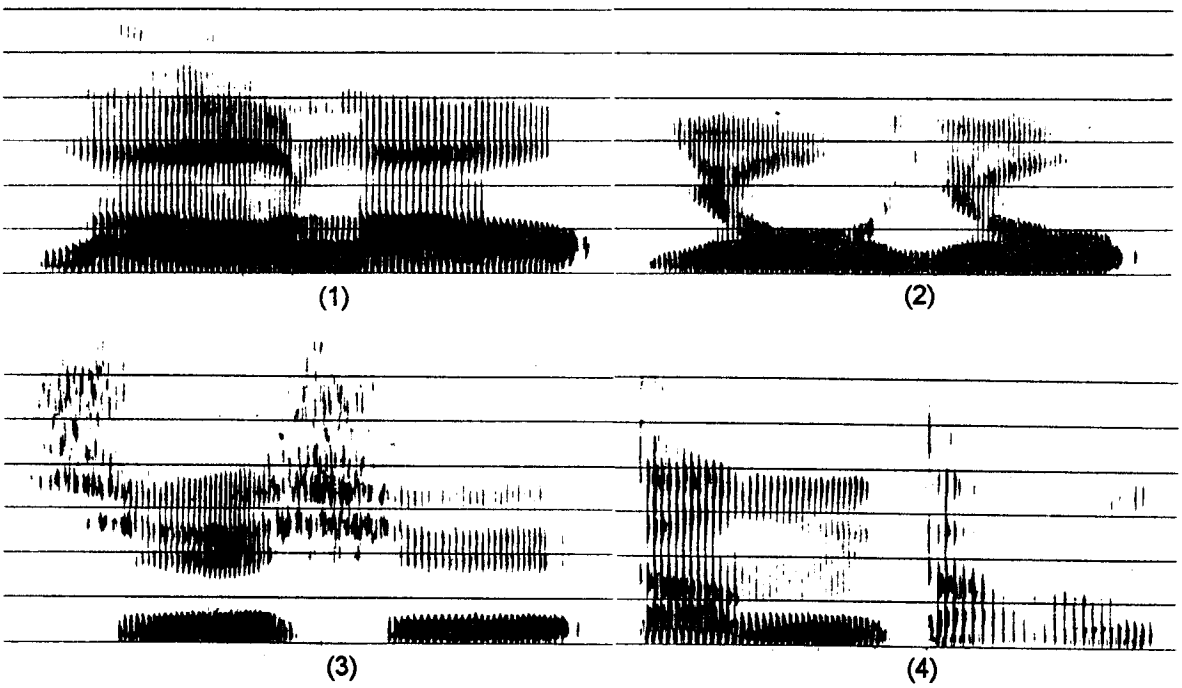

Fig. 1. Spectrographic examples of intersyllabic junctures in Standard Chinese: (1) /lao-lao/ (2) /iou-iou/ (3) /ɕy-ɕy/ (4) /pʻian-pʻian/

图 1. 普通话音节间音联语图举例:(1) 牢牢, (2) 悠悠, (3) 徐徐, (4) 偏偏

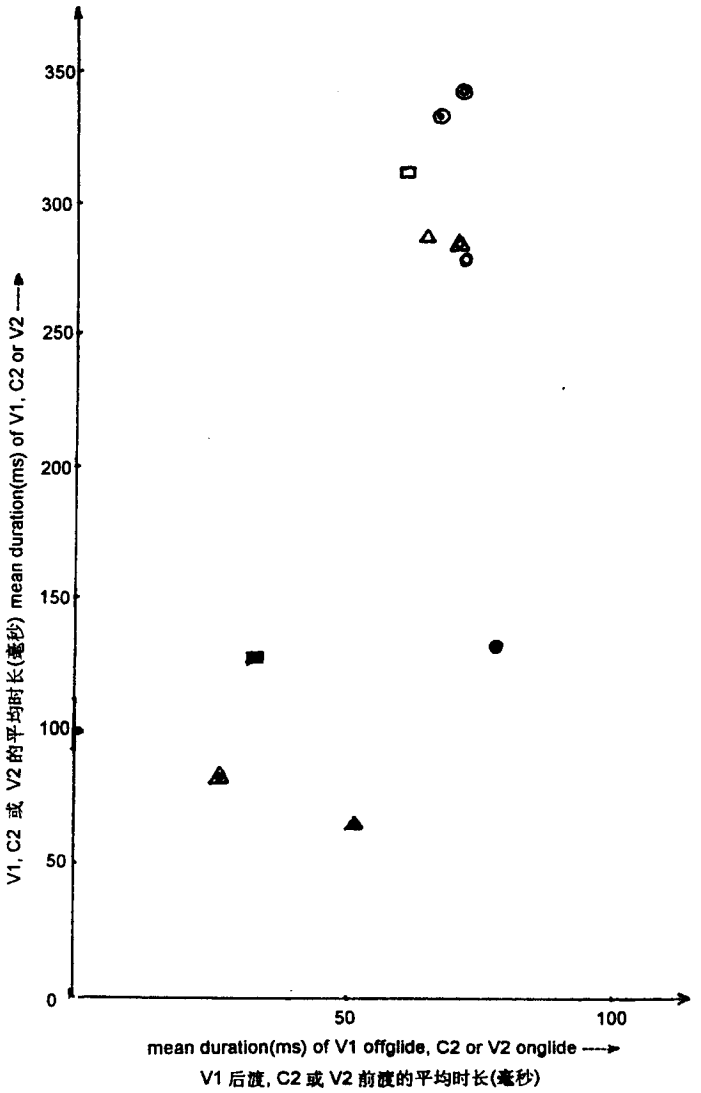

Fig. 2. A comparison of intersyllabic junctures in the NM type amd NT type words.
V1 offglide in NM type words: ◎ when 2nd syllable with zero initial,
○ when 2nd syllable with consonant initial;
C2 or V2 onglide in NM type words: ◉ when 2nd syllable with zero initial,
● when 2nd syllable with consonant initial;
V1 offglide in NT type words: ▭ when 2nd syllabe with zero initial,
△ when 2nd syllable with consonant initial,
◬ when 2nd syllable is /ts1/;
C2 or V2 onglide in NT type words: ▬ when 2nd syllable with zero initial,
▲ when 2nd syllable with consonant initial,
◭ when 2nd syllable is /ts1/.

图 2. 音节间过渡音时长范围比较.
正常重音型词中(1)前音节后过渡:◎后音节声母为零, ○ 后音节声母为辅音;
(2)后音节前过渡:◉后音节声母为零, ● 后音节声母为辅音;
轻声词中(1)前音节后过渡:▭后音节声母为零, △ 后音节声母为辅音, ◬后音节为"子";
(2)后音节前过渡:▬后音节声母为零, ▲ 后音节声母为辅音, ◭后音节为"子".

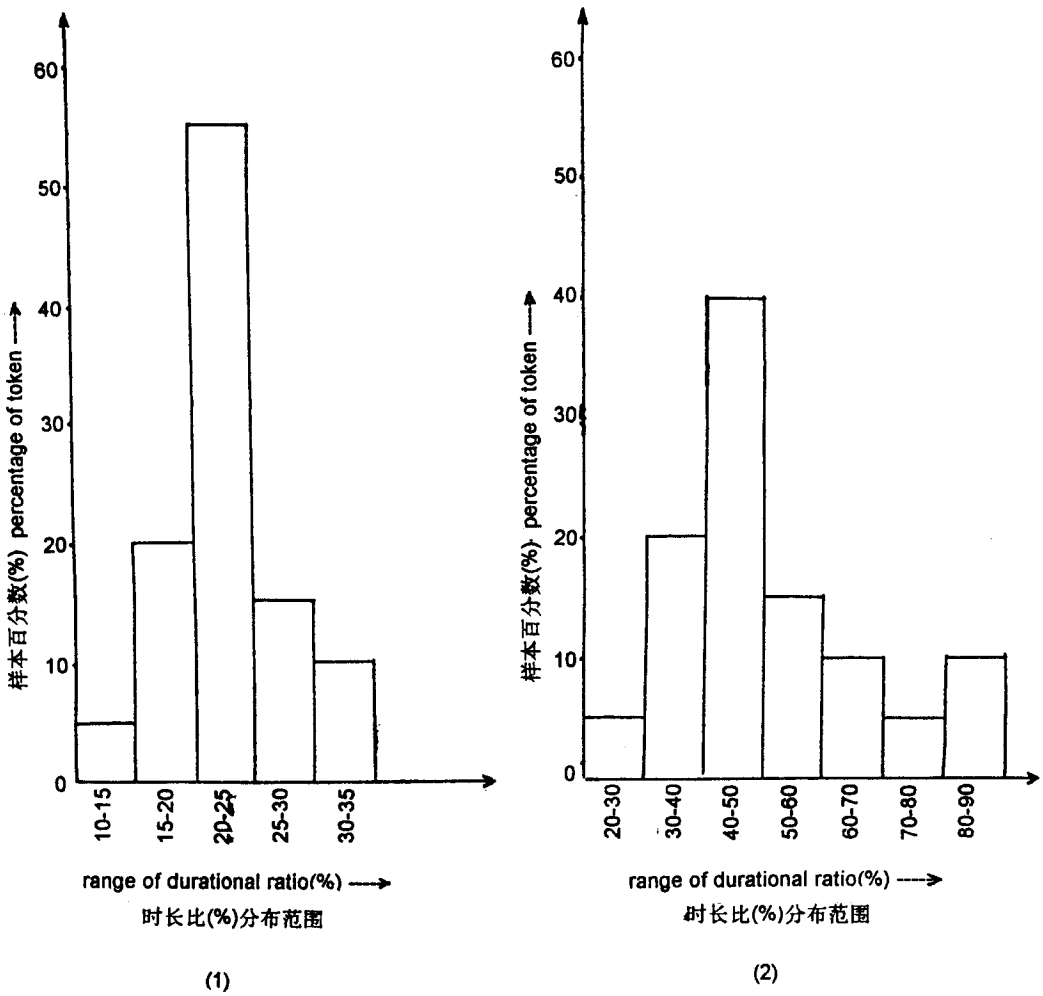

Fig. 3. The distribution of durational ratio: (1)the ratio of V1 offglide vs. V1;
(2)the ratio of C2 or V2 vs. C2 or V2.

图 3. 音节间过渡音时长比分布图: (1)前音节后过渡跟韵母时长比;
(2)后音节声母前过渡跟声母时长比.