Article

Language and Speech

Language *and* Speech
2016, Vol. 59(4) 433–461

DOI: 10.1177/0023830915614602
las.sagepub.com
SAGE

Seeking an Anchorage. Stability and Variability in Tonal Alignment of Rising Prenuclear Pitch Accents in Cypriot Greek

Charalambos Themistocleous
Seeger Center for Hellenic Studies, Princeton University, USA

Abstract

Although tonal alignment constitutes a quintessential property of pitch accents, its exact characteristics remain unclear. This study, by exploring the timing of the Cypriot Greek L*+H prenuclear pitch accent, examines the predictions of three hypotheses about tonal alignment: the invariance hypothesis, the segmental anchoring hypothesis, and the segmental anchorage hypothesis. The study reports on two experiments: the first of which manipulates the syllable patterns of the stressed syllable, and the second of which modifies the distance of the L*+H from the following pitch accent. The findings on the alignment of the low tone (L) are illustrative of the segmental anchoring hypothesis predictions: the L persistently aligns inside the onset consonant, a few milliseconds before the stressed vowel. However, the findings on the alignment of the high tone (H) are both intriguing and unexpected: the alignment of the H depends on the number of unstressed syllables that follow the prenuclear pitch accent. The 'wandering' of the H over multiple syllables is extremely rare among languages, and casts doubt on the invariance hypothesis and the segmental anchoring hypothesis, as well as indicating the need for a modified version of the segmental anchorage hypothesis. To address the alignment of the H, we suggest that it aligns within a segmental anchorage–the area that follows the prenuclear pitch accent–in such a way as to protect the paradigmatic contrast between the L*+H prenuclear pitch accent and the L+H* nuclear pitch accent.

Keywords

Prenuclear pitch accents, tonal alignment, tonal anchoring, tonal anchorage, Cypriot Greek

Corresponding author:
Charalambos Themistocleous, Seeger Center for Hellenic Studies, Program in Hellenic Studies, Princeton University, 107 Scheide Caldwell House, Princeton, NJ 08544, USA.
Email: themistocleous@gmail.com

1 Introduction

1.1 Theoretical background

The assumption that tonal timing with the segmental string signals lexical and postlexical distinctions dates back to the late 1940s (Haugen, 1949; Haugen & Joos, 1972). Specifically, Haugen proposed that in the Scandinavian varieties that have tonal systems 'the difference between two significantly contrastive tones may consist of nothing more than a different timing of the tonal curve in relation to the syllable stress' (Haugen, 1949, p. 279). Yet, it was not until the late 1970s and the advent of more sophisticated instrumental techniques and theoretical assumptions that the importance of timing became prevalent among theorists.

In their seminal works, Bruce, 1977 and Pierrehumbert, 1980 argued that tonal timing influences tonal perception and production, and demonstrated the highly systematic and, hence, language specific nature of tonal timing (Gussenhoven, 2002, 2004, 2007; Ladd, 2008; Pierrehumbert, 1980). To account for Swedish word accent distinctions, Bruce, 1977 employed an arrow-to-target approach. First, he proposed that a tonal projectile–the F0 movement–aims at certain H and L tonal targets that associate with specific points of the segmental string. Notably, the tonal contour is *sparsely* specified: it is only the tonal targets that are perceptually salient, whereas the tonal contour between two tonal targets is phonemically unspecified (Gussenhoven, 2002, 2004, 2007; Ladd, 2008; Pierrehumbert, 1980). The in-between tonal targets F0 contour is simply a product of interpolation (cf. Arvaniti, Ladd, & Mennen, 2006a, 2006b; Ladd, 2008; Pierrehumbert, 1980). Second, Bruce, in accord with Haugen, 1949, proposed that it is the early or late tonal timing that distinguishes the Swedish Accent I and Accent II. Specifically, even though tonal targets may be subjected to contextual effects triggered by the adjacent tones, such as tonal overshooting or tonal undershooting, the persistent relative timing of tones with the segmental string enables Swedish accents' categorical distinction (Bruce, 1977). Furthermore, in their prosodic typology of Swedish word accents, Bruce & Gårding, 1978, highlighting the dialect specific nature of timing, demonstrated that pitch accents across various Swedish varieties differ in the timing of their tonal targets (Bruce, 2005).

In her model of the American English intonation, Pierrehumbert, 1980 distinguished between tonal association and tonal alignment. Tonal association is an abstract phonological property that assigns pitch accents to prosodic constituents such as morae and syllables. On the contrary, tonal alignment is the relative timing of the tonal targets with the segmental string (see Ladd, 1983, p. 732; 2008, p. 179). Therefore, for Pierrehumbert, the distinction between Accent I and Accent II in Swedish is a matter of both association and alignment: tonal association presupposes that a pitch accent would be assigned differently with respect to prosodic constituents,[1] whereas tonal alignment by definition refers to the exact timing correspondence of a pitch accent's tones with the segmental string at the phonetic implementation. For example, in the Swedish words *anden* 'the duck' and *ànden* 'the spirit', the low and high (LH) tones associate with the same syllable but differ with respect to their exact alignment. The distinction between association and alignment becomes less controversial when it is only the placement of the pitch accent or stress that differs (e.g., the Swedish words *formel* [ˈfɔrːmɛl] 'formula' – *formell* [fɔrˈmɛlː] 'formal' and the English words the noun *permit* [ˈpɜːmɪt] – the verb *permit* [pəˈmɪt]) (Gussenhoven, 2004; for an alternative interpretation of the association of the Swedish word accent, see Ladd, 2008, p. 179). In these patterns, a simple pitch accent shift to another syllable has a categorical effect.

To conclude, a hugely important aspect of tonal structure is the alignment of tones with the segmental string. By studying Cypriot Greek (CG) prenuclear pitch accents' alignment, this paper aims to test existing hypotheses and to provide an account of tonal alignment.

1.2 The alignment of prenuclear pitch accents

To account for the alignment of LH pitch accents, Pierrehumbert, 1980 proposed the invariance hypothesis:

> [t]he variable timing of H^- in L*+H^- is, however, easily explained in our account, in which H^- is separated from L* by a fixed time interval, without regard to the segmental or syllabic character of the material following the accented syllable (Pierrehumbert, 1980, p. 80).[2]

Overall, the central idea behind this hypothesis is that the two tones which form a bitonal pitch accent are temporally related (see also Beckman & Pierrehumbert, 1986; Ladd, Faulkner, Faulkner, & Schepman, 1999; Pierrehumbert, 1980; Prieto & Torreira, 2007; Sadat-Tehrani, 2009; Schepman, Lickley, & Ladd, 2006). According to Pierrehumbert, 1980, a bitonal pitch accent comprises of one and only one starred tone–a tone denoted by the star (*) symbol–that associates to a metrically strong syllable–a stressed syllable–and a second tone, which leads or trails at a fixed distance and/or at a fixed time interval from the starred tone; in other words, a bitonal pitch accent must be either T*+T or T+T* (Arvaniti, Ladd, & Mennen, 2000; Grice, 1995; Ladd, 2008).

Nonetheless, in Standard Modern Greek (SMG) prenuclear pitch accents, neither the L nor the H align with the stressed syllable and there is no fixed distance between them or fixed slope for the rise (Arvaniti & Ladd, 1995; Arvaniti, Ladd, & Mennen, 1998). Therefore, the tone associated with the star symbol is uncertain. Arvaniti & Ladd, 1995 proposed that the SMG prenuclear pitch accents' most appropriate phonemic representation is L*+H.

Moreover, results by Arvaniti et al., 1998 led to the unexpected finding that the prenuclear pitch accent peak is stable and unaffected by the distance between the accented syllable and the right hand consonant. Specifically, they showed that the tones that comprise the SMG prenuclear pitch accent show notable precision in their alignment: the L aligns approximately 5 ms before the onset of the accented syllable and the H aligns on average 10.6 ms after onset of the first postaccentual vowel. Because the alignment of tones depends on the segmental structure, Arvaniti et al., 1998 stressed that the rise does not have a fixed duration or a fixed slope, as predicted by previous studies (Pierrehumbert, 1980). Instead, both the rise and the slope are adjusted according to the amount of time available for the rise. In addition, they suggested that the H aligns with the stressed syllable and not with the right edge of the word and concluded that the pitch accent's starred tone is the H and not the L; that is, they autosegmentally represent the pitch accent as an L+H*.[3]

The astonishing precision in the alignment of the SMG prenuclear pitch accent's tones led Ladd et al., 1999 to propose the segmental anchoring hypothesis. Specifically, based on the observation that the beginning and the end of the SMG prenuclear pitch accent align with specific segments regardless of the duration between the specified alignment points, Ladd et al., 1999 suggested that tonal alignment is defined with respect to landmarks 'anchors' in the segmental string, and that this anchoring is preserved under time pressure (cf. Atterer & Ladd, 2004; Dilley, Ladd, & Schepman, 2005).

In another study, Ladd, Mennen, & Schepman, 2000 showed that the Dutch prenuclear L aligns with the beginning of the stressed syllable and the H with the end of the syllable. Most importantly, in their findings there was a significant effect of the vowel length on the alignment of prenuclear accent peaks. For instance with long vowels, the peak aligned near the end of the vowel, but with short vowels the peak aligned with the following consonant. Ladd et al., 2000 concluded that 'both the beginning and the end of the movement can and must be precisely specified'.

Nevertheless, other studies cast doubt on the generality of the hypothesis. For example, Frota, 2002 investigated bitonal nuclear pitch accents in European Portuguese in declarative sentences signalling broad L*+H and narrow L+H* focus and demonstrated that 'H*+L has both a more constant slope and a more constant timing interval between its targets than H+L*' (Frota, 2002, p. 410). These findings suggest that the relation between the targets is different in the two accents, thus Frota, 2002 argues that the tones do not constitute independent targets, which align with reference to segmental landmarks.

Similarly Xu, in a series of studies, demonstrated that tones in Mandarin align with respect to the syllable as a whole and not with ad hoc segmental anchors (e.g., Xu, 1997, 1998, 2007). Highlighting the importance of the syllable in the overall speech organisation, (Xu & Liu, 2006, p.152) suggested that 'the syllable specifies the temporal alignment of all the basic phonetic elements referred to as phones, which include consonants, vowels, tones and phonation registers'.

Moreover, Prieto & Torreira, 2007 examined the effects of syllable structure type (open, closed), segmental composition, and speaking rate on the alignment of Peninsular Spanish L+H* prenuclear peaks with segmental landmarks and showed that syllable structure and speech rate affected tonal alignment in significant and consistent ways, with the peak in Consonant Vowel (CV) syllables aligned near the end of the accented vowel, and in CVC syllables near the beginning–mid part of the sonorant coda. In addition, peaks were located earlier in the syllable as speech rate decreased and later as speech rate increased.

In their study of tonal alignment and scaling patterns of the start and end points of the French late rise, Welby & Lœvenbruck, 2006 did not identify plausible segmental anchors for the low starting point of the late rise. In addition, they observed that speech rate affected the F0 alignment for some of their speakers. They observed that in CV and CVC syllables that end in an obstruent, the peak of the late rise aligned at the end of the vowel, whereas in CVC syllables, which end in a sonorant, the peak's alignment ranged from the end of the vowel to the end of the sonorant coda.

In addition, Welby & Lœvenbruck, 2006 observed that: (a) languages such as English, French, Dutch, and Neapolitan Italian vary in how strict or variable their tonal alignment is; and (b) within the same language, some tones have a strict alignment whereas other tones have a more variable alignment. Based on these observations, they proposed the segmental anchorage hypothesis: a tone can anchor within the segmental anchorage region, and they suggested that this region explains the alignment of the peak of the French late rise. According to Welby & Lœvenbruck, 2006, the segmental anchorage captures the variations in tonal alignment better than the very stable 'segmental anchors' which the segmental anchoring hypothesis predicts.

To conclude, tonal alignment is systematic and language specific; nevertheless, the exact conditions that determine tonal alignment are still elusive. The following section provides an overview of CG.

1.3 An overview of Cypriot Greek

Cyprus is an island which is located in the eastern Mediterranean, close to Egypt, Israel, Lebanon, Syria, Turkey, and Greece. The main languages spoken in Cyprus are Greek and Turkish.[4] Most CG speakers live in four major cities: Paphos, Limassol, Larnaca, and Nicosia, which is the capital city. CG is often separated into village CG and urban CG (Newton, 1972); village CG is considered basilectal and urban CG is considered acrolectal (cf. Arvaniti, 2006; Goutsos & Karyolemou, 2004; Papapavlou & Pavlou, 1998; Rowe & Grohmann, 2013). Hadjioannou et al., 2011 suggest that post-1974 'regional varieties are in the process of being levelled out, following demographic and social changes, and a pancyprian *Koiné* variety is fast emerging' (Hadjioannou et al., 2011, p. 510).

CG vowel inventory is comprised of five vowels: /e i a o u/. The consonantal inventory is comprised of singletons and geminates. The *only* singletons that exist are allophones of other consonants.

For instance, voiced stops are allophones of voiceless stops when the latter are preceded by a nasal as in /ˈpanta/ → [ˈpanda]. Overall, geminates exhibit greater length, plosive geminates exhibit longer aspiration, and affricate geminates exhibit longer frication (Armosti, 2009; Arvaniti & Tserdanelis, 2000; Botinis, Christofi, Themistocleous, & Kyprianou, 2004; Payne & Eftychiou, 2006; Tserdanelis & Arvaniti, 2001). In CG, /n/ and /s/ are the only consonants that occur as word-final (except in loan-words). In connected speech, if the two consonants precede another consonantal sound (except stops) the result of assimilation is a postlexical geminate. Additionally, when a final /s/ is followed by another /s/ or /ʃ/, the geminates [sː] and [ʃː] occur respectively (Armosti, 2009).

In their study of the acoustic characteristics of CG geminate consonants, Tserdanelis and Arvaniti, 2001 examined whether the L of an L+H aligns with the onset of the stressed syllable and noted that:

> …in words with intervocalic geminate sonorants (/m, n, l/) in stressed position the L tone aligned on average 34 ms after the onset of the geminate, whereas in words with intervocalic singletons, L aligned on average 9 ms before the onset of the consonant (Tserdanelis & Arvaniti, 2001, p. 34).

Note that the L+H constitutes a nuclear pitch accent: it is the accent, which is associated with the *keyword* in the carrier phrase ‘she or he said to him < keyword > suddenly and left’ (Tserdanelis & Arvaniti, 2001).

In declaratives, the two nuclear pitch accents !H* and L+H* signal broad and narrow focus, respectively (Themistocleous, 2011). Grice, Ladd, & Arvaniti, 2000 suggested that the CG polar question’s contour is identical to the SMG polar question contour and they autosegmentally represented it as L* H–L% (Grice et al., 2000). Postlexical prominence in polar questions associates with a low plateau: an L* pitch accent. Nevertheless, they pointed to a clear difference between SMG and CG polar questions: in CG the phrase accents of polar questions have a primary association with the boundary, whereas SMG phrase accents have an additional secondary association with the stressed syllable.

Themistocleous, 2014 examined final lengthening in CG statements and polar questions that are segmentally identical, but which differ only in their edge-tones, and showed that CG polar questions trigger greater degrees of lengthening (edge-tone lengthening) than the edge-tones of statements.

In his analysis of CG prosodic structure, Themistocleous, 2011, 2014) suggests that CG prosodic hierarchy comprises of the following domains: the phonological or prosodic word (*PrWd*), the intermediate phrase (*ip*), and the intonational phrase (*IP*). The prosodic word consists of a content word and its clitics. The stressed syllable is specified in the lexicon (e.g., *álla* [ˈalːa] ‘other’ – *allá* [aˈlːa] ‘but’); unlike SMG, CG does not favour enclitic stress.

1.4 The present study

The alignment of tones with the segmental string constitutes an essential property of pitch accents, yet its exact properties remain unclear. By exploring the timing of the CG L*+H prenuclear pitch accent, this study examines the predictions of the invariance hypothesis, the segmental anchoring hypothesis, and the segmental anchorage hypothesis on tonal alignment. These three hypotheses make different predictions: (a) the invariance hypothesis predicts that the distance between the two targets will remain constant irrespectively of the underlying segmental structure; (b) the segmental anchoring hypothesis predicts that the distance between the L and the H depends on the duration of segments; and (c) the segmental anchorage hypothesis predicts that the tones align within a specified region.

1.4.1 Experimental hypotheses. To test these three hypotheses, we propose the following experimental hypotheses:

The hypotheses in (1) concern the alignment of the L.

(1) *Hypothesis L-A*: the L anchors with respect to the onset of the stressed syllable.
Hypothesis L-B: the L anchors with respect to the left edge of the consonant before the stressed vowel (including consonants found at the coda of a preceding syllable).
Hypothesis L-C: the L anchors with respect to the left edge of the stressed vowel.

The hypotheses in (1) predict a different alignment of the L with regards to the syllable patterns in (2). The symbol V stands for vowel, the symbol C stands for a nasal [n] consonant, the symbol # stands for a word boundary, and the symbol σ_2 stands for the stressed syllable.

(2) a. V#CV: the stressed syllable's onset comprises of a singleton.
b. VC#V: the stressed syllable is onsetless.
c. VC#CV: the stressed syllable's onset comprises of a concatenated homorganic geminate [nː], which is the output of postlexical rules applied in the sequence VC#CV.

If *Hypothesis L-A* is correct, the L will be realised a few milliseconds before the onset of the stressed syllable. Accordingly, we expect the following:

(3) a. In V#CV, the L will align just before the consonant (see Figure 1(a)).
b. In VC#V, the L will align just before the stressed vowel (the second vowel in the sequence) (see Figure 1(b)). A possible resyllabification of the consonant with the vowel will not affect L alignment.
c. In VC#CV, the two nasal consonants will assimilate into a postlexical geminate and the L will align in the middle of the geminate (see Figure 1(c)).

If *Hypothesis L-B* is correct, we expect the following:

(4) a. In V#CV the L will align at the left edge of the consonant (Figure 2(a)).
b. In VC#V the L will align at the left edge of the consonant (Figure 2(b)).
c. In VC#CV the L will align at the left edge of the geminate consonant (Figure 2(b)).

If *Hypothesis L-C* is correct, we expect the L to align at the left edge of the vowel in the three syllable patterns (see Figure 3). This hypothesis is in line with claims in the literature that tones align with respect to the mora (c.f. Howie, 1974).

The following two hypotheses address the alignment of the H tone.

(5) a. *Hypothesis H-A*: the H aligns at the right edge of the accented word.
b. *Hypothesis H-B*: the H follows the L at a fixed duration (in a bitonal LH pitch accent).

Hypothesis H-A predicts that the H aligns with the right edge of the accented word. The selection of the right edge of the accented word has been motivated by Arvaniti & Ladd's, 1995 findings, which show that in SMG the H aligns near the right edge of the accented word. If confirmed, the predictions of this hypothesis would corroborate the segmental anchoring hypothesis that tones align with specific segmental anchors (see Ladd, 2008, pp. 169–188). So, if the prediction of this

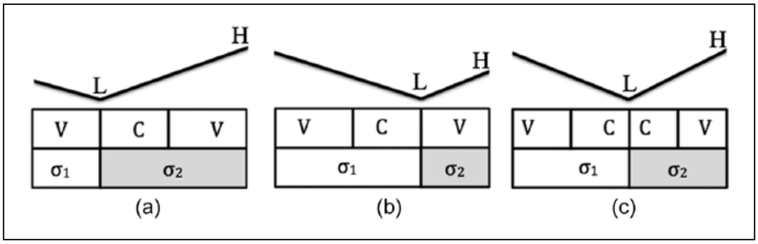

Figure 1. Stylised F0 curve illustrating the predictions of *Hypothesis L-A*. The second syllable (σ_2)–shaded box–consists of two segments (a), one segment (b), and two segments (c).

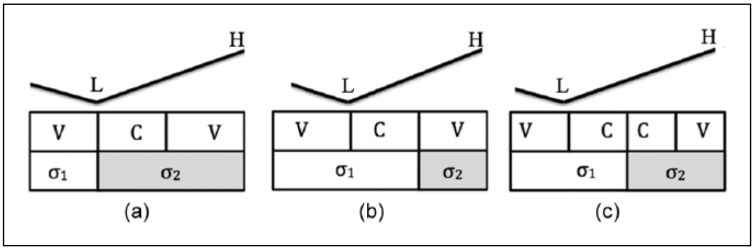

Figure 2. Stylised F0 curve illustrating the predictions of *Hypothesis L-B*. The second syllable (σ_2) – shaded box – consists of two segments (a), one segment (b), and two segments (c).

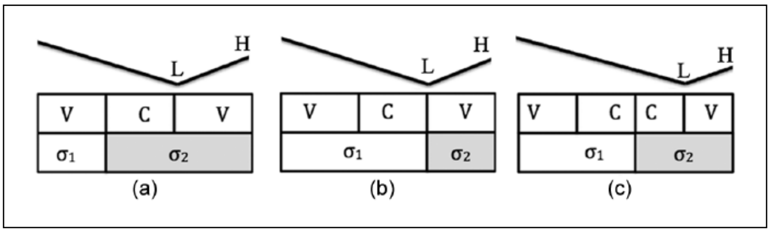

Figure 3. Stylised F0 curve illustrating the predictions of *Hypothesis L-C*. The second syllable (σ_2) – shaded box – consists of two segments (a), one segment (b), and two segments (c).

hypothesis is correct, the duration of the distance between the L and the H – everything else being equal – will be proportional to the duration of the segments, which constitute the accented word. In other words, when the duration of segments is short, the duration of the distance between the L and the H will be short and when the duration of the segments is long, the duration of the distance between the L and the H will be long. Figure 4 illustrates this hypothesis. In Figure 4(a), the vowel in σ_1 has shorter intrinsic duration than that in Figure 4(b); consequently, in Figure 4(a) the duration of the distance between the L and the H is shorter than the duration of the distance between the L and the H in Figure 4(b).

Hypothesis H-B is in accord with the invariance hypothesis (Pierrehumbert, 1980). If the prediction of this hypothesis is correct, the two tones that comprise the prenuclear rise are expected to follow each other at a fixed duration (see Figure 5). In other words, the duration of the segments that constitute the accented word does not influence the duration of the distance between the L and the H.

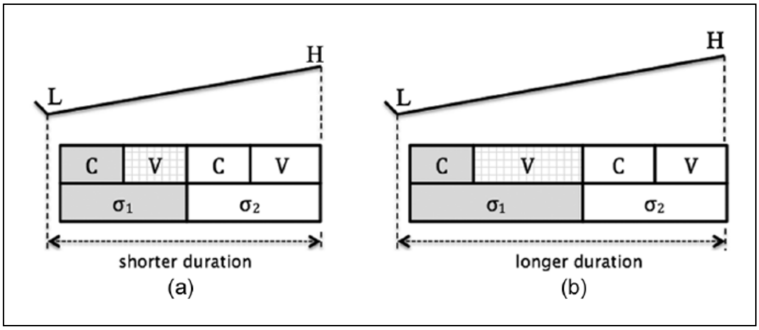

Figure 4. Stylised F0 curve illustrating the predictions of *Hypothesis H-A*. The first syllable (σ_1) – shaded box – stands for the stressed syllable.

Table 1. Speech material. The syllable after the # symbol constitutes the stressed syllable.

	Syllable Patterns		
	V#CV	VC#V	VC#CV
VOWEL [a]	to#náma wine.NEUT.ACC.SG [toˈnama] 'stream'/'sacramental wine'	tin#Ánna Anna.FEM.ACC.SG [tinˈanːa] 'Anna'	tin#Nána Nana.FEM.ACC.SG [tinˈnana] 'Nana'
VOWEL [i]	to#níma threat.NEUT.ACC.SG [toˈnima] 'thread'	tin#Ína Ina.FEM.ACC.SG [tinˈina] 'Ina'	tin#Nína Nina.FEM.ACC.SG [tinˈnina] 'Nina'

2 Experiment 1

By testing the experimental hypotheses, Experiment 1 aims to clarify the alignment of rising pre-nuclear pitch accents.

2.1 Method

2.1.1 Speech material. The following keywords are employed: *náma*, *níma*, *Ánna*, *Ína*, *Nána*, and *Nína*. The keywords *náma*, *níma*, *Nána*, and *Nína* consist of a CVCV syllable structure and the keywords *Ánna* and *Ína* consist of a VCV syllable structure. All keywords are stressed in the first syllable. Table 1 shows the syllable patterns that occur because of the adjacency of the article and the keyword.

The keywords were embedded in the carrier sentence in (6):

(6) elálen -mas óti TIN ÍNA mallónni -tin o Mános
e'lalemːas 'oti tin 'ina mːalːonːi tin o 'manos
talk.pst.3sg cl.acc.pl that the.art ina.acc scold.prs.3sg cl.acc.sg the.nom manos.nom
'she/he was telling us that Ina is being scolded by Manos'

The keyword and the preceding article are printed in boldface and small caps. The keywords, *Nana*, *Nina*, *Anna*, and *Ina* are proper female names and they are preceded by the article *tin* 'the.ACC', which ends in an /n/. The keywords *náma* and *níma* are neuter nouns and their article is *to* 'the.ACC', which ends in a vowel. /n/ and /s/ are the only consonants that occur word-finally (except in loanwords). When /n/ precedes another consonantal sound (except stops) in connected speech, it assimilates into a postlexical geminate (cf. Armosti, 2009; Payne & Eftychiou, 2006).[5] The article and the noun form a prosodic word.

The resumptive pronoun *tin* that follows the word *mallónni* constitutes an overt clitic and marks topics (Tsimpli, 1995).[6] Read with standard intonation, this phrase triggers four prenuclear pitch accents and a nuclear pitch accent in the rightmost constituent *o Mános*.

To evaluate *Hypothesis L-A*, *Hypothesis L-B*, and *Hypothesis L-C*, we manipulate the syllable pattern and to evaluate *Hypothesis H-A* and *Hypothesis H-B*, we manipulate vowel length. Specifically, in order to assess *Hypothesis H-A* (see also Figure 4), the vowels /a/ and /i/ that differ in their intrinsic duration were selected (Lehiste, 1970; Peterson & Lehiste, 1960): /a/ is longer than /i/. Specifically, Fourakis, Botinis, & Katsaiti, 1999 showed that in SMG the stressed vowel /a/ (M = 122.84, SD = 15.35) is significantly longer than the stressed vowel /i/ (M = 86.25, SD = 16.25). Also, in their study of SMG and CG vowels, Themistocleous & Logotheti, 2014 show significant differences in the duration of CG vowels and report that in CG /a/ is the longest vowel and /i/ the shortest one (/ a > o > e > u > i /).

To minimise segmental effects on the fundamental frequency contour and to facilitate F0 tracking, we selected words containing sonorants. The only voiceless consonant included in this material is the alveolar stop [t] but, because of its position in the segmental string, it does not affect F0 measurements.

2.1.2 Speakers. Eight female speakers participated in the experiment. All speakers were in their early twenties and at the time of the recording they were undergraduate students at the University of Cyprus. The speakers were raised in Nicosia and did not have any regional accents. The speakers reported no hearing or articulatory problems. Since all speakers were studying English literature and linguistics at the university they were competent English speakers, and in addition had basic knowledge of French from their secondary school studies. All speakers were naïve to the experimental hypotheses.

2.1.3 Procedure. Speakers were seated comfortably at a desk in a sound-treated recording booth at the University of Cyprus. No instructions about the prosodic pattern or any explanation of the purposes of the experiment were provided. The speakers read the sentences out loud at a comfortable, self-selected rate. More specifically, to control for practice and fatigue effects on the recordings and to prevent a continuous monotonous reading, the test sentences were presented in random order, one sentence per slide in Microsoft PowerPoint 2010. Each sentence was presented 10 times. The speakers manually changed the slide after each recording. The main investigator was present during the recording phase, and his role was mainly auxiliary: to start the microphone, to correct the speaker's distance from the microphone, etc. Recordings were made on a Zoom H4n audio recorder (sampling frequency 44.1 kHz). For the acoustic analysis, the open source software Praat 5.3.32 was used (Boersma & Weenink, 2012). The first repetition was considered preparatory and it was removed from the data. Also, the last repetition was removed to avoid fatigue effects. Except for the first and the last repetition, no other data was removed. For the first experiment, 384 utterances (8 speakers × 6 keywords × 8 repetitions) were produced.

2.1.4 Measurements. Figure 6 shows the waveform and the spectrogram with a superimposed F0 contour of the test utterance. The tonal contour comprises of four pitch accents: three prenuclear and one nuclear pitch accent. The first prenuclear pitch accent associates with the first content word of the carrier sentence *elálen mas óti tin Ína mallónni tin o Mános*, the second with the

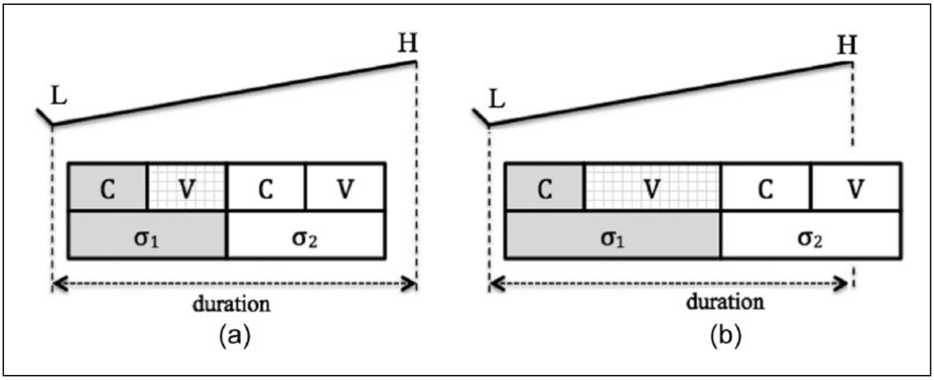

Figure 5. Stylised F0 curve illustrating the predictions of *Hypothesis H-B*. The first syllable (σ1) – shaded box–stands for the stressed syllable.

keyword, and the third with the word *mallónni*. A downstepped nuclear pitch accent !H* associates with the last content word of the carrier phrase (i.e., the word *Mános*) (the overall contour shown in Figure 6 is autosegmentally analysed as L*+H L*+H L*+H L*+H !H* L-L%).

The utterances were manually segmented and labelled in Praat by using simultaneous inspections of waveform and spectrogram following the standard criteria for segmentation proposed by Peterson & Lehiste, 1960. Because the segments that comprise the speech material were predominantly nasals and liquids followed by vowels, the segmentation was straightforward due to clear differences in intensity.

Specifically, the following tones' temporal positions were measured:

L1: The temporal position of the L.
H: The H temporal position.
L2: The temporal position of the L that follows the H.

The L1 is the local minimum of the F0 located between the two prenuclear peaks (see Figure 6). The L2 is the local minimum that lies between the peak of the designated prenuclear pitch accent and the following prenuclear pitch accent, and the H is the local maximum of the F0 between the L1 and the L2.

In addition, segments' temporal positions were measured and the following distances were calculated from the temporal position of tones and segments (see Figure 6):

LH: The distance between the L1 and the H.
LC: The distance between the L1 and the left edge of the intervocalic C (i.e., [n] or [nː]).
LV: The distance between the L1 and the left edge of the stressed vowel in the keyword.
HW: The distance between the H and the right edge of the keyword.
HL2: The distance between the H and the L2.
L2C: The distance between the L2 and the left edge of the consonant [lː] of the stressed syllable of the word [mːaˈlːonːi].
L2V: The distance between the L2 and the stressed vowel [o] of the word [mːaˈlːonːi].

The information about the temporal boundaries of segments and the location of tones was automatically extracted by using Praat scripts and the aforementioned distances were calculated in R 3.0.2 (R Core Team, 2012).

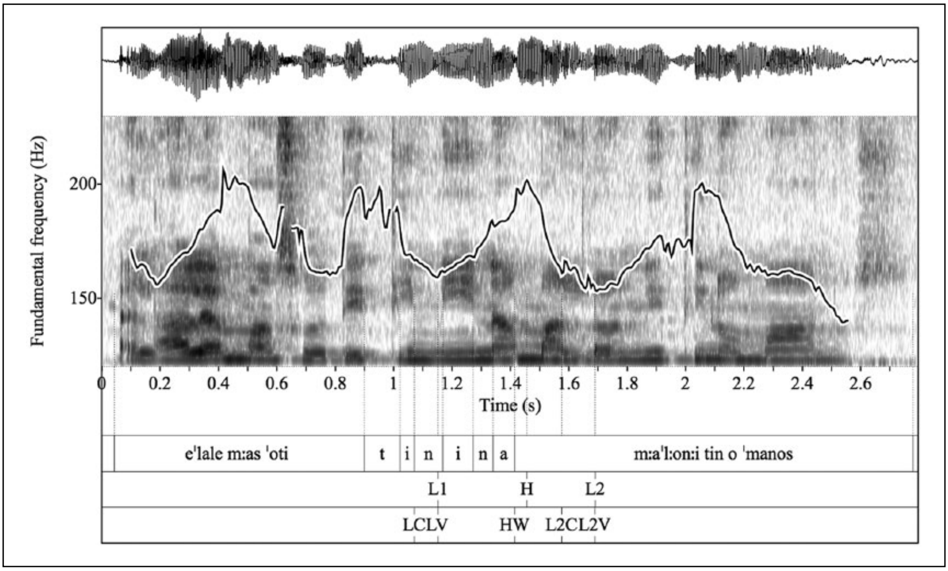

Figure 6. Waveform, spectrogram, and F0 contour–superimposed on the spectrogram–of the test utterance [eˈlale mːas ˈoti tin ˈina mːaˈlːonːi tin o ˈmanos]; the gloss is 'she/he was telling us that Ina is being scolded by Manos'. The L1 and the H correspond to the L and H tone of the designated prenuclear pitch accent and the L2 is the L tone of the following prenuclear pitch accent.

2.1.5 Statistics and analysis. In Experiment 1, two-way repeated measures ANOVA were conducted on the aforementioned measurements (dependent variables). The independent variables were (a) *keyword* with six levels (to#'nama, to#'nima, tin#'ana, tin#'ina, tin#'nana, tin#'nina), (b) *syllable pattern* with three levels (V#CV, VC#V, and VC#CV), and (c) *vowel*, with two levels ([a] and [i]). The statistical analysis was carried out in R 3.0.2 (R Core Team, 2012). For the ANOVA, the ezANOVA function from the 'ez' package was employed (Lawrence, 2011).[7] Before running the ANOVA, Mauchly's tests for sphericity violation were performed. If the assumption of sphericity was violated, the degrees of freedom were corrected by using Greenhouse–Geisser estimates. Furthermore, the pairwise comparisons between group levels with Bonferroni corrections are reported.

2.2 Results

Figure 7 shows the alignment of tones with the segmental string. The filled squares represent the mean segmental durations and the black dots indicate the tonal targets' position in the segmental string. On average, singleton nasals (i.e., [n]) are shorter (M = 75 ms) than geminate nasals (i.e., [n:]) (M = 134 ms). Furthermore, the vowel duration differs: [i] vowels are on average shorter (M = 86 ms) than [a] vowels (M = 118).

In Figure 7, the first two dots – from left to right – correspond to the L1 and the H respectively; the third dot corresponds to the L2. Overall, the L1 and the L2 align inside the syllable onset. The H aligns after the right edge of the accented word. The results for the L1, H, and L2 are reported in the following.

2.2.1 The prenuclear L1 tone. Table 2 shows the mean duration and *SD* for the distance LC and the distance LV for each syllable pattern (V#CV, VC#V, and VC#CV) and vowel ([a] or [i]). The negative values for the distance LV indicate that the L1 comes before the V. The L1 aligns after the left

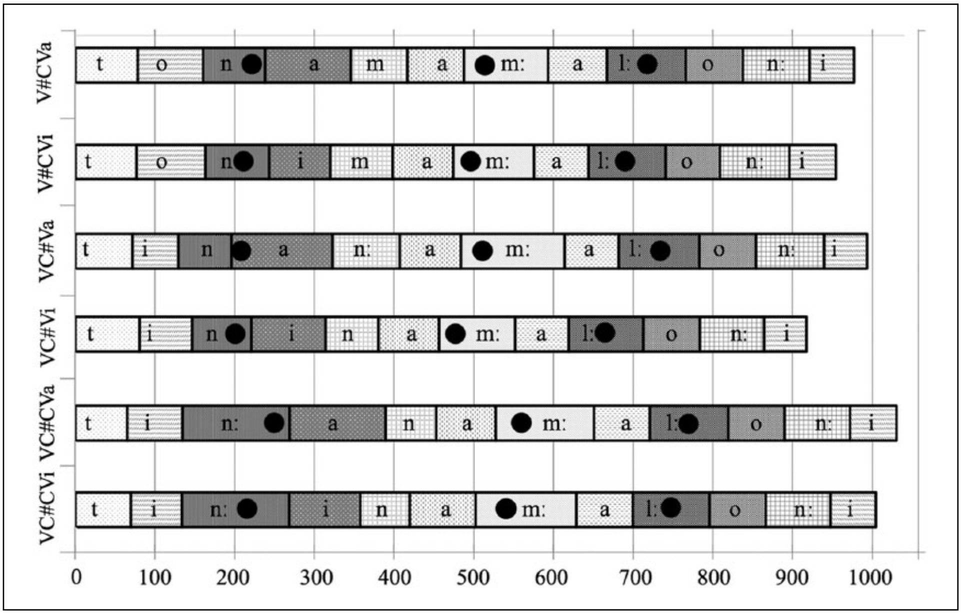

Figure 7. Mean segmental durations (in ms) of segments comprising the experimental material for each *syllable pattern* (V#CV, VC#V, and VC#CV) and *vowel* ([a] or [i]). The black dots from left to right correspond to the L1, the H, and the L2.

Table 2. Mean duration and *SD* for the distance LC and the distance LV for the *syllable pattern* (V#CV, VC#V, and VC#CV) × *vowel* ([a] or [i]).

	V#CV*a*		V#CV*i*		VC#V*a*		VC#V*i*		VC#CV*a*		VC#CV*i*	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Distance LC	59	51	38	41	90	43	52	52	118	64	75	38
Distance LV	−17	45	−41	41	23	41	−22	48	−15	56	−59	39

edge of the keyword's stressed syllable and just before the stressed vowel, except for the syllable pattern VC#V*a* ([tin#ˈanːa]).

Boxplots in Figure 8 show the findings for the distance LV. Boxplots (in Figure 8 and in figures that follow) visually represent the maximum and minimum values, the interquartile range (IQR), and the median. Specifically, the top of the box indicates the 25th percentile of the data, the bottom of the box indicates the 75th percentile, and the thick line in the middle of the box, indicates the 50th percentile (the median). The lines, which extend horizontally from the box and end in a vertical stroke, indicate the minimum and maximum values respectively.

Syllable patterns (i.e., V#CV, e.g., [to ˈnama]; VC#V, e.g., [tin ˈanːa]; and VC#CV, e.g., [tin ˈnana]) provide an account for the alignment of the L1. Specifically, in the three segmental patterns, the L1 aligns inside the onset consonant.

A noticeable effect is this: when the syllable pattern is VC#CV, which triggers a geminate, the distance LC is greater (M = 97 ms, SD = 57 ms) than in V#CV (M = 49 ms, SD = 47 ms) and VC#V (M = 71 ms, SD = 51 ms). The syllable pattern has significant effects on the distance LC F(1.88, 13.16) = 38.69, $p < .001$, $\eta^2 = .3$.

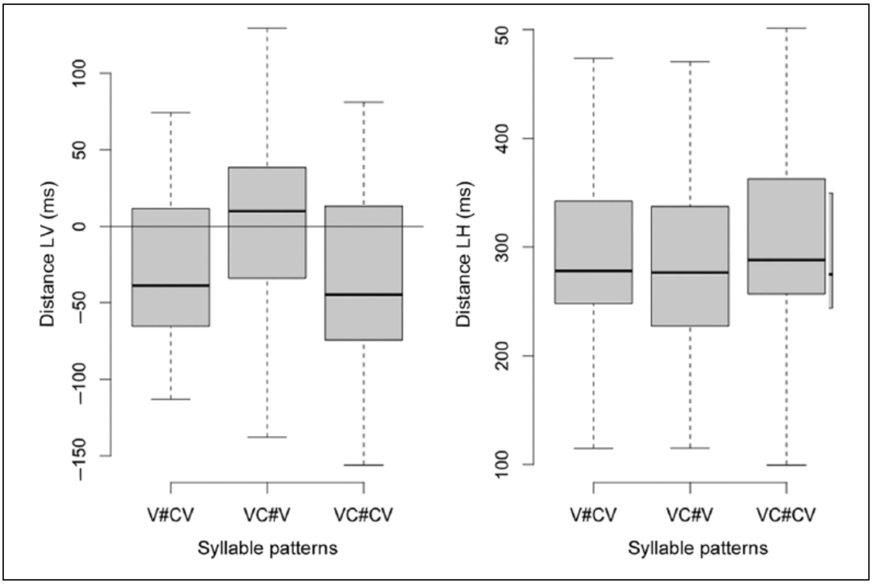

Figure 8. Distance LV (left panel) and distance LH (right panel) for the three syllable patterns: V#CV (e.g., [to'nama]), VC#V (e.g., [tin'anːa]), and VC#CV (e.g., [tin 'nana]. The thin horizontal line in the left panel indicates the left edge of the stressed vowel.

Moreover, the syllable pattern has significant effects on the distance LV $F(2, 14) = 23.94$, $p < .001$, $\eta^2 = .3$. Overall, the L1 aligns 22.15 ms before the vowel's left edge:

i. In V#CV (e.g., [to'nama]) and VC#CV (e.g., [tin'nana]) the L1 aligns inside the consonant (V#CV: $M = 30$ ms before the vowel, and VC#CV: $M = 37$ ms before the vowel).

ii. In VC#V (e.g., [tin'anːa]) the L1 aligns at the vowel's left edge ($M = .6$). Post hoc tests with Bonferroni corrections suggest that the alignment of the L1 in VC#V differs significantly from the alignment of the L1 in V#CV ($p < .05$) and VC#CV ($p < .05$), whereas the alignment of the L1 in V#CV does not differ from the alignment of the L1 from VC#CV. In VC#V the L1 precedes the vowel's left edge when the vowel is an [i] ($M = 22.2$) but it follows the vowel's left edge when the vowel is an [a] ($M = 23.4$).

The distance LH is on average 297 ms (VC#CV: 316 ms, V#CV: 292 ms, and VC#V: 283 ms) (see Figure 8, right panel). Specifically, the effect of *vowel* on the distance LH was not significant $F(1, 7) = 0.57$, $p = .05$ whereas the effect of *syllable pattern* on the distance LH was significant $F(2, 14) = 4.37$, $p < .05$. Post hoc tests show that the distance LH in VC#CV differs from that in V#CV ($p < .05$) and also from that in VC#V ($p < .05$).

2.2.2 The prenuclear H. Overall, the H aligns approximately 25 ms after the keyword's right edge (see Figure 9, left panel).

Because the H aligns consistently with the right edge of the keyword, the effects of the syllable pattern $F(2, 14) = 1.16$, $p = .34$ and the *vowel* $F(2, 7) = 3.61$, $p = .09$ on the distance HW were not significant. In addition, the distance HL2 is constant across the three syllable patterns (see Figure 9, right panel); as a result, the effect of the syllable pattern on the distance HL2 was not significant $F(2, 14) = 1.53$, $p = .25$.

2.2.3 The L2 tone. Table 3 shows the mean duration in ms and the *SD* for the distance L2C and the distance L2V for each syllable pattern (V#CV, VC#V, and VC#CV) and vowel ([a] or [i]). The L2

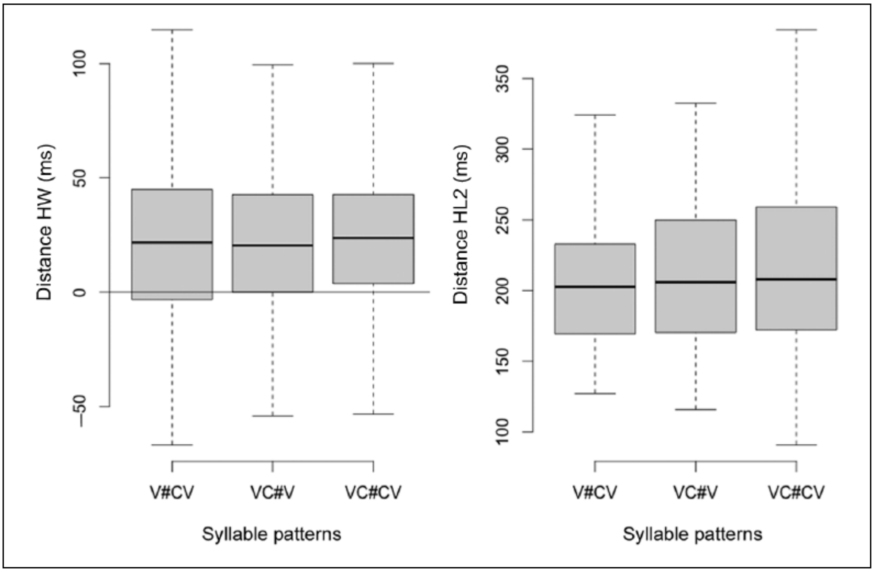

Figure 9. Distance HW (left panel) and distance HL2 (right panel) for the three syllable patterns: V#CV (e.g., [to ˈnama]), VC#V (e.g., [tin ˈana]), and VC#CV (e.g., [tin ˈnana]). The thin horizontal line in the left panel indicates the right edge of the keyword.

Table 3. Mean duration in ms and *SD* for the distance L2C and the distance L2V for each syllable pattern (V#CV, VC#V, and VC#CV) and vowel ([a] or [i]).

	V#CV*a*		V#CV*i*		VC#V*a*		VC#V*i*		VC#CV*a*		VC#CV*i*	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Distance L2C	52	43	54	49	59	44	55	47	52	44	58	54
Distance L2V	−46	44	−42	47	−42	42	−39	46	−46	41	−37	50

aligns inside the onset consonant of the stressed syllable of the word [mːaˈlːonːi]. Observe the similarities in the alignment of the L1 and the L2: both Ls align inside the onset consonant of the stressed syllable.

Specifically, the L2 aligns inside the stressed consonant of the word [maˈlːonːi] at a fixed distance: on average 42 ms before the stressed vowel (see Figure 10).

Consequently, the effect of syllable pattern on the distance L2C $F(2, 14) = .47$, $p = .63$ and the effect of syllable pattern on the distance L2V $F(2, 14) = .38$, $p = .7$ were not significant.

2.3 Discussion

Next we discuss the implications of the results on the experimental hypotheses.

2.3.1 The alignment of the L. Overall, the L aligns as follows: (a) when the syllable pattern is VC#V (e.g., [tin#ˈanːa]), the L1 aligns at the stressed vowel's left edge and not before the consonant [n] of

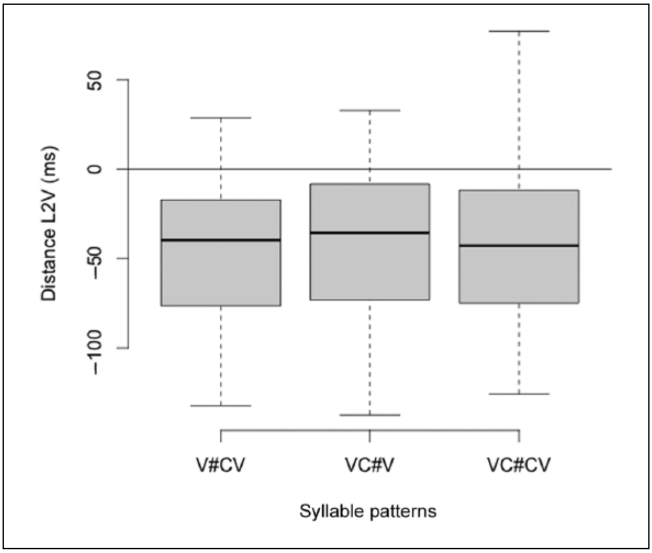

Figure 10. Distance L2V for the three syllable patterns: V#CV (e.g., [to ˈnama]), VC#V (e.g., [tin ˈana]), and VC#CV (e.g., [tin ˈnana]). The thin horizontal line indicates the beginning of the vowel of the following stressed syllable.

the preceding word [tin]; (b) when the syllable pattern is VC#CV (e.g., [tin#ˈnana]), the L1 aligns inside the geminate consonant, just before the stressed vowel, as in Tserdanelis & Arvaniti, 2001; lastly, (c) when the syllable pattern is V#CV (e.g., [to#ˈnama]), the L1 aligns inside the onset consonant. Note that the alignment of the L1 is replicated by the alignment of the L2: the two Ls align inside the onset consonant.

Noticeably, this finding does not agree with Tserdanelis & Arvaniti, 2001, who report that the L of an L+H aligns before the onset consonant. However, in their study the L+H constitutes a nuclear pitch accent and not a prenuclear one, so this dissimilarity between our findings and those reported by Tserdanelis & Arvaniti, 2001 might suggest a different alignment of the CG prenuclear and nuclear L. This claim should be empirically tested (see also Themistocleous, 2011). The implications of these findings on the experimental hypotheses are discussed below.

Since the L1 aligns inside the onset consonant (in V#CV and VC#CV) or at the left edge of the vowel (in VC#V), the prediction of *Hypothesis L-A*, that the L is stably realised a few milliseconds before the onset of the stressed syllable, is not supported. In addition, the prediction of *Hypothesis L-C*, that the L anchors with respect to the left edge of the stressed vowel, is confirmed only for VC#V but not in the other two syllable patterns.

But if *Hypothesis L-A* and *Hypothesis L-C* do not account for the results, what does? To answer this we need to consider again the alignment of the L1 in VC#V: the L1 aligns at the left edge of the vowel. This suggests that the syllable structure affects the alignment of the L. To clarify this, compare the alignment of the L in the two syllable patterns: VC#V and V#CV. In VC#V the L aligns after the consonant, whereas in V#CV the L aligns before the consonant. (Note these syllable patterns differ only in the syllabification of the string VCV.) Consequently, the L does not align with respect to the left edge of the consonant; thus, we must reject the prediction of *Hypothesis L-B*, that the prenuclear L anchors with respect to the consonant's left edge. The second and most important consequence is that it is the prosodic structure, and more specifically the syllable, that influences the alignment of the L. The middle of the stressed syllable's onset is the obvious anchor of the L, and when the syllable is onsetless the anchor is the left edge of the vowel.

2.3.2 The alignment of the H. At this point let us consider the alignment of the prenuclear peak: the H aligns approximately 25 ms after the keyword's right edge. This finding is in line with the prediction of *Hypothesis H-A*, that the H aligns a few milliseconds after the right edge of the keyword. Nevertheless, *Hypothesis H-B*, which states that in a bitonal LH pitch accent the H follows the L at a fixed duration, is not supported because the distance between the L1 and the H is dependent on the alignment of the L with respect to the syllable patterns (V#CV, VC#V, and VC#CV).

Overall, because the L1 and the H seem to have specified anchors, the results corroborate the segmental anchoring hypothesis and highlight the importance of the prosodic structure. Nevertheless, because Experiment 1 tested specifically the alignment of the L, it does not provide an account of the factors that influence the alignment of the H. To evaluate the H's alignment, and more specifically the predictions of *Hypothesis H-A*, Experiment 2 has been designed.

3 Experiment 2

Experiment 1 showed that the H aligns approximately 25 ms after the keyword's right edge. However, because the distance between the designated pitch accent and the following one has not been manipulated, the results that concern the H tonal alignment were not conclusive. Experiment 2 therefore tests the predictions of *Hypothesis H-A* that the H consistently aligns with the keyword's right edge. If the claim of this hypothesis were correct, we would expect that the H would be realised at the right edge of the accented word. However, if this hypothesis claim were false, we would expect that the alignment of the H would depend on the proximity of the following stressed syllable. This experiment aims to test whether the distance between the H and the following stressed syllable determines its alignment. To address this goal, we manipulated the number of unstressed syllables which follow the stressed syllable, which associates with the prenuclear pitch accent, and the following stressed syllable.

3.1 Method

3.1.1 Speech material. The speech material comprises of five sentences. The sentences differ in the number of unstressed syllables between the stressed syllable of the word *dhílone* [ˈðiloněe] 'stated', which bears the prenuclear pitch accent, and the stressed syllable of the keyword, which follows. Specifically, the number of unstressed syllables has been manipulated from two to six syllables. To this purpose, the following *keywords* have been employed: *dhíchroni* 'two years old', *dhekáchroni* '10 years old', *dhodhekáchroni* '12 years old', *dhekapentáchroni* '15 years old', and *sarantapentáchroni* '45 years old' (see Table 4). All keywords are adjectives and function as predicates.

To minimise segmental effects on the fundamental frequency contour and to facilitate F0 tracking, words containing mostly voiced or sonorant sounds were selected.

3.1.2 Speakers. Nine female speakers participated in Experiment 2. All speakers were in their early 20s. The speakers were undergraduate students at the University of Cyprus at the time of the recording. All speakers were brought up in Nicosia and they did not have any regional accents. The speakers reported no hearing or articulatory problems. All speakers were naïve to the experimental hypotheses. Since all speakers were studying English literature and linguistics at the university, they were very competent in English; in addition, the speakers had basic knowledge of French from their secondary school studies.

Table 4. Test materials with Interactional Phonetic Alphabet (IPA) transcription. Small caps in boldface indicate the intervening unstressed syllables between the stressed syllable of the word *dhílone* and the stressed syllable of the keyword.

Utterances	Number of syllables
I Mélani dhíLONE dhí chroni. /iˈmelani ˈðilonːe ˈðixɾoni/ 'Melanie stated that she was two years old'	Two
I Mélani dhíLONE DHEkáchroni. /iˈmelani ˈðilonːe ðeˈkaxɾoni/ 'Melanie stated that she was 10 years old'	Three
I Mélani dhíLONE DHODHEkáchroni. /iˈmelani ˈðilonːe ðoðeˈkaxɾoni/ 'Melanie stated that she was 12 years old'	Four
I Mélani dhíLONE DHEKAPEntáchroni. /iˈmelani ˈðilonːe ðekapeˈndaxɾoni/ 'Melanie stated that she was 15 years old'	Five
I Mélani dhíLONE SARANTAPEntáchroni. /iˈmelani ˈðilonːe saɾandapeˈndaxɾoni/ 'Melanie stated that she was 45 years old'	Six

3.1.3 Procedure. Speakers were seated comfortably at a desk in a sound-treated recording booth at the University of Cyprus. Speakers read sentences aloud, at a comfortable, self-selected rate. Test utterances were presented in random order 10 times each, one sentence per slide, in Microsoft PowerPoint 2010. Speakers pressed the space bar of the keyboard to change slides. All sentences read were produced with broad focus.

The main investigator was present during the recording phase, and his role was mainly auxiliary: to start the microphone, to make sure that the speaker's distance from the microphone was kept stable, etc. Recordings were made onto a Zoom H4n audio recorder (sampling frequency 44.1 kHz), and transferred to a PC using a compact *SD* card. For the acoustic analysis, the open source software Praat 5.3.32 was used (Boersma & Weenink, 2012).

The first repetition was considered preparatory and was removed from the data; also, the last repetition was removed to avoid fatigue effects. Except for the first and last repetition, no other data were removed. Overall, the second experiment comprises of 360 utterances (9 speakers × 8 repetitions × 5 settings).

3.1.4 Measurements. The acoustic material was manually segmented and labelled; Figure 11 shows the waveform, spectrogram, and F0 contour – superimposed on the spectrogram – of the test utterance *i Mélani dhílone sarantapentáchroni*.

The contour comprises of two consecutive rising L*+H prenuclear pitch accents. The first prenuclear pitch accent associates with the stressed syllable of the first word of the utterance – that is, the word 'Mélani' – and the second with the stressed syllable of the keyword. A downstepped !H* nuclear pitch accent that conveys broad focus associates with the keyword, the last lexical constituent of the utterance.

Segmentations and measurements were carried out in Praat 5.3.32 acoustic analysis software (Boersma & Weenink, 2012). The L1 in the recorded utterances falls within two prenuclear peaks (see Figure 11); thus, the lowest frequency between the two peaks – the local minimum – constitutes the L1. Conversely, the H is the highest frequency – the local maximum – of the contour that

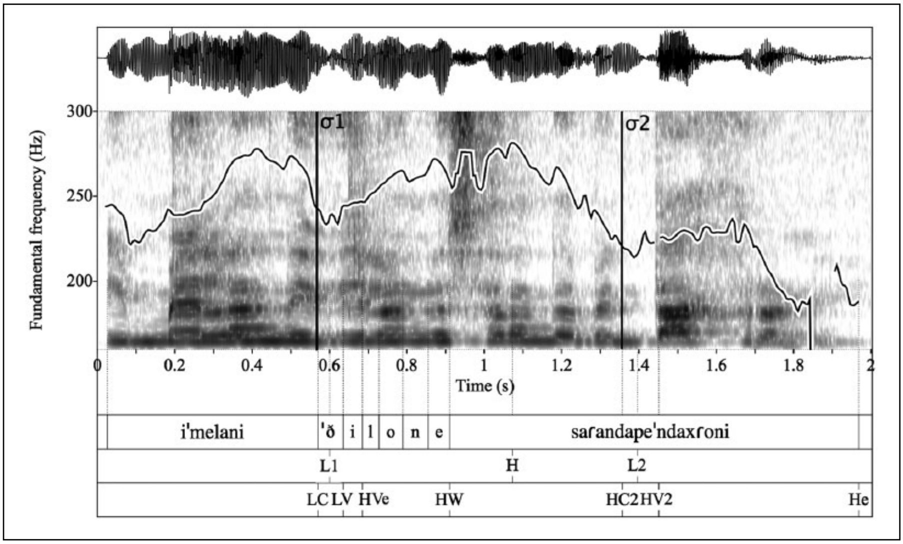

Figure 11. Waveform, spectrogram, and F0 contour – superimposed on the spectrogram – of the test utterance *i Mélani dhílone sarantapentáchroni* [iˈmelani ˈðilonːe saɾandapeˈndaxɾoni]. The vertical solid lines labelled σ1 and σ2 indicate the left edge of the stressed syllable of the words [ˈðilonːe] and [saɾandapeˈndaxɾoni] respectively. The L1, the H, and the L2 (central tier) and the points labelled in the bottom tier indicate measurement points.

follows the L1. The local minimum of the F0, which follows the H, constitutes the L2. Manual corrections in the automatic F0 detection were made only when there was an obvious pitch tracking error. Specifically the following measurements were made:

L1: The temporal position of the L1.
H: The temporal position of the H.
L2: The temporal position of the L2.

In addition, the following distances were calculated (see Figure 11):

LH: The distance between the L1 and the H.
LC: The distance between the L1 and the σ1.
LV: The distance between the L1 and the left edge of the stressed vowel in the second word /ˈðilonːe/.
HVe: The distance between the H and right edge of the stressed vowel in the second word /ˈðilonːe/.
HW: The distance between the H and right edge of the second word /ˈðilonːe/.
HC2: The distance between the H and the σ2.
HV2: The distance between the H and the stressed vowel of the keyword.
HL2: The distance between the H and the L2.
He: The distance between the H and the end of the utterance.
σ1σ2: The distance between the stressed syllable of the word *dhílone* and the stressed syllable of the keyword (i.e., dhekáchroni, dhodhekáchroni, etc.).

The information about the temporal boundaries of segments and the location of tones were automatically extracted by using Praat scripts. The data were imported in R 3.0.2 (R Core Team, 2012) and the aforementioned distances were calculated.

3.1.5 Statistics and analysis. For the Experiment 2, a one-way repeated measures ANOVA has been conducted with the number of unstressed syllables with five levels (i.e., two syllables, three syllables, four syllables, five syllables, and six syllables) as an independent factor and the aforementioned measurements as the dependent variables. The statistical analysis was carried out in R 3.0.2 (R Core Team, 2012). For the ANOVA, the ezANOVA function from the 'ez' package has been employed (Lawrence, 2011). Before running the ANOVAs, Mauchly's tests for sphericity violation were performed. When the assumption of sphericity was violated, the degrees of freedom were corrected by using Greenhouse–Geisser estimates. Furthermore, post hoc tests using pairwise comparisons between group levels with Bonferroni corrections are reported.

3.2 Results

In Experiment 2, the L persistently aligns inside the onset consonant, a few milliseconds before the stressed vowel. However, the findings on the alignment of the H are intriguing and unexpected: the alignment of the H varies depending on the proximity of the following L2: the distance LH is proportional to the distance HL2. Next we report the results in detail.

The alignment of the L1 is fixed (see Figure 12). Specifically, the L1 aligns consistently inside the onset consonant of the accented syllable, approximately 20 ms (*Mdn* = 19 ms) before the vowel. Therefore, the number of unstressed syllables has non-significant effects on the distance LV $F(4, 32) = 0.81$, $p = .529$.

Depending on the number of the unstressed syllables, the alignment of the H varies. Observe Figure 13. The distance LH correlates strongly with the distance σ1σ2. The correlation is positive. In other words, the distance LH is proportional to the distance σ1σ2: when the duration of the distance σ1σ2 increases, the duration of the distance LH also increases. Moreover, the effect of the number of unstressed syllables on the distance LH results in the terraced effect shown in Figure 14.

Consequently, the number of unstressed syllables has a highly significant effect on the distance LH $F(4, 32) = 85.55$, $p < .0001$, $\eta^2 = .85$. Similarly, the number of unstressed syllables has significant effects on the distance HC2 $F(4, 32) = 24.05$, $p < .0001$, $\eta^2 = .57$ (see Table 5).

The H aligns on average 225 ms (*SD* = 89) before the L2 (see Figure 15). Notably, the number of unstressed syllables has significant effects on the distance HL2 $F(4, 32) = 7.81$, $p < .0001$, $\eta^2 = .37$.

Post hoc tests with Bonferroni corrections suggest that the number of unstressed syllables has non-significant effects on the distance HL2 in two contrasts: (a) between two and three unstressed syllables and (b) between four, five, and six unstressed syllables.

3.3 Discussion

In Experiment 2, we tested the factors that influence the alignment of the H; namely, the number of unstressed syllables has been modified. The results have been revealing. The number of unstressed syllables has no significant effects on the alignment of the L1, which has a fixed alignment. On the other hand, the number of unstressed syllables has significant effects on the alignment of the H. Next we discuss the implications of these findings on the experimental hypotheses.

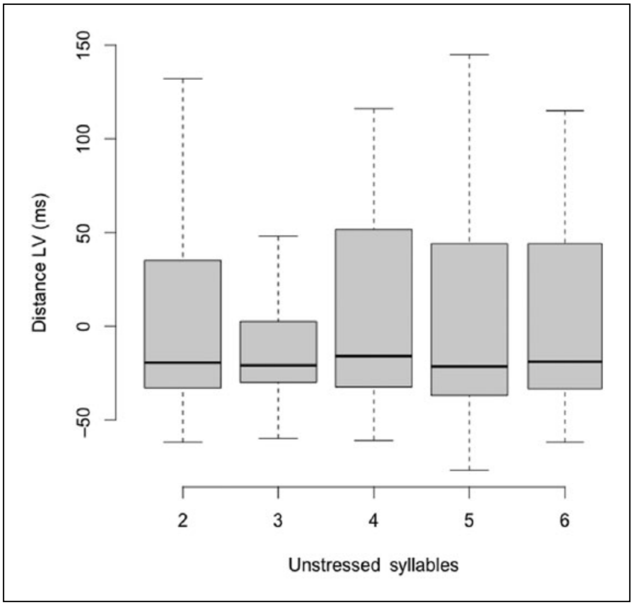

Figure 12. The distance LV (in ms) (ordinate) as a function of the number of unstressed syllables (abscissa). The negative values in the ordinate of the left panel indicate that the L aligns before the left edge of the vowel.

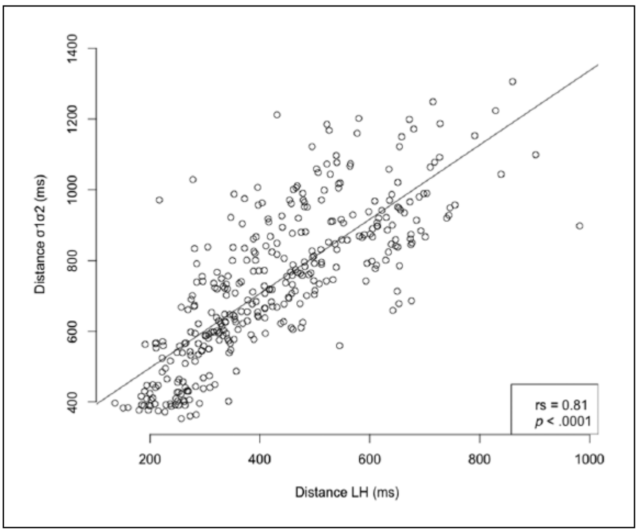

Figure 13. The distance σ1σ2 (in ms) (ordinate) as a function of the distance LH (in ms) (abscissa).

1. *The alignment of the L.* The L aligns inside the onset consonant – as in Experiment 1 – on average 20 ms before the stressed vowel. Therefore, *Hypothesis L-A*'s claim that the L anchors before the onset consonant of the stressed syllable, and *Hypothesis L-B*'s claim that the L anchors with respect to the left edge of the consonant (including consonants found at

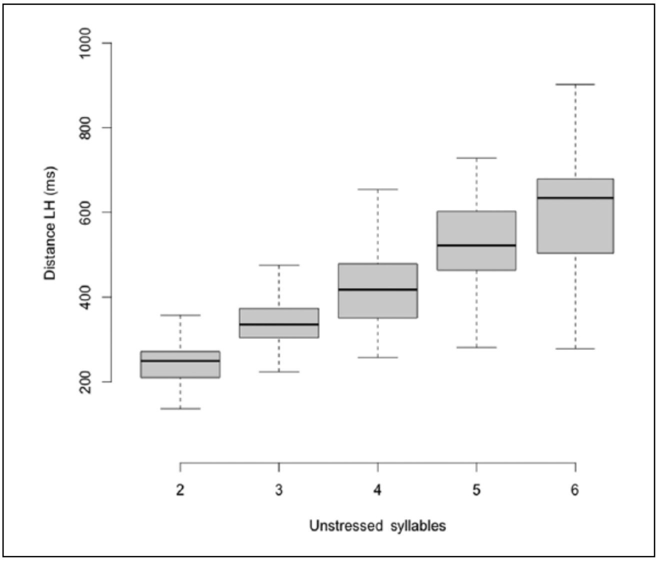

Figure 14. Distance LH (ordinate) as a function of the number of unstressed syllables (abscissa) between the designated pitch accent and the following one.

Table 5. Mean duration and *SD* for distance HC2.

Number of syllables	Distance HC2	
	Mean	*SD*
Two	124	50
Three	207	54
Four	256	101
Five	279	108
Six	351	189

the coda of a preceding syllable), are not confirmed. The claim of *Hypothesis L-C* that the L anchors with respect to the stressed vowel has not been confirmed either (see also the discussion in Experiment 1).

2. *The alignment of the H.* The distance LH is proportional to the number of unstressed syllables. Consequently, the claim of Hypothesis H-B that the distance LH is fixed is not confirmed. Also, Hypothesis H-A's claim that the H consistently aligns a few milliseconds after the accented word's right edge has not been confirmed.

However, compare this finding with that in Experiment 1. In that experiment, the H had a fixed alignment approximately 25 ms after the accented word's right edge. So does the alignment of the H differ in the two experiments? To answer this question, we need to compare the distance HL2 in the two experiments, when the number of unstressed syllables is the same, that is, two syllables. Note, however, that the two experiments differ in their segmental material. To address this issue, we employ the normalised distance HL2, which we calculate as follows (see (7)):

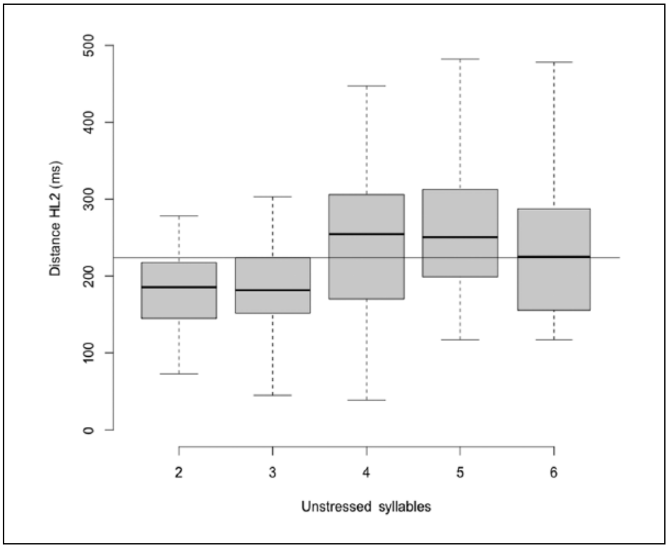

Figure 15. The distance HL2 (in ms) (ordinate) as a function of the number of unstressed syllables (abscissa) between the designated pitch accent and the following one.

(7) Normalised distance HL2 = distance HL2 / distance σ1σ2.

In Experiment 1, the mean normalised distance HL2 is 0.41 (*SD* =0.96) and in Experiment 2 the mean normalised distance HL2 is 0.41 (*SD* = 0.11). A *t test* showed that the two experiments do not differ in the normalised distance HL2. Therefore, because in Experiment 1 the number of unstressed syllables is constant in all experimental modifications, the fixed alignment of the H is a consequence of the experimental design. So, this justifies a rejection of *Hypothesis H-A* in both experiments: the H does not anchor to the accented word's right edge but it 'wanders' in the area after the L1 and before a following pitch accent.

Another important implication of these findings is that the type of the following pitch accent does not affect the alignment of the H. Specifically, Experiment 1 and Experiment 2 differ by design in the pitch accent that follows the designated prenuclear pitch accent (in Experiment 1 the L*+H is followed by another L*+H, whereas in Experiment 2 the L*+H is immediately followed by an !H), yet the normalised distance HL2 is the same in the two experiments. The repercussions of these findings are discussed in the following.

4 Final discussion

Tonal alignment signals lexical and postlexical distinctions, but the exact properties of tonal alignment are controversial. For example, there is a great dispute on whether the two tones of a bitonal pitch accent are timed with respect to tones, specific segments, or prosodic constituents (such as the syllable nucleus, the syllable onset, and the prosodic word). The dispute gave rise to three hypotheses: (a) the invariance hypothesis, which predicts that in a bitonal pitch accent the distance between the two tones is fixed, and it does not change even when the segmental composition changes; (b) the segmental anchoring hypothesis, which predicts that the tones align with specific segmental anchors; and (c) the segmental anchorage hypothesis, which predicts that tones align within a region instead of a specific anchoring point. By examining the alignment of the CG prenuclear pitch accent, this study tests the predictions of these hypotheses.

In the following, we discuss the implications of the findings. Section 4.1 summarises the results, discusses the properties of the CG prenuclear pitch accent, and compares the findings to the ones that have been reported for SMG. Finally, Section 4.2 discusses the repercussions of the findings on the experimental hypotheses and examines the effects of pitch accents' paradigmatic contrasts on tonal alignment.

4.1 The LH pitch accent in CG

Considering that by design the experimental utterances of this study differ in length, experimental modifications, etc., the precision in the alignment of the L is truly astonishing. The L has a fixed alignment inside the onset consonant of the accented syllable: in Experiment 1 it aligns on average 22 ms before the stressed vowel, and in Experiment 2 it aligns on average 20 ms before the stressed vowel.[8] An important implication of these findings is that they demonstrate that the alignment of the L depends on the syllable structure: the L anchors to the onset consonant, and when the syllable is onsetless it anchors to the left edge of the nucleus.

As for the alignment of the H, the results in the two experiments have been both unexpected and intriguing. Figure 16 illustrates a stylised version of the five LH pitch accents that we examined in Experiment 2. As opposed to the fixed alignment of the L, the alignment of the H varies greatly, depending on the H's proximity to an upcoming tone. More specifically, the distance between the L and the H is proportional to the distance (in number of unstressed syllables) between the L and the upcoming tone (T). Observe that our results demonstrated that the type of T does not influence the alignment of the H (e.g., L*+H or !H*).

Overall, the fixed alignment of the L has been observed in other languages (see also Caspers & van Heuven, 1993 for Dutch; Prieto, van Santen, & Hirschberg, 1995 for Spanish; Arvaniti et al., 1998 for Greek; Ladd et al., 1999 for English; and Prieto, 2005 for Catalan; see Welby, 2006 for the L of the French early rise).

However, this 'wandering' of the H over multiple syllables is extremely rare. Besides CG and two other languages that provide evidence for a similar phenomenon: Tagalog (personal communication with Sun-Ah Jun) and Bulgarian (Dimitrova & Jun, 2015), to the best of our knowledge, this phenomenon has not been attested elsewhere. Moreover, the 'wandering' of the H, by casting doubt on the invariance hypothesis and the segmental anchoring hypothesis, as well as by indicating the need for a modified version of the segmental anchorage hypothesis, calls attention to established approaches in autosegmental phonology with respect to tonal timing.

4.2 Evaluating hypotheses: anchoring vs. anchorage

So what do these findings tell us about the experimental hypotheses discussed in this paper? The answer is – a lot. Because the distance between the L1 and the H is not fixed but varies, depending on the number of unstressed syllables that follow the stressed syllable (see Figure 16), the invariance hypothesis is not confirmed (e.g., Prieto et al., 1995, for Mexican Spanish; Arvaniti et al., 1998, for SMG; Prieto & Torreira, 2007, for Spanish; Cho, 2011, for phrase initial tones in Seoul Korean).

Moreover, as the H does not have a designated anchor, it adds to the mounting evidence against the predictions of the segmental anchoring hypothesis; see for instance Frota, 2002 for European Portuguese; (Xu, 1997, 1998, 2007) for Mandarin Chinese; Prieto & Torreira, 2007 for Peninsular Spanish. In this line, Welby & Lœvenbruck, 2006 provided comparable evidence against the

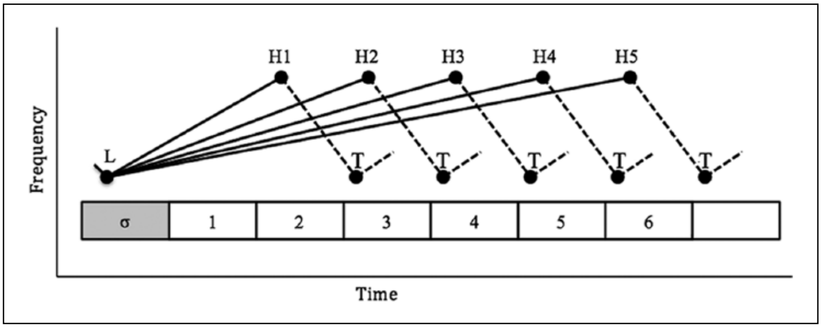

Figure 16. Stylised F0 curves of five superimposed LH pitch accents. The L represents the L of an LH; each H – numbered from one to five – represents an H of the LH; the Ts represent an upcoming tone; the grey box labelled σ represents the stressed syllable; the numbered boxes from one to six represent the unstressed syllables.

segmental anchoring hypothesis and concluded that it did not account for their findings. Specifically, they examined the alignment of the L and the H of the French late rise. The L showed a great deal of variability depending on the speaker and on the speaking rates. The H had variable alignment depending on the syllable structure. In CV syllables, the H aligned at the end of the vowel or just beyond it; in closed syllables that end in a sonorant (CVCson), the H aligned at the end of the vowel or in the coda consonant. In closed syllables that end in an obstruent (CVCobs), the H aligned at the end of the vowel or in the voiced part of the consonant.

To account for their findings, they proposed the segmental anchorage hypothesis. This hypothesis claims that the tones align within a region: the *segmental anchorage*. For the French H, this is the region stretching from approximately 20 ms before the end of the vowel to the end of the AP. However, notice that the segmental anchoring hypothesis and the segmental anchorage hypothesis are not mutually exclusive but might coexist in a language (Welby & Lœvenbruck, 2006). For instance, in languages like French there are both segmental anchors and segmental anchorages. In other languages, such as SMG, there can only be segmental anchors.

In CG the L has a fixed anchor, whereas the H does not have a fixed anchor but it aligns within a segmental anchorage (SA). We define the SA as the area where a tone can anchor, ranging from a phonologically determined starting point up to a phonologically determined ending point.

To account for the starting and the ending point of the SA, we should consider the other pitch accents in the language's tonal inventory and whether an earlier or later tonal alignment can cause ambiguity in the perception of the pitch accent. In CG, besides the L*+H that serves as a prenuclear pitch accent, there is another LH pitch accent, the L+H*, which signals narrow focus (Themistocleous, 2011, 2012). In Figure 17 the H1 corresponds to the peak of the L+H*, whereas the H2 corresponds to the peak of the L*+H. The H1 of the L+H* and the H2 of the L*+H align between the L1 and the L2. The two tones differ in their SAs: the H1 aligns within the nucleus of the accented syllable (SA1) whereas the H2 approaches the L2 (SA2). The boundary between the SA1 and SA2 – indicated in Figure 17 by the dashed vertical line – constitutes a differential threshold. Therefore, the exact alignment of the H with respect to this threshold distinguishes the L+H* from the L*+H.[9]

Demonstrating this differential threshold, Pierrehumbert & Steele, 1989 showed, in a perceptual imitation task, that the alignment of the H has categorical effects and distinguishes the nuclear L+H* pitch accent from the (pre)nuclear L*+H pitch accent in American English. Their findings were corroborated by later studies (cf. Dilley & Brown, 2007). Essentially, speakers are extremely

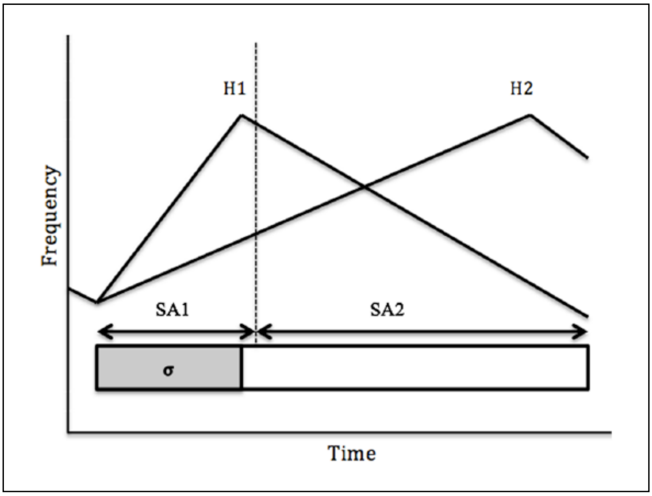

Figure 17. H1 is the peak of the nuclear pitch accent L+H* and H2 the peak of the prenuclear pitch accent L*+H. The dotted vertical line indicates a category boundary. The SA1 is the segmental anchorage of H1 and the SA2 is the segmental anchorage of H2. The L1 is the L of the two pitch accents: L+H* and the L*+H; the L2 is the L of a following rising pitch accent.

sensitive to acoustic landmarks, such as peaks Stevens, 2002, and to the perceptually salient differential thresholds in the timing of these landmarks that permit pitch accents' distinction ('t Hart, Collier, & Cohen, 1990). Observe that languages may differ in the number of possible rising pitch accents that can contrast in the same environment and correspondingly they distribute SAs. For instance, CG displays a two-way distinction in the timing of the H in the LH pitch accents (i.e., L*+H and L+H*), whereas Catalan displays a three-way distinction in the timing of the H (i.e., an L*+H and L+<H*, and L+H*) (Prieto, 2014).

Languages may differ in the exact timing mechanisms they employ to preserve the categorical contrast between rising pitch accents (Gussenhoven, 2004, 2007; Hirschberg, 2002; Ladd, 2008; Pierrehumbert, 1980; Silverman & Pierrehumbert, 1990). To clarify this, let us compare the alignment of the CG prenuclear pitch accent with that of the SMG, another Greek variety. The two varieties are similar in that they contain in their phonemic inventory a prenuclear L*+H and a nuclear L+H*, but they differ in the alignment of their prenuclear pitch accents (see also Arvaniti & Baltazani, 2005; Baltazani & Kainada, 2015; Themistocleous, 2011). The SMG L consistently aligns just before or at the very onset of the stressed syllable, whereas the CG L aligns inside the onset consonant. The SMG H anchors on average 10–20 ms after the onset of the postaccentual vowel (Arvaniti, 2007; Arvaniti & Ladd, 1995; Arvaniti et al., 1998, 2006a, 2006b; Baltazani, 2006), whereas the CG H varies in its alignment depending on the position of the following tone. In the two varieties, the paradigmatic contrast with L+H* is preserved as follows: in CG, the H aligns at a maximum distance from the L1 and in SMG the tones have unambiguously specified anchors. In other words, in CG, the exact alignment of the H is determined not by direct anchoring of tones, but by the alignment of tones within the SA.

This study adds to the factors that influence tonal alignment (such as boundaries of prosodic domains, tonal context, segmental context, speech rate, etc.) another dimension: the paradigmatic dimension. Specifically, the paradigmatic dimension refers to the constraints on alignment imposed by other tones in the tonal inventory. To avoid ambiguity in the production of a pitch accent, speakers maintain the alignment of the pitch accent's tones within boundaries of their SAs or they anchor them to specific segments. To conclude, the results of this study highlight the importance of the paradigmatic contrast in tonal alignment, challenge earlier hypotheses on tonal alignment, and provide the first (to our knowledge) in-depth account of CG prenuclear pitch accents.

Acknowledgements

I am truly grateful to Sun-Ah, Sun and to the two anonymous reviewers for their helpful comments and suggestions, which have greatly improved this paper. I would also like to thank Kleanthes Grohmann, Helen Ayres, and Spyros Armostis for their comments.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Notes

1. Haugen, 1949 considers juncture as a suprasegmental constituent. This line of thought is followed by later studies that associate pitch accents not only to prosodic constituents but also to the edges of these constituents (Goldsmith, 1976, p. 13).
2. Pierrehumbert, 1980 indicates a trailing or leading tone by using a macron sign as in T^{-}.
3. In a later study, Arvaniti & Baltazani, 2005 analyse the prenuclear pitch accent as L*+H to differentiate it from the nuclear L+H* pitch accent.
4. In 1974, Turkish military operations led to a subsequent de facto partition of the island; since then, Turkish Cypriot is spoken in the northern part whereas Cypriot Greek is spoken in the southern part; communication between Turkish Cypriots and Greek Cypriots is sparse (Hadjioannou, Tsiplakou, & Kappler, 2011).
5. /s/ also assimilates into a postlexical geminate when it precedes a sibilant sound.
6. In CG, clitic placement is enclitic, as opposed to SMG, which is proclitic (Agouraki, 2010; Chatzikyriakidis, 2012; Grohmann & Leivada, 2012; Mavrogiorgos, 2010).
7. The 'ez' package 'facilitates easy analysis of factorial experiments, including purely within-Ss designs (a.k.a. 'repeated measures'), purely between-Ss designs, and mixed within-and-between-Ss designs' (Lawrence, 2011, p.2).
8. In Experiment 1, we measured the alignment of the L of a subsequent prenuclear L*+H (i.e., the L2); again, the L aligned inside the onset consonant.
9. Note that tonal timing is not the only way that languages maintain the categorical contrast between pitch accents. For example, (Gussenhoven, 2004, pp. 90–92) suggests that the greater peak delay may alternate in different contexts with greater peak height to maintain nuclear and prenuclear pitch accent contrast (Gussenhoven, 2002, 2004; Knight, 2008).

References

't Hart, J., Collier, R., & Cohen, A. (1990). *A perceptual study of intonation. An experimental-phonetic approach to speech melody*. Cambridge, UK: Cambridge University Press.

Agouraki, Y. (2010). It-clefts and stressed operators in the preverbal field of Cypriot Greek. *Lingua: International Review of General Linguistics*, *120*(3), 527–554.

Armosti, S. (2009). *The phonetics of plosive and affricate gemination in Cypriot Greek* (PhD Thesis). University of Cambridge, Cambridge.

Arvaniti, A. (2006). Linguistic practices in Cyprus and the emergence of Cypriot Standard Greek. *San Diego Linguistic Papers*, 1–24.

Arvaniti, A. (2007). Greek phonetics: The state of the art. *Journal of Greek Lingusitics*, *8*, 97–208.

Arvaniti, A., & Baltazani, M. (2005). Intonational analysis and prosodic annotation of Greek spoken corpora. In S.-A. Jun (Ed.), *Prosodic typology. The phonology of intonation and phrasing* (pp. 84–117). Oxford, UK: Oxford University Press.

Arvaniti, A., & Ladd, D. R. (1995). *Tonal alignment and the representation of accentual targets*. Paper presented at the XIIIth International Congress of Phonetic Sciences, *Stockholm, Sweden*.

Arvaniti, A., Ladd, D. R., & Mennen, I. (1998). Stability of tonal alignment: The case of Greek prenuclear accents. *Journal of Phonetics*, *26*(1), 3–25.

Arvaniti, A., Ladd, D. R., & Mennen, I. (2000). What is a starred tone? Evidence from Greek. *Papers in Laboratory Phonology V: Acquisition and the Lexicon, V*, 119–131.

Arvaniti, A., Ladd, D. R., & Mennen, I. (2006a). Phonetic effects of focus and "tonal crowding" in intonation: Evidence from Greek polar questions. *Speech Communication*, *48*(6), 667–696.

Arvaniti, A., Ladd, D. R., & Mennen, I. (2006b). Tonal association and tonal alignment: Evidence from Greek polar questions and contrastive statements. *Language and Speech*, *49*, 421–450.

Arvaniti, A., & Tserdanelis, G. (2000). On the phonetics of geminates: Evidence from Cypriot Greek. *Proceedings of the 6th International Conference on Spoken Language Processing (ICSLP2000)* (Vol. 2) (pp. 559–562).Beijing, China: China Military Friendship Publish.

Atterer, M., & Ladd, D. R. (2004). On the phonetics and phonology of "segmental anchoring" of F0: Evidence from German. *Journal of Phonetics*, *32*(2), 177–197.

Baltazani, M. (2006a). *Characteristics of pre-nuclear pitch accents in statements and yes-no questions in Greek. Proceedings of the ISCA tutorial and research workshop on experimental linguistics* (pp. 81–84). Athens, Greece: University of Athens.

Baltazani, M., & Kainada, E. (2015). Drifting without an anchor. How pitch accents withstand vowel loss. *Language and Speech*, *58*(1), 84–113.

Beckman, M., & Pierrehumbert, J. (1986). Intonational structure in Japanese and English. *Phonology Yearbook*, *3*, 255–309.

Boersma, P., & Weenink, D. (2012). Praat: Doing phonetics by computer [Computer program]. Version 5.3.32. Retrieved from http://www.praat.org/

Botinis, A., Christofi, M., Themistocleous, C., & Kyprianou, A. (2004). *Duration correlates of stop consonants in Cypriot Greek*. Paper presented at the FONETIK 2004, Stockholm. Retrieved from www.ling.su.se/fon/fonetik_2004/botinis_2_fonetik2004.pdf

Bruce, G. (1977). *Swedish word accents in sentence perspective*. Lund, Sweden: Gleerup.

Bruce, G. (2005). Intonational prominence in varieties of Swedish revisited. In Sun-Ah Jun (Ed.), *Prosodic typology: The phonology of intonation and phrasing* (pp. 410–429). Oxford, UK: Oxford University Press.

Bruce, G., & Gårding, E. (1978). A prosodic typology of Swedish dialects. In E. Gårding, G. Bruce, & R. Bannert (Eds.), *Nordic prosody* (pp. 219–228). Lund, Sweden: Gleerup.

Caspers, J., & van Heuven, V. J. (1993). Effects of time pressure on the phonetic realization of the Dutch accent-lending pitch rise and fall. *Phonetica*, *50*(3), 161–171.

Chatzikyriakidis, S. (2012). A dynamic account of clitic positioning in Cypriot Greek. *Lingua: International Review of General Linguistics*, *122*(6), 642–672.

Cho, H. (2011). The timing of phrase-initial tones in Seoul Korean: A weighted-constraint model. *Phonology*, *28*(3), 293–330.

Dilley, L. C., & Brown, M. (2007). Effects of pitch range variation on F0 extrema in an imitation task. *Journal of Phonetics*, *35*(4), 523–551.

Dilley, L. C., Ladd, D. R., & Schepman, A. (2005). Alignment of L and H in bitonal pitch accents: Testing two hypotheses. *Journal of Phonetics*, *33*(1), 115–119.

Dimitrova, S., & Jun, S. A. (2015). Pitch accent variability in focus production and perception in Bulgarian declaratives. In The Scottish Consortium for ICPhS 2015 (Ed.), *Proceedings of the 18th International Congress of Phonetic Sciences*. Glasgow, UK: The University of Glasgow. Retrieved from https://www.internationalphoneticassociation.org/icphs-proceedings/ICPhS2015/Papers/ICPHS0832.pdf

Fourakis, M., Botinis, A., & Katsaiti, M. (1999). Acoustic characteristics of Greek vowels. *Phonetica: International Journal of Speech Science*, *56*(1–2), 28–43.

Frota, S. (2002). Tonal association and target alignment in European Portuguese nuclear falls. In C. Gussenhoven & N. Warner (Eds.), *Laboratory Phonology VII* (pp. 387–418). Berlin, Germany; New York, NY: Mouton de Gruyter.

Goldsmith, J. (1976). *Autosegmental phonology* (PhD Thesis). Massachusetts Institute of Technology, Cambridge, MA.

Goutsos, D., & Karyolemou, M. (2004). Introduction. *International Journal of the Sociology of Language*, *168*, 1–17.

Grice, M. (1995). Leading tones and downstep in English. *Phonology*, *12*(02), 183–233.

Grice, M., Ladd, R., & Arvaniti, A. (2000). On the place of phrase accents in intonational phonology. *Phonology*, *17*(2), 143–185.

Grohmann, K., & Leivada, E. (2012). Interface ingredients of dialect design Bi-x, socio-syntax of development, and the grammar of Cypriot Greek. In A. M. Di Sciullo (Ed.), *Towards a biolinguistic understanding of grammar. Essays on interfaces*. Amsterdam, Netherlands: John Benjamins.

Gussenhoven, C. (2002). Intonation and interpretation: Phonetics and phonology. *Speech Prosody 2002: Proceedings of the first international conference on speech prosody* (pp. 47–57). Aix-en-Provence, France: Laboratoire Parole et Langage.

Gussenhoven, C. (2004). *The phonology of tone and intonation*. Cambridge, UK: Cambridge University Press.

Gussenhoven, C. (2007). *Intonation*. In P. de Lacy (Ed.), *The Cambridge handbook of phonology* (pp. 253–280). Cambridge, UK: Cambridge University Press.

Hadjioannou, X., Tsiplakou, S., & Kappler, M. (2011). Language policy and language planning in Cyprus. *Current Issues in Language Planning*, *12*(4), 503–569.

Haugen, E. (1949). Phoneme or prosodeme? *Language: Journal of the Linguistic Society of America*, *25*(3), 278–282.

Haugen, E., & Joos, M. (1952/1972). Tone and intonation in East Norwegian. In D. Bolinger (Ed.), *Intonation. Selected Readings* (pp. 414–436). Cambridge, UK: Penguin Press.

Hirschberg, J. (2002). Communication and prosody: Functional aspects of prosody. *Speech Communication*, *36*(1–2), 31–43.

Howie, J. M. (1974). On the domain of tone in Mandarin. Some acoustical evidence. *Phonetica: International Journal of Speech Science*, *30*(3), 129–148.

Knight, R.-A. (2008). The shape of nuclear falls and their effect on the perception of pitch and prominence: Peaks vs. plateaux. *Language and Speech*, *51*(3), 223–244.

Ladd, D. R. (1983). Phonological features of intonational peaks. *Language: Journal of the Linguistic Society of America*, *59*(4), 721–759.

Ladd, D. R. (2008). *Intonational phonology*. 2nd ed. Cambridge, UK; New York, NY: Cambridge University Press.

Ladd, D. R., Faulkner, D., Faulkner, H., & Schepman, A. (1999). Constant 'segmental anchoring' of F0 movements under changes in speech rate. *Journal of the Acoustical Society of America*, *106*(3 Part 1), 1543–1554.

Ladd, D. R., Mennen, I., & Schepman, A. (2000). Phonological conditioning of peak alignment in rising pitch accents in Dutch. *Journal of the Acoustical Society of America*, *107*(5), 2685–2696.

Lawrence, M. (2011). ez: Easy analysis and visualization of factorial experiments. R package (Version 3.0.0). Retrieved from http://cran.r-project.org/web/packages/ez/ez.pdf

Lehiste, I. (1970). *Suprasegmentals*. Cambridge, MA; London: M.I.T. Press.

Mavrogiorgos, M. (2010). *Clitics in Greek: A minimalist account of proclisis and enclisis*. Cambridge, UK: Cambridge University Press.

Newton, B. E. (1972). *Cypriot Greek. Its phonology and inflections*. Hague, Netherlands; Paris, France: Mouton.

Papapavlou, A., & Pavlou, P. (1998). A review of the sociolinguistic aspects of the Greek Cypriot dialect. *Journal of Multilingual and Multicultural Development*, *19*, 212–220.

Payne, E., & Eftychiou, E. (2006). Prosodic shaping of consonant gemination in Cypriot Greek. *Phonetica: International Journal of Speech Science*, *63*(2–3), 175–198.

Peterson, G., & Lehiste, I. (1960). Duration of syllable nuclei in English. *The Journal of the Acoustical Society of America*, *32*(6), 693–703.

Pierrehumbert, J. (1980). *Phonology and phonetics of English intonation* (PhD Thesis). Massachusetts Institute of Technology.

Pierrehumbert, J., & Steele, S. (1989). Categories of tonal alignment in English. *Phonetica: International Journal of Speech Science*, *46*(4), 181–196.

Prieto, P. (2005). Stability effects in tonal clash contexts in Catalan. *Journal of Phonetics*, *33*(2), 215–242.

Prieto, P. (2014). The intonational phonology of Catalan. In S.-A. Jun (Ed.), *Prosody typology II. The phonology of intonation and phrasing* (pp. 43–81). Oxford: Oxford University Press.

Prieto, P., van Santen, J., & Hirschberg, J. (1995). Tonal alignment patterns in Spanish. *Journal of Phonetics*, *23*, 429–451.

Prieto, P., & Torreira, F. (2007). The segmental anchoring hypothesis revisited: Syllable structure and speech rate effects on peak timing in Spanish. *Journal of Phonetics*, *35*(4), 473–500.

R Core Team (2012). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from www.R-project.org/

Rowe, C., & Grohmann, K. (2013). Discrete bilectalism: Towards co-overt prestige and diglossic shift in Cyprus. *International Journal of the Sociology of Language*, *2013*(224), 119–142.

Sadat-Tehrani, N. (2009). The alignment of L+H* pitch accents in Persian intonation. *Journal of the International Phonetic Association*, *39*(2), 205–230.

Schepman, A., Lickley, R., & Ladd, R. (2006). Effects of vowel length and "right context" on the alignment of Dutch nuclear accents. *Journal of Phonetics*, *34*, 1–28.

Silverman, K., & Pierrehumbert, J. (1990). The timing of prenuclear high accents in English. In J. Kingston & M. Beckman (Eds), *Papers in laboratory phonology* (pp. 72–106). Cambridge: Cambridge, UK: Cambridge University Press.

Stevens, K. N. (2002). Toward a model for lexical access based on acoustic landmarks. *The Journal of the Acoustical Society of America*, *111*(4), 1872–1891.

Themistocleous, C. (2011). *Prosodia kai plirophoriaki domi stin Atheniaki kai kypriaki Ellinici (Prosody and information structure in Athenian and Cypriot Greek)*. National and Kapodistrian University of Cyprus, Athens. Retrieved from www.charalambosthemistocleous.com/

Themistocleous, C. (2012). Meaning and form in tonal representation. In G. Fragaki, A. Georgakopoulos, & C. Themistocleous (Eds.), *Current trends in Greek linguistics* (pp. 271–289). Newcastle-upon-Tyne, UK: Cambridge Scholars Publishing.

Themistocleous, C. (2014). Edge-tone effects and prosodic domain effects on final lengthening. *Linguistic Variation*, *14*(1), 129–160.

Themistocleous, C., & Logotheti, A. (2014). Standard Modern Greek and Cypriot Greek vowels: A sociophonetic study. *Paper presented at the 6th International Conference on Modern Greek Dialects and Linguistic Theory (MGDLT6)*, September 25–28, 2014, *Patras*.

Tserdanelis, G., & Arvaniti, A. (2001). The acoustic characteristics of geminate consonants in Cypriot Greek. In Y. Aggouraki, A. Arvaniti, J. Davy, D. Goutsos, M. Karyolaimou, A. Panayotou, …A. Roussou (Eds.), *Proceedings of the 4th international conference on Greek linguistics* (pp. 29–36). Thessaloniki, Greece: University Studio Press.

Tsimpli, I. (1995). *Focusing in Modern Greek*. In K. Kiss (Ed.), *Discourse configurational languages* (pp. 176–206). Oxford, UK; New York, NY: Oxford University Press.

Welby, P. (2006). French intonational structure: Evidence from tonal alignment. *Journal of Phonetics*, *34*, 343–371.

Welby, P., & Lœvenbruck, H. (2006). Anchored down in anchorage: Syllable structure, rate, and segmental anchoring in French. *Italian Journal of Linguistics*, *18*(1), 39–124.

Xu, Y. (1997). Contextual tonal variations in Mandarin. *Journal of Phonetics*, *25*, 61–83.

Xu, Y. (1998). Consistency of tone-syllable alignment across different syllable structures and speaking rates. *Phonetica: International Journal of Speech Science*, *55*(4), 179–203.

Xu, Y. (2007). Timing and coordination in tone and intonation—An articulatory-functional perspective. *Lingua: International Review of General Linguistics*, *119*, 906–927.

Xu, Y., & Liu, F. (2006). Tonal alignment, syllable structure and coarticulation: Toward an integrated model. *Italian Journal of Linguistics*, *18*(1), 125–159.