

THE ROLE OF SEGMENTAL SANDHI IN THE PARSING OF SPEECH:  
EVIDENCE FROM GREEK.

DISSERTATION

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By

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## ABSTRACT

Spoken languages, in addition to having inventories of distinctive sound segments (phonemes) can also employ variants of these sounds (allophones) to distinguish word- or phrase-internal segments from those that occur at the edges of such meaningful units. When allophones that normally mark word-internal positions occur at word or phrase edges, this could be indicative of a higher-than-normal degree of cohesion between two adjacent words or phrases. These segmental changes between words or phrases are called (external) segmental sandhi. The nature and range of variation in the pronunciation of these allophonic segments may be influenced by factors such as speech rate and casual versus careful style and how these extra-grammatical properties interact with the aerodynamic and coarticulatory patterns of the target sounds but also by the intonationally-marked prosodic and syntactic structure of utterances. This dissertation examines the relationship between prosodic and syntactic structure and segmental allophonic processes (sandhi) at the edges of words in Greek, a language with a rich inventory of such segmental processes. In particular, it investigates the exact phonetic nature of segmental sandhi in an effort to

understand whether such processes can result in deterministically categorical segmental changes or in more probabilistic and continuous variation. It also examines whether such segmental processes have an effect on the processing of structurally ambiguous sentences, in order to establish whether the various outcomes of segmental sandhi can be correlated with particular morphosyntactic structures. The establishment of these facts for Greek contributes to understanding and explaining how languages may incorporate external sandhi processes into their morpho-phonological structure and how speakers and listeners may exploit them in the production and parsing of speech.

Dedicated to Lamprini Tserdaneli

1949-1979

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## CHAPTER 1

### Introduction

Phonological theory in the last century has focused a great deal of attention on fundamental issues relating to the shapes of words and the nature of lexical contrast. Considerably less attention has been paid to the shapes of phrases and larger constituents and the nature of syntactic contrast. Yet we know that adults are very good at understanding spoken language even though the sentences that they hear are often quite ambiguous locally. This dissertation investigates one persistent type of phonological process that speakers might use in stringing words together into coherent, easily comprehensible phrases and sentences- namely, segmental sandhi, sound alternation-producing processes that occur at the edges of words when they are juxtaposed in more or less closely-knit sequences. Specifically, this dissertation investigates segmental sandhi in Greek, a language with a rich inventory of such sound alteration processes. It addresses these specific questions about the nature of sandhi in the language.

First, what is the exact phonetic outcome of sandhi in Greek? Does it result in categorical sound alterations or in more continuous types of sound variation? Second, what is its probability of occurrence in different contexts? Third, what is its relationship to prosodic structures that are marked by different intonational patterns? In order to answer these questions, careful examination of the exact phonetic outcome and the probability of occurrence between certain types of words and phrases is necessary. This study shows that sandhi processes in Greek are not homogeneous on either of these dimensions. For example, some sandhi processes seem to apply categorically and to result in non-continuous phonetic output while others seem to be optional and result in continuous phonetic variation.

At the same time, some evidence will be presented to support the thesis that segmental processes such as the Greek sandhi could have an effect on the processing of ambiguous sentences. The establishment of this fact for Greek strengthens the claim that speakers can exert detailed co-articulatory control on the pronunciation of specific sound sequences between words for the purposes of disambiguation, and that listeners can be sensitive to very small changes in the segmental shape of such lexical items, in addition to more noticeable prosodic changes, when there is a strong “ecological” demand, such as a noisy room or a public address, for correctly parsing ambiguous sentences.

These results address a larger issue that has been a problem for all theories of phonological structure since the days of the structuralists– namely, how to capture the systematicities observed in the variable output of certain sound modifications at the edges of words and phrases. The linguistic problem of ‘free’ allophonic variation, not easily captured by non-variable phonological rules, can be solved first by looking at sociolinguistic and pragmatic constraints on spoken language (such as dialect and style), and secondly by carefully describing and understanding the precise way speakers of specific languages may organize structural constituents in discourse, especially under pressure to disambiguate. This dissertation focuses on the latter, that is, on describing the contextual phonetic variability in Greek and on understanding and explaining the control principles which are relevant to this problem.

The rest of this chapter will discuss in more detail how segmental sandhi is traditionally described in the linguistic literature and then offer some specific examples of segmental sandhi in Greek and how it fits in the prosodic structure of Modern Greek as it has been described by various researchers so far. The last two sections offer a summary of this chapter and an outline of the entire dissertation.

## 1.1 Defining Segmental Sandhi.

Languages with very similar sound inventories can nevertheless show great variation in how their contrastive sounds are distributed and modified across the thousands of different words used in everyday speech by their speakers.

Traditional linguistic research has described these contrastive sounds as distinctive *segments*, that is, discrete units of sound which speakers can string together to form syllables, words, and phrases. In addition to the inventory of distinctive segments, or phonemes, every language has specific combinatory rules that allow or disallow certain segmental sequences at specific positions in a word. Languages can also employ more or less categorical variants of these sounds. The exact phonetic realization of these modified sounds is subject to additional sets of rules involving at least prosodic and morphological constraints. For example in American English the first sound in the word *taught* is usually pronounced differently from the last sound in the same word, even though they are both spelt the same way in the writing system and are probably considered to be the same sound by literate adult native speakers<sup>1</sup>. If the same phoneme /t/ is found at the beginning of a word and in a stressed syllable it is usually aspirated and pronounced as [t<sup>h</sup>]; if it is found at the end of a word-final syllable it can be less

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<sup>1</sup> And indeed they are classified as the same abstract element by most linguists analyzing English such as Chomsky and Halle (1968).

aspirated or even unreleased, pronounced as [t̚]. If the /t/ is found at the beginning of a non-word-initial unstressed syllable such as in the word *computer* it can also be pronounced as yet a different sound- the flap [ɾ]<sup>2</sup>. Furthermore, if the word *taught* is used in a phrase in which the following word starts with an unstressed vowel, then the /t/ found at the end of a word-final syllable may also be pronounced as a flap [ɾ]:

(1) I taught a class at Ohio State.

The productive mastery of this kind of word-internal or between-word allophony for a single distinctive segment is considered a characteristic of native-like fluency in the language. The exact pronunciation of the segment /t/ which is part of the sound inventory of American English is always determined by its particular position within a syllable, which in turn is part of a particular foot, word, phrase, and utterance. The likelihood of the sound category /t/ being phonetically realized as [t<sup>h</sup>], [t̚], or [ɾ] will depend largely on the language-specific rules of American English that govern the prosodic, morphological, lexical and phrasal structure of

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<sup>2</sup> Presumably, literate English speakers can establish a connection between word-medial [ɾ] and word-final [t] in related words such as *compute* and *computer* or *heat* and *heating*. But for illiterate adults or young children that connection may not be a very salient one.

the language. Moreover, the observation that the American English /t/ may be pronounced as [r] not only within a particular word such as *computer* but also, when the right conditions are met, across two separate words such as *taught* and *a* as in (1) is an example of between-word allophony or external segmental sandhi. This type of between-word sound modification can be contrasted with the word-internal allophony of the sound /t/, as in morphologically complex words like *computer*, composed of the verb *compute* and the agentive suffix *-er*. This type of word-internal allophony is an example of internal segmental sandhi. The Sanskrit term *sandhi*, which can be translated roughly as ‘joining,’ was first used by Indian grammarians some 2500 years ago for describing junctural segmental phenomena such as assimilations and deletions between morphemes and words in Sanskrit. The term was picked up by European grammarians and was used as a cover label to describe a variety of junctural phenomena as described by Ternes (1986:11):

In 19<sup>th</sup> and 20<sup>th</sup> century linguistics, including present day usage, ‘sandhi’ has become a cover-term for a veritable host of the most divergent phenomena, among them assimilations or dissimilations of all kinds, allomorphic or morphophonemic alternations, atonic forms and proclitics of various sorts, elision (as in French *l’homme*), synaloepha (as in Spanish *la amiga*), French liaison, French enchaînement, Celtic mutations, Italian raddoppiamento sintattico, Tuscan gorgia, English short forms (as in *we’re*), Notker’s Anlautgesetze in Old High German, and many others. Most of these phenomena have, at some stage of the history of their linguistic processing, vaguely been attributed to an endeavor of achieving ‘ease of articulation’ [...] or even, horrible dictu, ‘euphony’ [...] (with reference to French *t* in *va-t-il*).

The term has been used as a convenient loosely defined umbrella label for what Andersen (1986) refers to as *liminal*<sup>3</sup> phenomena of variation at the edges of various constituents. It has also been used to describe tonal alternations that are conditioned by position relative to word and phrase boundaries in languages like Shanghai Chinese. Bloomfield (1935), cited in Ternes (1986:11), defined sandhi as “[f]eatures of modulation and of phonetic modification [...] in many syntagmatic constructions.” In addition to internal vs. external sandhi a distinction between lexical vs. post-lexical processes also exists in the linguistic literature, especially in more recent generative theories that employ cyclical application of rules and in word-internal and word-external domains. The underlying observation captured by the term external sandhi, though, is that when allophones which normally mark word-internal positions occur at word or phrase edges, this could be interpreted as an indication of a higher-than-normal degree of cohesion between two adjacent words or phrases. Alternatively, the absence of sandhi, when one would expect it, could be indicative of weak or interrupted cohesion between constituents due to the presence of additional conditions for its application.

Consider for example the following sentence:

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<sup>3</sup> Perhaps because these sound modifications at the boundaries (limens) between words are some times just barely noticeable by native speakers of a language.

(2) While I taught a student left the classroom.

Here the final /t/ of the word *taught* is less likely to be pronounced as a flap [ɾ], even though some, but not all, of the conditions for the American English sandhi process of flapping are met. The /t/ is the last segment in a word-final syllable and the following word begins with an unstressed vowel. But unlike the *taught* and *a* in (1) where they were part of the same verb phrase and also, most likely, the same prosodic phrase, in (2) above the word *taught* belongs to a different clause than the word *a* and there is a very good chance that in many productions of (2) by native speakers there may be a prosodic break between the two syntactic phrases *while I taught* and *a student left the classroom*. The importance of the prosodic structure in correctly predicting that the phoneme /t/ will be phonetically realized as [t̬] or [ɾ] is thus evident.

A different kind of phonological conditioning comes from the effect of local context, that is, of the types of adjacent segments found at the end of one word and the beginning of another, on segmental sandhi seems to be as important as the effect of prosodic organization into syllables, words and phrases. Smith (1997:497), for example, discusses how the devoicing of final /z/, in words like *falls* and *pause* in American English can be influenced by segmental context:

[A] speaker may devoice /z/ in almost any environment, but the likelihood of devoicing varies greatly and depends on the preceding and following segmental context, as well as the position of the /z/ in the prosodic structure of the utterance.

She also points out that, in addition to the influence of local segmental context, more global organizational influences of prosodic structure can also affect the realization of this segmental sandhi process (493):

With regard to the effect of position within the utterance, the results indicate a substantially greater likelihood of devoicing for /z/ in final position in the sentence than anywhere in the middle of the sentence.

Furthermore, processes such as /z/ devoicing and /t/ flapping in American English need not result in completely deterministic types of allophonic variation, but also in probabilistically defined types of variation. A process such as /t/ flapping in English could vary in its probability of application in different contexts and at the same time, when it is applied, it could vary as to the actual phonetic outcome that sometimes might not match exactly the notion of *flapping* per se. Bod et al. (2003) argue that most research in phonology in the past century has concentrated on the endpoints of these types of probabilistic allophonic variation processes under the premise that language is categorical and that non-categorical continua are only artifacts of non-linguistic performance factors. However, more recent carefully controlled observations and descriptions of a variety of

phonological processes in many languages, and especially of connected-speech phenomena, have undermined such a foundational theoretical premise.

Working with a language such as Greek with a good many external sandhi rules, Arvaniti and Pelekanou (2001) and Baltazani (2002) have experimentally shown that segmental sandhi can be better understood as a probabilistic process that depends on a variety of local and prosodic factors. They argue that many “phonological rules” in Greek need to be re-examined and better described and characterized in light of such experimental results gathered from spontaneous and laboratory speech. That is, contra earlier descriptions by many Greek and non-Greek linguists, (Chatzidakis 1905, Condoravdi, 1990, Malikouti-Drachman and Drachman 1992, Nespors and Vogel 1986, Kaisse 1985), Greek sandhi phenomena cannot easily be reduced into a series of categorical phonological rules with uniform outputs.

## 1.2 The function(s) of sandhi

There is strong evidence collected in many studies such as Lehiste (1972), Scott and Cutler (1984), Holst and Nolan (1995), Bybee (2000), and Pierrehumbert (2001), that the likelihood of occurrence of a given process can be greatly modulated when other considerations come into play, such as the speaker’s efforts to disambiguate an ambiguous phrase and the frequency of the relevant

constituents participating in a given process. External segmental sandhi has been traditionally viewed as having a “delimitative” or “junctural” function at the word level and less frequently at the phrase level. It is possible though that the variable interpretation by listeners of intonational and syntactic constituents when there are possible ambiguities in the speech signal can be influenced by either the presence, or not, of segmental sandhi, as well as by the type of segmental output of these sandhi processes (category shifts or continua of variation).

Such a functional view of sandhi is hypothesized in this study and it is demonstrated experimentally that it is a viable interpretation of the underlying control mechanisms for some sandhi phenomena (see chapters 2 and 3). This means that certain segmental sandhi can be understood as cues towards the “correct” parsing of an utterance when more than one analysis is possible in the cognitive system of the listener, helping him or her to choose the parsing that corresponds more closely with the speaker’s intended meaning, as in the temporary ambiguity from English in the example in (2) above (the presence of the NP *a student* either within the VP preceding it or its attachment to the VP following it). The exact description and accurate prediction of the occurrence of segmental sandhi is then of great importance in understanding how the listener parses the prosodic and syntactic structure of a particular sentence, given the intentional and constrained variability generated by the speaker. Thus, a likely place to examine the interaction between intonation (melody) and segmental

allophony on the one hand, and intonational phrasing (“prosody” proper) and syntactic structure on the other, especially with regard to a functional construal of segmental sandhi, is within the frame of structural and scope ambiguities.

### 1.3 Sandhi processes in Greek

Descriptions of sandhi phenomena, especially those that involve vowel-vowel sequences, have had a long history in the linguistic literature of Greek, starting with Hadzidakis’s (1905) and Triantafyllides’s (1941) original analyses. These early descriptive accounts were based on mostly impressionistic and introspective observations, something that resulted in many disagreements between various proposals about the domains of application of the rules and their probability of occurrence, as well as the nature of their outputs (whether they are continuously variable or categorical alternations). Segmental sandhi processes in Greek have thus historically been understood more as categorical modifications of phonological segments and their features. However, recent studies in languages like English and Korean have shown that many sandhi processes such as /s/ palatalization or /z/ de-voicing can have gradient output often interpreted as the result of gestural modifications and overlaps (Zsiga 1995, Jun 1995, Smith 1997). Not until recently have researchers of Greek started to investigate the exact

phonetic nature of these processes as well as the various factors that might influence their realizations (Fallon 1994, Pelakanou & Arvaniti 2001, Baltazani to appear). The results of these phonetic studies as well as the earlier descriptive and phonological analyses have identified at least the sandhi processes listed in table 1.

	<b>Vocalic Processes</b>	<b>Examples</b>
<b>a</b>	Degemination of identical consecutive vowels	/ta atoma/ ‘the individuals’ → [tatoma]
<b>b</b>	Deletion of first vowel in a sequence of non-identical vowels	/to atomo/ ‘the individual’ → [tato]
<b>c</b>	Devoicing or deletion of unstressed high vowels	/su kostise/ ‘to-you (it) cost’ → [s(ʉ) kostise]
<b>d</b>	Diphthongization of non-identical vowels	/o. i.pnos/ ‘the sleep’ → [o̞i.pnos].
	<b>Consonantal Processes</b>	
<b>e</b>	Stop voicing after a word-final nasal (the nasal is usually deleted; if not, it assimilates to the place of articulation of the following stop)	/tin porta/ ‘the door’ → [ti(m) borta].
<b>f</b>	/n/-deletion before sonorants and fricatives	/tin lira/ ‘the lyre’ → [ti lira]
<b>g</b>	/s/ voicing before sonorants	/laos mu/ ‘people my’ → [laoz mu].
<b>h</b>	/n/-resyllabification before a word-initial vowel [In accented syllables /n/ resyllabification is evident from tonal alignment (Arvaniti & Baltazani, 2002)]	/o.tan. e.fta.se/ ‘when arrived’ → [o.ta.ne.fta.se]
<b>i</b>	Degemination of identical consecutive consonants	/laos su/ ‘people your’ → [lao su]

Table 1.1. Segmental sandhi processes in Greek.

Most of the early research on Greek sandhi viewed these processes as categorical, while being largely agnostic as to the exact nature of the effects of speech rate or various discourse functions such as focus and topicalization on their phonetic realization. Alternatively, Kaisse (1985) described many of the sandhi processes in table 1 as either Fast Speech Rules, which can apply every time speech rate goes up regardless of prosodic or junctural considerations, or as processes strictly predictable by syntactic constituency. Nespor and Vogel (1986), on the other hand, used some of these sandhi processes in Greek to motivate several prosodic constituents in a non-isomorphic relationship to syntactic structure. For example the rule of /s/ voicing is claimed to apply only within Intonational Phrases but not between them. (See section 1.4 below for their prosodic model). Along the same lines, Condoravdi (1990) proposes the Minimal Phrase as the domain of application for /n/ deletion, and several other vowel deletion sandhi, for which the question of whether their application is probabilistic in nature or not, or if the output of these processes is categorical or gradient, is also never raised.

Conversely, Fallon (1994) collected data from a spoken corpus which clearly showed that several vowel degeminations are continuous and that they can be applied probabilistically between almost any type of lexical, prosodic and syntactic groupings, blocked categorically only by silent pauses. Tserdanelis

(2003) showed that many speakers would produce ‘filled’ pauses between a word with a final /s/ and a word with an initial /s/ as perhaps the result of phrase final lengthening too. Arvaniti & Baltazani (2002) continued the experimental investigation of sandhi phenomena from recorded spoken utterances, by varying the intonational as well as the syntactic structure of sentences. Their acoustic analyses and transcriptions of sandhi rules agree with Fallon’s findings. They illustrate a continuum of application that ranges from obligatory and categorical within prosodic words to increasingly optional and varying in probability of application within intermediate phrases and intonational phrases. This distribution of probabilities defies a deterministic rule framework in the sense that sandhi processes are continuously more or less likely to occur as a function of a complex of grouping forces from the lexicon, prosody and syntax. At the same time, when vowel degemination sandhi does apply it does not reflect a categorical opposition between sequences of two vowels and a singleton vowel but a continuum of more or less reduced durations. Arvaniti and Baltazani (2002) speculated as to the role of various tonal events coupled with morphosyntactic constraints in modulating these probabilities.

Baltazani (to appear), based on a series of carefully designed production studies, presents a comprehensive analysis of the continuous output of vowel deletion and degemination sandhi in Greek. By manipulating focus and prosodic phrasing she concludes that these types of continuous acoustic assimilations are

the result of overlapping articulatory gestures phrase-medially. In other words, there is no time for articulators to reach the target positions of both vowels in a vowel-vowel sequence between prosodic words and intermediate phrases, unless one of the words is in focus, in which case there is an increase in gestural and subsequent acoustic durations (see also Fourakis et al. 1999). In the examples listed in (3), Baltazani created phrases with the vowel sequence /o#u/, a possible sandhi site of vowel deletion, which, according to traditional accounts of the so-called vowel dominance hierarchy in Greek, should have as its output [o] categorically since for Greek: o>a>u>i>e<sup>4</sup> (Chatzidakis, 1905).

- (3) a. Tha su etimaso nostimo]<sub>WD</sub> uzaki me meze  
 ‘I’ll prepare tasty ouzo with tidbits’
- b. An exi meze nostimo]<sub>IP</sub> uzaki pinun oli.  
 ‘if the tidbits are tasty, ouzo everybody will drink’
- c. Tha su etimaso ena nostimo [uzaki]<sub>F</sub> oxi bira  
 ‘I’ll prepare for you tasty OUZO, not beer’
- d. Tha su etimaso ena [nostimo]<sub>F</sub> uzaki  
 ‘I’ll prepare for you TASTY ouzo

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<sup>4</sup> This means that /o/ should never delete when followed or preceded by /a,u,i,e/, /a/ should only delete when followed by /o/, etc.

She found no evidence for such a vowel hierarchy<sup>5</sup>. Instead, most speakers in her experiment produced outputs of /o#u/ sandhi that were reduced centralized vowels being neither canonical /o/ nor /u/. What she also found was that the stronger the prosodic break, the longer the vowels, and the less likely for sandhi to be categorical (i.e. deletion of one or the other vowel). Thus in sentence (a) in which a prosodic word (pW) boundary exists between the two vowels, sandhi was a lot more probable than in (b) where a stronger prosodic boundary, an intermediate phrase (ip), is present. Vowel sandhi is even less likely to apply when one or the other vowel is part of a focused lexical item as in (c-d). She also tested various combinations of the five Greek vowels and she found that with acoustically similar vowels such as between the mid vowels /o#e/ sandhi is more likely to apply in the form of vowel coalescence, where the output is a reduced and centralized vowel, or to have one of the vowels deleted, rather than between less similar vowels e.g. /i#a/. Comparable results were obtained by Pelakanou & Arvaniti (2001) in their analysis of a corpus of news broadcasting, interviews and spontaneous speech. More specifically they found evidence for types of sandhi with non-continuous phonetic output (e.g. identical consonant degemination) and for sandhi with continuous phonetic output (e.g. /s/-voicing, vowel degemination and deletion) across various phrasings.

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<sup>5</sup> It needs to be noted that Chatzidakis was describing Greek from about 100 years earlier; one has to allow for both Chatzidakis being right and Baltazani being right if Greek has changed in that respect since the beginning of the 20th century.

These studies show very clearly the complex factors behind some of the sandhi processes attested in Greek. The sandhi rules appear to be optional in many cases, while continuous output is very common despite early phonological accounts of categorical non-continuous sound modifications. Furthermore, the data and analyses presented above have shown unequivocally that the exact nature and scope of the various sandhi rules requires further investigation, using both laboratory data and acoustically examined spontaneous speech.

#### 1.4 The prosodic structure of Greek.

Different accounts invoke prosodic structure in different ways. Some of these differences involve disagreements about what the prosodic structures are and how they interact with segmental information. In this section a brief sketch of the various prosodic structures proposed for Greek will be presented in order to show how segmental sandhi is realized within the prosodic hierarchy of Greek.

Various models have been proposed since the 1980s for the prosodic structure of Greek, and they all acknowledge the following facts: Modern Greek, unlike Classical Greek which was most likely a pitch accent language (Allen, 1987), is a dynamic stress language employing only stressed/unstressed contrasts at the lexical level. In Greek stress is realized as a slight increase in amplitude and

pitch as well as duration of the nucleus of the stressed syllable (Arvaniti, 1992, 2000). Lexical stress in Greek is also not fixed. There are no distinctions of phonological weight among the Greek vowels (Thumb 1895, Fourakis et al. 1998) and stress cannot be predicted by the word's metrical structure except only on a very limited basis from morphological factors (Joseph and Philippaki-Warbuton 1987). It is therefore very common for segmentally identical words to be distinguished only by stress placement even within the same grammatical category: For example: /<sup>l</sup>no.mos/<sup>6</sup> 'law' vs. /no.'mos/ 'county' [Nouns], /<sup>l</sup>per.no/ 'take' vs. /per.'no/ 'pass' [Verbs] and /<sup>l</sup>po.te/ 'when' vs. /po.'te/ 'never' [Adverbs] (Botinis, 1989). Lexical stress in Greek can appear on only one of the last three syllables of a word, the so-called Stress Well Formedness Condition<sup>7</sup> (SWFC), and no further to the left: /a.ka.'no.ni.stos/ 'irregular', /a.ka.'ma.tis/ 'lazy', /ka.θo.li.'kos/ 'catholic' (among others, Mirambel 1949, Botinis 1989, Arvaniti 1992). Furthermore, stress must shift one (sometimes two) syllable generally to the right when the SWFC is violated by the addition of a suffix: /<sup>l</sup>ma.θi.ma/ 'lesson' Nom. SG. vs. /ma.'θi.ma.ta/ 'lessons' Nom. PL, /ki.'ta.zo/ 'I look at', /ki.ta.'zo.mu.na/ 'I was looking at myself' (among others, Mirambel 1949, Botinis

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<sup>6</sup> Stress is marked with a [<sup>l</sup>] before the stressed syllable in the phonological transcriptions. Syllable breaks are marked with a period and word breaks with #.

<sup>7</sup> Also known as the "rule of limitation" or the "trisyllabic window" for stress.

1989). Finally, when a clitic is attached to the right of a word that is stressed on the antepenultimate syllable, the SWFC also would be violated if the combination defines a phonological word- hence the need to call the material on the right something else other than a regular word (Joseph, 2002)- but the lexical stress does not shift as in /ma.'θi.ma.ta/ (hence the hesitation of calling the material on the right a suffix). In this case, an additional (non- lexical) stress is added to the final syllable of the word: /'ma.θi.ma/ 'lesson' vs. /'ma.θi.'ma # mu/ 'lesson-my' and not \*/ma.'θi.ma # mu/ a fact discussed by, among others, Nespor and Vogel 1986, Botinis 1989, and Arvaniti 1992.

Having as a starting point the more or less agreed upon facts about the prosodic structure of Greek discussed so far, the more theoretical analysis of the prosodic structure of the language reflects the advancements of phonological theory over time. Earlier accounts that discussed the prosody of Greek were largely descriptive and impressionistic in nature. They focused on explaining the relationship between traditional phonological notions such as segments, syllables, feet, on the one hand, and stress, rhythm, and intonation on the other. As far back as the late 1800s Greek and non-Greek linguists gave detailed, albeit largely impressionistic, accounts of the general patterning of prosody in Greek, including syllable structure, durational characteristics of consonants and vowels, stress, and phrasal intonation (Thumb 1895, Chatzidakis 1905, Mirambel 1949, Newton 1972, Setatos 1974). In these classic accounts of Greek phonology we find the

basic prosodic characteristics of Modern Greek presented in the light of the then-current theoretical approaches to phonology, especially in the generative grammar framework of Chomsky and Halle (1968) reflected in Newton and Setatos. These accounts take the segment (usually understood as a bundle of features) to be the basic phonological unit, largely ignoring other not so easily identifiable (in the alphabetical tradition) elements of phonology such as the syllable, the foot, stress, accent, tone and other metrical or rhythmic characteristics spanning more than one alphabetic segment, orthographic word or even phrase. With the advent of non-linear phonological theories such as the Autosegmental and Metrical Theory of Goldsmith (1979, 1990) and Liberman and Prince (1977) the focus of research on Greek shifted from trying to account for prosodic phenomena strictly at the segmental or featural level to developing models of hierarchically organized prosodic constituent structures (Malikouti-Drachman and Drachman 1981, Nespor and Vogel 1986, Condoravdi 1990, Arvaniti 1992, Arvaniti and Baltazani 2002). At the same time the acoustic characteristics of Greek prosody were also being investigated in a more empirical way in the past 20 years with many studies such as (Dauer 1980, Fourakis 1986, Botinis 1989, Arvaniti 1992, 1994, Fallon 1993, Botinis et al 1999, Baltazani and Jun 1999, Baltazani 2002).

We can now examine in more detail some of the most influential proposed models for the prosodic constituency of Greek that have used the facts discussed above as their basis. While ignoring larger theoretical issues such as the nature and

phonetic manifestation of stress and rhythm in phonology in general, Nespov and Vogel (1986), based on some earlier work by Selkirk (1979,1980), proposed the following prosodic constituents hierarchically organized from bottom (syllable) to top (Phonological Utterance):

Syllable	( $\sigma$ )
Foot	( $\Sigma$ )
Phonological word	( $\omega$ )
Clitic group	( $C$ )
Phonological phrase	( $\Phi$ )
Intonational phrase	( $I$ )
Phonological Utterance	( $U$ )

Table 1.2. Prosodic constituents in Greek proposed by Nespov and Vogel (1986).

This strict layering of prosodic constituents was proposed as a universal hierarchy that is available to be utilized by any language. At the same time this hierarchical layering is parsed exhaustively with respect to each prosodic category as shown in the sample utterance from Greek in figure 1.1.

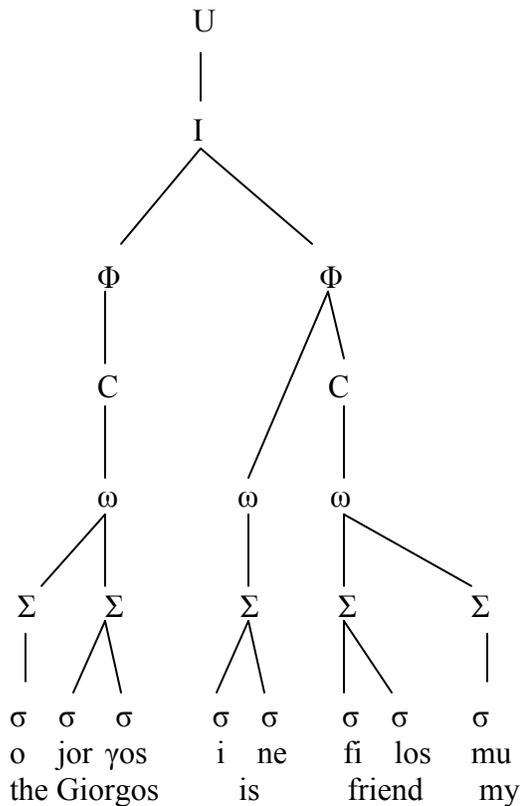


Figure 1.1 The Nespov and Vogel (1986) prosodic hierarchy model.

In Nespov and Vogel's model, prosodic trees are constructed by generative phonological rules that refer to morphological and syntactic constituents. They motivate each prosodic constituent by reference to domains of applicability of different processes that involve the modification of the sound pattern of a language (whether segmental or prominence related) without a strict isomorphic relation to morphosyntactic constituents but still largely based on them. Their model, like many other generative accounts, is thus very contingent on syntactic structure.

More specifically with regard to the prosodic structure of Modern Greek, they use evidence drawn from various segmental sandhi processes and stress assignment in order to motivate the distinction between phonological word and clitic group, on the one hand, and between the intonational phrase and the phonological utterance, on the other. To motivate the Clitic Group (C) as a separate prosodic constituent they use the facts about Greek given above- especially the stress insertion rule which describes the addition of stress when a clitic is attached to a phonological word. They posit that the differential behavior of stress placement with regard to suffixation vs. cliticization is strong evidence for the need to posit an intermediate constituent between the phonological word and the phonological phrase. That is, in Greek, within a phonological word we have stress shift when the trisyllabic window is violated due to suffixation or compounding,<sup>8</sup> whereas within a clitic group we have stress insertion, and within a phonological phrase nothing happens to stress assignment. In addition, they argue that segmental sandhi phenomena such as post-nasal voicing assimilation (Newton 1972, Arvaniti and Joseph 2000) cannot be explained with reference only to morpho-syntactic boundaries<sup>9</sup>, but that an intermediate constituent, the Phonological Phrase ( $\Phi$ ), is necessary between the clitic group and the Intonational Phrase (I), (pg. 35-36):

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<sup>8</sup> Actually the facts about compounding are more complicated than that. See below in the discussion of Arvaniti (1991, 1997) for more details.

<sup>9</sup> However, contra later models such as Jun (1993), they still build phonological phrase boundaries from the syntactic structure, rather than positing alignment constraints between independently motivated constituents and syntactic (and discourse) constituents.

- a. /sin+'pleko/ 'with+knit' → /si(m)'bleko/ 'engage (ω)
- b. /ton/ # /pa'tera/ 'theACC. father' → /to(m)/ # /ba'tera/ (C)
- c. /'ðen/ # /pi'razi/ 'not matters' → /'ðe(m)/ # /bi'razi/ (Φ)
- d. /'exun/ # /'pleksi/ '(they) have knitted' → /'exun/ # /'pleksi/ (I)
- but not → \*/'exu(m)/ # /'bleksi/

They use the data above to argue that the domain of post-nasal voicing in Greek includes constituents all the way up to the Phonological Phrase (Φ), shown in (c) which should be differentiated from a hierarchically higher constituent, the Intonational Phrase (I), shown in (d). This means that between two intonational (I) phrases post-nasal voicing is not possible. In (a) the morphologically complex word with the prefix /sin/ and the verb /pleko/ surfaces as [sim'bleko] forming thus one phonological word. The rule also applies within a clitic group (b) and a phonological phrase (c) but not across two phonological phrases in (d) despite the fact that syntactically (d) and (c) are the same kind of phrase (VP). Using similar data from other languages they claim that there is a general nonisomorphism between the maximal domains in the syntactic and prosodic hierarchies. Thus, their approach is unlike some earlier approaches to Greek prosody such as Kaisse (1985). They do not offer any motivation or independent evidence from segmental sandhi or stress patterns for positing the foot (Σ) or the phonological utterance (U)

for Greek, however; nor do they discuss the syllabic structure of Greek in much detail.

Condoravdi (1990) also uses evidence from postlexical rules (i.e. external sandhi without reference to morpho-syntactic relations) to motivate an extra prosodic constituent in Greek, which she calls the Minimal Phrase ( $z$ ). Condoravdi maintains the strict layering approach to prosodic structure of Nespor and Vogel, as well as the exhaustiveness of parsing (i.e. a string is exhaustively parsed with respect to each prosodic category). Thus a Minimal Phrase ( $z$ ) in Greek, according to her analysis, is defined and distinguished from the Phonological Phrase ( $\Phi$ ) as follows (p. 79):

(5) Minimal Phrase:

- a. From left to right map all material up to and including the lexical head of a maximal projection<sup>10</sup> into a minimal phrase  $z$ .
- b. Map all unassociated material within the same maximal projection into a  $z$ .

Phonological Phrase:

From left to right map all material up to the right end of a maximal projection into a phonological phrase  $\Phi$ .

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<sup>10</sup> This is of course a syntactic notion again, similar to the ones used in the Nespor and Vogel model.



Botinis (1989) and Arvaniti (1991), two detailed phonetic studies, provide the first detailed experimental accounts (from both production and perception experiments) for some of the prosodic constituents proposed by Nespors and Vogel and Condoravdi for Greek. They both focus on stress and its phonetic manifestation, especially with regard to lexical and postlexical processes such as affixation, compounding, and cliticization. Botinis (1989) focuses on the relation between stress and prosodic constituency, relying mostly on measurements of f<sub>0</sub>, duration and amplitude at various points in elicited utterances. He posits the following prosodic categories for Greek (p. 26): First, lexical stress is the prosodic representation of a word (sic) at the lexical level<sup>13</sup>. This corresponds roughly to Nespors and Vogel's (ω). Second, word stress is the prosodic representation (or marker) of a word at the morphological level (excluding clitics). Third, phrase stress is the prosodic representation (or marker) of a phrase at the syntactic level (includes clitics) and sentence stress is the prosodic representation (or marker) of a sentence at the semantic-contextual level. His constituents with relation to stress (especially the contrast between word and phrase stress) and the phonetic data collected from his laboratory experiments are disputed by Arvaniti's analysis and experimental data, however. Arvaniti (1992) found no phonetic evidence for phrasal stress, as a phonetically distinct level of "prominence" in a series of

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<sup>13</sup> Probably Botinis means that stress functions as a prosodic marker for constituency at various prosodic levels; which means that F<sub>0</sub>, duration and amplitude are all direct phonetic correlates of stress as a segmental, distinctive, scalar feature.

production and perception experiments; that is, subjects failed to differentiate between lexical (word) stress and phrasal (enclitic) stress. She also found no evidence for the mora (proposed as a prosodic constituent for other languages) or the foot as defined for Greek by Nespov and Vogel (but see Arvaniti, 1997 for a different view on feet in Greek). She also reports that there does not seem to be evidence for word final lengthening in Greek either.

Baltazani and Jun (1999) examined the intonational structure of Greek. They tested experimentally the effect of focus and topicalization on the prosodic structure of declarative sentences. They argue that the difference between topic and focus in Greek is marked in syntax as well as in prosody. They discuss the phenomenon of clitic doubling with topicalized objects, as well as the tonal events that accompany focused objects within the autosegmental-metrical approach to intonational phonology (Ladd, 1986). Their main finding was that focus causes the deletion of a boundary tone after the focused word and the de-accenting of all following words, and that focus is usually phonetically marked by a lengthening of the entire syllable to which the pitch accent is anchored. This finding is incompatible with Condoravdi's claims discussed above regarding focused elements being set off as their own independent phonological phrases.

Arvaniti and Baltazani (2002) used their prosodic analysis of Greek to design an annotation system (GRToBI) based on other similar systems designed for English, Japanese and other languages (Silverman et al., 1992). The basic

prosodic structure for Greek adopted in this model is given below with the mora and the foot in parentheses since they claim that they do not seem to participate in any phonological processes in Greek.

I	intonational phrase
ip	intermediate (phonological) phrase
PrW	Prosodic Word
(F	Foot)
σ	syllable
(μ	mora)
/x/	segmental string

Table 1.3. Prosodic Structure of Greek used in GRTToBI.

However, Arvaniti (1997) claims to have found evidence for foot structure in blending neologisms (used as jokes) in Greek (cf. Engl. smoke+fog → smog : Gr. /'varka/ 'boat' + /ar'kuða/ 'bear' → /var'kuða/ 'boat-bear') further claiming that all syllables in Greek are redundantly monomoraic, with extrametrical syllables dominated directly by the Prosodic Word and not by Feet. They also capture in their annotation system the types of tonal and segmental events that can play a role in the organization of Greek prosodic structures such as pitch accents, phrase accents, boundary tones and segmental sandhi. They stress the importance of segmental sandhi in the prosodic organization of Greek based on evidence collected from utterances with segmental sandhi at various junctures and under

various tonal events. Many of their findings contradict earlier claims about the prosodic domains of applications of several of these rules. For example n-deletion was found to apply even between phonological phrases (contra Nespor and Vogel) or minimal phrases (contra Condoravdi) in their data.

From the discussion of the various models above it is evident that the application or not of the various sandhi rules in Greek is clearly affected by the prosodic groupings as realized in various utterances. However, in somewhat circular reasoning, most of the researchers mentioned above have used segmental sandhi to motivate many of the prosodic categories proposed that are posited in their prosodic models in order to explain the segmental sandhi in Greek. The question about the role of intonationally marked prosodic structure on segmental sandhi is still largely unanswered, even though Arvaniti and Baltazani (2002) have started investigating the interaction of tonal events with the traditionally proposed prosodic categories and their purported segmental correlates. Additional phonetically oriented studies (Fallon 1994, Botinis et al. 1995, 1999, Pelekanou and Arvaniti 2001, Baltazani, to appear) have examined other difficult aspects of the problem of interaction between prosodic structure and segmental sandhi, focusing especially on vowels and hiatus resolution with regard to prosodic structure. For example, Botinis and his colleagues have collected evidence of vowel lengthening under focus, complementing the results of Arvaniti (1991) for (limited and non-distinctive) vowel lengthening under stress. These results are

important in order to further establish the appropriate relationship between prosodic structure on one hand, and external segmental sandhi on the other.

## 1.5 Summary

This chapter introduced the problem of understanding the nature of segmental phonetic variability at the edges of words, especially under conditions of possible competing prosodic organizations of speech. The history and use of the term sandhi was examined (section 1.1) and some particular sandhi phenomena from a language with a rich inventory of sandhi, Greek, were described in more detail<sup>14</sup> (section 1.3). In order to understand better the exact nature and possible functional role of sandhi processes within a particular language, the prosodic structure of the language needs also to be accurately described and understood. This is because (i) there is a lot of work showing that prosodic structure can play a role in parsing syntactic structure and (ii) many researchers have suggested that segmental sandhi domains are prosodic constituents. Thus, various models of the prosodic structure of Greek were also presented and discussed and examples from previous studies were shown (section 1.4). In this chapter it was also proposed that a likely

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<sup>14</sup> See chapter 2 for additional information on a subset of these sandhi processes used in designing the experimental materials for the experiments described there and in chapter 3.

place to examine the interaction of prosody and segmental alternations, especially with regard to a functional interpretation of segmental sandhi, is within syntactically ambiguous sentences (section 1.2).

## 1.6 Outline of the dissertation.

This dissertation reports the results of three distinct studies. First, a production experiment and a perception experiment were designed in order to establish the phonetic facts pertaining to the production of segmental sandhi in syntactically ambiguous sentences in Greek. Second, a subset of the productions from the first study were used in a perception experiment to explore the interaction between segmental sandhi and the intonational marking of prosodic constituents in the parsing of these ambiguous sentences. Third, a recorded database of child-directed and adult-directed spontaneous speech was used in order to calculate the frequency of occurrence of segmental sandhi in unscripted spontaneous speech directed towards children vs. that directed towards adults. In chapter 2 the results of the production experiment are reported and the acoustic properties of a subset of sandhi phenomena in Greek are discussed. In chapter 3 the results of the perception experiment are reported and the effect of segmental sandhi in the disambiguation of ambiguous sentences in Greek is discussed. In chapter 4,

frequency results extracted from a recorded database of spontaneous child-directed and adult-directed speech are reported by way of giving a comparison between the sandhi frequencies in child-directed vs. adult-directed speech in Greek. These results are discussed in terms of their implications for accounts of the role of frequency in the acquisition of sandhi by children. If adults indeed use sandhi as a cue, then they must have learned to do this. Presumably this learning process must start early, so a comparison of what children are exposed to and what adults are exposed to can help us understand the learning mechanism for incorporating phonological processes such as segmental sandhi in one's native language system. Chapter 5 provides a summary and conclusion of the thesis.

## CHAPTER 2

### FIRST PRODUCTION EXPERIMENT

#### 2.1 Background

In order to investigate the interaction between segmental sandhi and prosodic structure it is necessary to find sites in possible sentences where the application or not of a sandhi process could interact with the presence or not of some type of a prosodic boundary. The construction of such sentences would offer the possibility to test at least two effects: First, whether or not sandhi will take place given a particular segmental sequence and a particular prosodic context and second, if sandhi does happen, whether the output sound sequence of the segments participating in the process would show continuous variation or discontinuous, phoneme-level substitutions.

In order to understand how a given segmental sandhi process fits in the phonological system of a particular language, it is necessary to have adequate knowledge of the allowable sound sequences, the phonotactic rules, of the

language in question. For example, in American English, no words under normal conditions can begin with a flap [ɾ] or a [ðɹ] cluster since the flap and the sequence /ðr/ are not permissible word-initial sounds that language. If a sandhi process turns a word-final /t/ or /d/ into a flap [ɾ] then one can safely assume that segmental sandhi has occurred between the two words in American English. In a language like Greek, where there are severe phonotactic restrictions on word-final obstruents, it is even more imperative to know what the sound sequences permitted by the phonotactics of the language are in order to better understand how segmental sandhi fits in the overall phonological system of the language. This is because segmental sandhi conditions are constrained by lexical choice in a way that tonal markers or prosodic structure are not. For example, the large majority of words in Greek ends either in a vowel or in /s/ and /n/. Although there are loanwords and onomatopoeic words that end in almost any other consonant, their token and especially type frequencies are extremely low. In the 1,000 most frequent lemmas (types) in Greek extracted from the (ILSP-HNC) Hellenic National Corpus™ (Hatzigeorgiu et al. 2000) there are no words that end in a consonant other than /s/ and /n/. In the 1,000 most frequent lexemes (types) there are only three, the prepositions *ἐκ* /ek/ ‘whence’ and *ὕπέρ* /iper/ ‘pro’ and the noun *γκολ* /gol/ ‘goal’. These observations about allowable word-final consonants in Greek are important in understanding why many of the segmental sandhi processes in Greek seem to involve either vowel-vowel sequences or consonant-

consonant sequences where the first consonant is /n/ or /s/. The relative type and token frequencies of word-final vowels vs. word-final /n,s/, as well as the same types of frequencies for words that begin with a vowel vs. those that begin with a consonant would constitute another set of relevant factors.

Given, thus, the fact that if a Greek word ends in a consonant the probability of its being a /n/ or a /s/ is very high, looking for segmental sandhi that involves the participation of /s/ or /n/ would be a good starting point in order to find plausible contexts for the interaction of segmental sandhi with prosodic boundaries. The interaction of segmental information with a prosodic boundary is crucial in the hypothesis laid out in chapter one of this thesis about the functional exploitation of segmental sandhi by speakers and listeners of a language. If speakers on the other hand were not sensitive to prosodic boundaries in applying segmental sandhi, sentences with structural surface ambiguities would be ideal in order to test these two competing hypotheses because it has been shown from various experiments in a number of languages (Schafer et al. 2000 *inter alia*) that a successful strategy of structural or scope disambiguation is the manipulation of prosodic constituents. Such manipulation could interact with the phonetic realization of several segments especially in the temporal and quality domains of segmental information. Consider the following English sentence taken from Lehiste (1973):

(1) He rolled over the carpet.

The preposition *over* could be part of the compound verb *roll over* or part of a prepositional phrase containing the noun phrase *the carpet*. This kind of structural ambiguity can be schematized below:

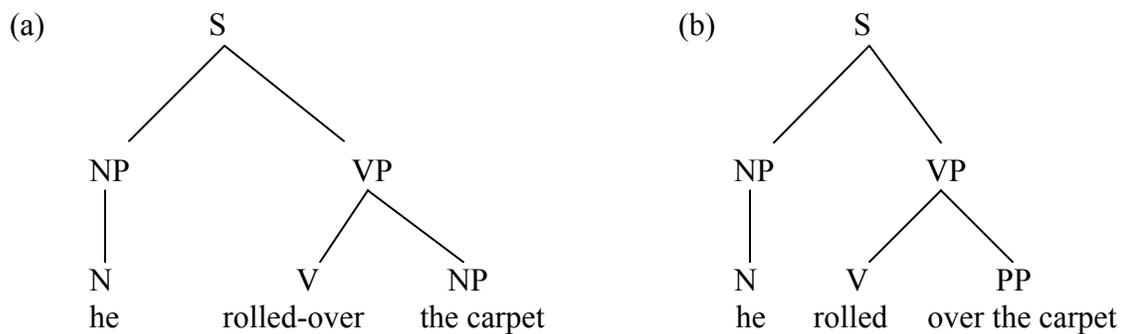


Figure 2.1 Structural ambiguity

A possible question that could elicit the structure shown in Figure 2.1 (a) would be “What did he roll over?” and one that would elicit (b) would be “Where did he roll over?” The ambiguity here rests on the attachment of the preposition *over* to either the verb or the noun phrase. If we think of this utterance as a speech act then we might expect that there should be a way that the speaker’s intention could take a phonetic form compatible or more felicitous with one reading of this sentence and less compatible or felicitous with the alternative reading. We can think of this as an “ecological” or environmental-contextual pressure on the language user when

planning out a possibly ambiguous sentence like (1). Speakers who are being understood more easily could have several advantages in communicative situations or even in other expressive behavior that requires not so much the transfer of factual information but rather the correct interpretation of the speaker's condition and quality. One could speculate about possible ecological advantages that could have provided a positive selection pressure for grammatical mechanisms that could disambiguate possible utterances in human languages. These mechanisms may be pragmatic, lexical, or morpho-syntactic and indeed they are in most cases<sup>15</sup> when speakers can arrange constituents in a non-ambiguous way; but they could also be prosodic, especially when there is no easy way for the syntax to resolve standing structural and scope ambiguities such as the one in (2) above from English<sup>16</sup>. In particular the prosodic re-deployment in order to group together various syntactic constituents has been shown experimentally to be done at the earliest possible moment in the production of ambiguous sentences in English (Kjelgaard and Speer, 1999). A methods strategy for the experimental and theoretical investigation of sandhi in Greek would then be more informative if

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<sup>15</sup> For example the ambiguous sentences “(a) bear left at the zoo” and “I saw a man with a telescope” are only ambiguous when uttered out of context due to the inherent lexical ambiguities of the English words *bear* and *left* and the syntactic freedom for two possible attachments for prepositional phrases such as *with X* in English. In most natural communicative situations though, such lexical or syntactic ambiguities usually do not persist since context, and also sometimes strong semantic bias of particular words (cf. Blodgett 2004), is always a potent disambiguation factor. (E.g. was the discussion about a bear or about driving directions? Was the discussion about my new telescope or about seeing someone holding a telescope walking down the street?)

<sup>16</sup> The fact, however, that human languages are still replete with possible sources of ambiguity whether at the lexical or the phrasal level is very interesting and counters the argument proposed here. Perhaps being ambiguous is sometimes preferred in locally defined domains of discourse.

sentences with similar ambiguities were examined and analyzed. Good reading materials for a recording experiment would then be ambiguous sentences that contain words with segmental information susceptible to segmental sandhi at sites where speakers might insert a prosodic break in order to resolve such ambiguities.

This chapter presents the results from a production experiment designed to elicit segmental sandhi in potentially ambiguous sentences from native speakers of Greek. The materials were constructed so as to offer possible segmental contexts for four different types of segmental sandhi in sentences with more than one possible meaning due to different viable syntactic structures. This experiment, as will be described below in more detail, involved read laboratory speech. It is probably true that speakers in a recording room would tend to employ very formal styles which are perhaps not reflective of their everyday casual speech style. Ladefoged (2003) points out that “even obtaining data from a carefully controlled group in a laboratory experiment is really a kind of fieldwork. You need to determine how to set up an appropriate group and how to elicit the speech sounds you are trying to investigate.” However, the gain of considerable control over the materials during the recording procedure in a laboratory environment is invaluable for trying to establish the limits of variability in connected speech and especially in order to clearly describe and analyze the pronunciation phenomena of interest to this thesis. Especially in light of some claims that seem to maintain the viewpoint that most of connected speech phenomena such as segmental sandhi seem to

belong to a Fast Speech module of grammatical competence (Kaisse, 1985). In order to show that this is not the case, in addition to a gain in control in a laboratory situation, one more advantage exists for such a choice: If sandhi processes are present in formal self-monitored laboratory speech one can surmise that in natural everyday casual speech the application of sandhi could be even more widespread than is revealed in the laboratory. A more natural progression in the investigation of segmental sandhi would then be to first establish some of the phonetic facts in a carefully controlled environment, and then to proceed to investigate the frequency and the phonetic nature of the same phenomena in spontaneous unscripted speech. The latter is undertaken by this study in a second production experiment described in chapter 4.

For the experiment described in this chapter four different segmental sandhi processes in Greek were chosen. The first one is /s/ voicing before voiced obstruents. The second one is vowel degemination. The third one is consonant degemination, and the fourth one is affricate formation. These processes were chosen because they occur in more productive environments than other sandhi processes, especially with regard to the construction of possible ambiguous sentences in Greek. In the following sections these four different sandhi processes are described in more detail.

### 2.1.1 /s/-voicing.

In previous discussions of this process in the literature on Greek, /s/ voicing has been claimed to apply categorically whenever the right segmental environment is found, both word-internally in deriving complex forms and post-lexically at word edges. For example, word-internally, in the formation of compounds such as *τρισδιάστατος* ‘three-dimensional’ /trisði'astatos/ [trizði'astatos], from *τρεις* /tris/ ‘thrice’ and *διάστατος* /ði'astatos/ ‘dimensional’ the /s/ of *τρεις* will invariably be voiced in all productions of this word and the outcome of the /s/ voicing will always be a fully voiced [z] indistinguishable from an underlying /z/ in a similar context. This fact about compounding is related to the phonotactic restriction against sequences of /s/ followed by a voiced obstruent morpheme-internally. That is, while there are words such as *σμίλη* ‘chisel’ /<sup>h</sup>zmili/ and *κόσμος* ‘world’ /<sup>h</sup>kozmos/ there are no words \*/<sup>h</sup>smili/ or \*/<sup>h</sup>kosmos/<sup>17</sup>. These are impossible lexemes in the language. This phonotactic constraint is also evident in the common L2 pronunciation by Greek speakers of English words such as *smoke* or *smile* as [zmouk] and [zmail]. This sandhi process of /s/ -> [z] can apply post-

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<sup>17</sup> The fact that Greek words such as *σμίλη* /zmili/ and *κόσμος* /kozmos/ are spelled with an *s* in Greek (the Greek letter *σ*) and not with a *ζ* (the Greek letter *z*) is synchronically irrelevant because there are no alternations.

lexically, too, as in the phrase *ο φίλος μου* /o 'filos mu/ -> [o 'filoz mu] ‘the friend my.’

The categorical application of /s/ voicing sandhi within most of the prosodic constituents posited for Greek has been noted by researchers such as Nespor and Vogel (1987) and Condoravdi (1990). However, in most accounts of sandhi in Greek the focus has been on whether or not the processes apply across the boundaries between certain morpho-syntactic and prosodic constituents. The question about the exact phonetic output has only been addressed by a few studies and up until recently it has eluded careful experimental documentation in Greek. Most notably, the studies of Fallon (1994), Pelekanou and Arvaniti (2001) and Baltazani (2003), have raised similar questions and have provided some experimental data for some of these sandhi processes. Pelekanou and Arvaniti identified a continuous variation in the output of /s/ voicing in their corpus. The /s/ realization in their data ranged from fully voiced [z], to partially voiced [s], to no voicing at all. They also point out that these three different realizations could be found across both a prosodic word (PrWd) and an intermediate phrase boundary (ip) in the GPToBI model of Greek prosody (presented in chapter 1).

There are similar results of continuous variation for assimilatory external sandhi processes in English such as for /z/ devoicing and /s/ palatalization in English (Smith 1997, Zsiga 1995). The cases of /z/ devoicing sandhi in English in phrases such as *falls perceptibly* (Smith 1997) and /s/ voicing in Greek are

illustrative of how these sandhi processes are language-specific and depend on a variety of other factors, most notably the phonotactics and phoneme frequencies of each language and perhaps the morphology too, in addition to the phonetic realization of each segment according to objective acoustic and articulatory criteria. For example, the rarity of word-final /z/ in Greek is due to the phonotactic restrictions of the language, but within those restrictions, the rarity of word-final voiced stops in Greek in particular could be compounded by their overall low phoneme frequency in the language. It is interesting that in sequences such as *this month* or compounds such as *misgivings* English /s/ is not normally voiced. Alternatively, Greek /z/, being very infrequent at the end of morphemes or word-finally, normally does not get devoiced in rare sequences with a /z/-final loanword from French or English such as in *η πλαζ του Σαρωνικού* /i plaz tu saroniku/ ‘the beach of Saronikos’ where final /z/ devoicing similar to the English sandhi could apply. Smith (1997) and Zsiga (1995) assume the model proposed by Browman and Goldstein (1989) which explains such phenomena of continuous variation as the result of language specific co-articulation rules which can arise from gestural overlap and gesture reduction between successive articulatory targets. However, Holst and Nolan (1995) and Ladd and Scobbie (2003) present data from English and Sardinian respectively for which they argue that such a view of continuous output due to assimilatory gestural overlap cannot account for some cases of post-lexical segmental sandhi such as /s/ to /ʃ/ assimilation in English and stop lenition

and degemination in Sardinian that seem to have non-continuous outputs. That is, there are cases of complete neutralization between the post-external sandhi sound sequences and identical word internal or underlying sound sequences found in the lexica of English and Sardinian<sup>18</sup>. Pelakanou and Arvaniti's (2001) account of the /s/ voicing sandhi in Greek as the result of gestural overlap was the result of analyzing nine cases of /s/+sonorant across prosodic words and intermediate phrases. The interesting question, however, is whether there is a correlation between this continuous acoustic output and speakers' intention to convey a disjuncture between adjacent words to the listener. Under such ecological pressure the patterning of this type of continuous acoustic variability could correlate with a successful articulatory strategy to resolve between competing prosodic and morphosyntactic groupings. Production of these types of ambiguous sentences as discussed in section 2.1 above would then offer crucial additional information in understanding any systematicities in the patterning of external segmental sandhi if there are any.

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<sup>18</sup> Browman (2003) points out, however, that the similarity between /s+f/ and /ʃ+f/ in the most conjoined tokens in the Holst and Nolan (2003) data from English could be an artifact of non-linearities in the mapping from articulation to acoustics. Unlike Zsiga (1995) and Smith (1997), Holst and Nolan relied exclusively on qualitative judgments from spectrograms.

### 2.1.2 Vowel degemination

Traditionally this segmental sandhi phenomenon in Greek has been understood as the categorical deletion of one of two identical vowels in a sequence across a word boundary. In other words, the claim is that whenever there is sequence of two identical vowels across word boundaries the total duration of the two vowels is comparable to that of a single vowel in similar segmental and prosodic position. Word-internally, sequences of two identical vowels are rare in Greek but by no means unattested. For example *ποίηση* /'pi.i.si/ 'poetry' for two /i/'s in a row and *ωοειδές* /o.o.i.'ðes/ 'oval' for two /o/'s in a row.<sup>19</sup> Kaisse (1977) and Nespor (1987) treated identical vowel degemination as a categorical rule that applies everywhere post-lexically except when vowel deletion would result in stress clash. However, Fallon (1994) showed that vowel degemination can occur even in these environments. A possible stress clash is avoided by the deletion of the first stress along with the vowel that carries it: *αλλά αυτό* /a'la a'fto/ 'but this' can result in a sequence [ala'fto] and not \*[a'la'fto]. Pelekanu and Arvaniti (2001) found identical vowel degemination to be obligatory within prosodic words (PrWd in their GRTToBI annotation system described in chapter 1) but not across them or

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<sup>19</sup> Most of the words containing two identical vowels belong to a formal register but some of these words have become part of the colloquial vocabulary too. For example the word for *poem* has two possible pronunciations: (i) a colloquial degeminated /'pi.ma/ and (ii) a formal /'pi.i.ma/ with three syllables and vowel hiatus.

across intermediate phrases (ip in the GRTToBI system) where, in their data, it was found to be optional. Fallon also notes that degemination is more likely to happen when the two identical vowels are /a/ or /e/ rather than /i/ or /o/. He did not have any instances of /u/ sequences in the corpus he worked from. /u/ is indeed the least frequent of the five Greek vowels, a fact that shows the importance of frequency factors when examining the interaction between segmental and prosodic constituents. Fallon (1994), however, did not include any detailed and instrumentally analyzed qualitative data, whether acoustic or articulatory, as to the exact output of this sandhi rule when it is claimed to be either categorical or optional.

### 2.1.3 Consonant degemination.

Similar to the shortening of sequences of identical vowels discussed in the previous section, whenever there are two identical consonant sequences in Greek across a morpheme or word boundary, the sequence of the two consonants is shortened to become similar to a singleton segment rather than a geminate segment. The fact that neither geminate consonants nor long vowels are normally<sup>20</sup> found in the standard language (Arvaniti 1999) only makes such a sandhi process

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<sup>20</sup> Though vowels could be lengthened when functioning as hesitation placeholders, especially /e/.

all the more plausibly categorical in Greek. Pelekanou and Arvaniti (2001) found the rule to be categorical in its application within and across PrWd's. Tserdanelis (2003) examined sequences of two /s/ segments across word boundaries and confirmed the non-optional nature of this sandhi rule in both normal and fast tempo. Furthermore, he presented durational measurements of the phonetic output of /s/ degemination that showed no significant difference between the duration of an underlying singleton /s/ and a degeminated /s/. The duration of both fricatives, whether they were an underlying single /s/ or as the result of the sandhi rule of identical consonant degemination, fell within the same durational patterns in similar prosodic positions for a canonical Greek /s/. Moreover, Tserdanelis (2003) found no significant effect on the application of the /s/ degemination rule even when an intermediate phrase (ip) prosodic boundary was present at the juncture between a word final /s/ and a word-initial /s/. That is, /s/ degemination appeared to be categorical in its application and to result in a non-continuous output that showed duration variability similar to that of underlying singleton /s/ irrespective of the strength of the prosodic boundary (PrWd or ip) that separated the two identical underlying segments.

#### 2.1.4 /t+/s/ affricate formation.

This type of sandhi, to my knowledge, has not been investigated before in Greek since, due to the phonotactic restrictions of the language, few morphemes and lexical items, with the exception of a number of loanwords from English and French mostly and some native acronyms and onomatopoeic words, end in /t/ or any other kind of obstruent. It is hypothesized here however that whenever a word-final /t/ is followed by a word-initial /s/ this /t#s/ sequence could be affricated. That is, the /t#s/ sequence could have durational and spectral characteristics more similar to the affricate /ts/ than to other stop plus /s/ sequences (e.g. /ps/ and /ks/)<sup>21</sup>. Fourakis et al. (2003) have indeed shown that in Greek the sequence /ts/, at least word-initially, is different in its temporal characteristics from the sequences /ps/ and /ks/. In their data, /s/ was shorter in /ts/ combinations than in any other cluster (i.e. /st/, /ps/, /sp/ etc.) whereas /t/ showed no comparable durational difference in /st/ vs. /ts/ clusters. The different temporal coordination of homorganic stop plus fricative clusters, characteristic of affricates cross-linguistically (Bolozky, 1980 for Hebrew, Prinz & Wiese, 1991 for German), seems to hold for Greek /ts/ then as well. It would thus be very interesting to see whether the characteristics of stop plus /s/ sequences in non-word-initial and especially in derived positions across morpheme boundaries or between words

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<sup>21</sup> See also Joseph and Lee (1988).

could result in affricated sequences similar to underlying /ts/ affricates in Greek. This type of affricate formation sandhi in Greek could then be interpreted as one more cohesion-marking phenomenon between words in Greek within certain prosodic constituents such as the vowel and consonant degemination and /s/ voicing sandhi discussed above.

## 2.2 Experiment method

In order to see whether these four sandhi processes discussed in the previous sections are obligatory or optional in their application and, whether when they do apply, they exhibit continuous or categorical/discrete types of phonetic variation, the following production experiment was carried out.

### 2.2.1. Materials

Three different types of structurally ambiguous sentences were constructed to serve as the reading corpus for this experiment. The first type of ambiguity had to do with how a prepositional phrase (PP) can attach itself to two previous syntactic constituents in a sentence. The second type of ambiguity had to do with the scope an adjective can have in a phrase with two nouns. The third type of

ambiguity involved the two possible attachments of a clitic to either a noun phrase (enclitic) or verb phrase (proclitic) in Greek. All three types of ambiguous sentences contained environments for segmental sandhi at a potential phrase boundary.

#### 2.2.1.1 First set of materials (PP attachment ambiguity).

In the first set of materials six sentences with a prepositional phrase attachment ambiguity were presented to the readers. For example, the sentence in (2) can have two possible meanings listed in (3) and (4) since the prepositional phrase (PP) /me aftopepiθisi/ ‘with confidence’ can be attached either to the verb phrase (VP) /vlepage/ ‘we saw’ (3) or to the noun phrase (NP) /poles jinekes/ ‘many women’ (4). That is, either the subject of the sentence *we* was performing the action of the verb with confidence or the object of the verb *women* was confident.

- (2) Βλέπαμε πολλές γυναίκες με αυτοπεποίθηση.  
/vlepage po'les ji'nekes me aftope'riθisi/  
(We)<sup>22</sup>saw many women with confidence.

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<sup>22</sup> Greek is a Pro-drop language and thus overt subjects in Greek are optional and used only for emphasis or contrast.

(3)  $_{VP}[^1vlepame \text{ } _{NP}[po'les \text{ } ji'neke(s)] \text{ } _{PP}[me \text{ } aftope'pi\theta isi]]$

Paraphrased Meaning: *We looked with confidence at many women.*

(4)  $_{VP}[^1vlepame \text{ } _{NP}[po'les \text{ } jineke(z) \text{ } _{PP}[me \text{ } aftope'pi\theta isi]]]$

Paraphrased Meaning: *We saw many women who were confident.*

This type of surface ambiguity, could perhaps be resolved with the application or not by speakers of segmental sandhi (/s/ voicing in this case) in addition to the possible different alignments of prosodic breaks between the constituent words of the utterance. In (2) above the final /s/ in the words /poles/ ‘many’ and /jinekes/ ‘women’ may be voiced since the following segment at the beginning of the respective following words /jinekes/ ‘women’ and /me/ ‘with’ is a voiced fricative [j] or a nasal [m]. The voicing or not of /s/ before /j/ or /m/ in this case can be a cue to one reading as opposed to another. If this standing ambiguity is resolved prosodically in Greek (and if the domain of [s]-voicing is the type of prosodic constituent that contrasts the two readings) then a voiceless [s] is expected in reading (3) and a voiced [z] in reading (4). Moreover, there was an effort to construct sentences with no semantic bias to either of the two possible interpretations with regard to the PP attachment by selecting words of similar frequency and with no obvious semantic connections. There were six sentences with this type of ambiguity.

### 2.2.1.2 Second set of materials (Adjective Scope Ambiguity)

In the second set of materials six sentences with a different type of ambiguity were constructed and with one additional segmental sandhi process locus. The type of ambiguity is shown in the example sentence below:

- (5) Ἦρθαν νέοι υπάλληλοι και ιδιοκτήτες στη συγκέντρωση  
/i'rθan 'nei ipa'lili ke iðio'ktites sti si'gedrosi/  
(They)came new employees and employers to-the reception.

- (6) VP[i'rθan NP['nei (i)pa'lili] NP[ke iðio'ktites] PP[sti si'gedrosi]]

Paraphrased Meaning: *Employers and new employees came to the reception.*

- (7) VP[i'rθan NP['nei ipa'lili ke iðio'ktites] PP[sti si'gedrosi]]

Paraphrased Meaning: *Both the employees and the employers who came to the reception were new.*

In the example sentence in (5) above the adjective /'nei/ 'new' can refer to either /ipa'lili/ 'employees' alone as in (6) or to both nouns /ipa'lili ke iðio'ktites/ 'employees and employers' as in (7). In these constructions speakers could degeminate the sequences of two identical vowels /i/ that comes from juxtaposing

the /i/ at the end of /'nei/ 'new' with the /i/ at the beginning of / ipa'lili / 'employees'. The prediction is that they would be more likely to do so in the reading in (6) but not in the reading in (7). It is possible that when speakers intend to link the adjective /'nei/ 'new' only to the immediately following noun / ipa'lili / 'employees' the two /i/'s will be degeminated (shortened); but when /'nei/ 'new' is intended to modify both nouns /i/-degemination may be blocked as the result of inserting a prosodic boundary between the adjective and the following nouns in order to denote the association of the adjective with both nouns. Six sentences with this type of ambiguity were used. Three had /a/ as the vowel in the identical vowel sequence and three had the vowel /i/.

### 2.2.1.3 Third set of materials (Clitic Attachment Ambiguity)

In the third set of materials twelve sentences with an ambiguous clitic pronoun, a short function word that always needs to be attached to a preceding or following word, were constructed, offering yet another locus for the last two segmental sandhi processes, identical stop degemination and affricate /ts/ formation. This type of clitic attachment ambiguity, also used in Tserdanelis (2003), is shown in the example below:

(8) Το ρομπότ σου κατέστρεψε το γραφείο.  
/to ro'bot su ka'testrepse to gra'fio/  
The robot your destroyed the desk

(9) NP[to ro'bot su] VP[ka'testrepse NP[to gra'fio]]

Paraphrased Meaning: *Your robot destroyed the desk*

(10) NP[to ro'bot] VP[su ka'testrepse NP[to gra'fio]]

Paraphrased Meaning: *The robot destroyed your<sup>23</sup> desk*

Tserdanelis (2003) found that speakers would always disambiguate these types of sentences by inserting a prosodic boundary between the first NP and the following VP. In (9) this break, an intermediate phrase boundary (ip), would be marked by a H- phrase tone that aligns with the end of the clitic pronoun /su/ 'your', since in this case the clitic attaches to the noun to its left as a possessive enclitic. By contrast in (10) the H- tone marking the prosodic break would align with the end of the noun /ro'bot/ 'robot' since the pronoun in this case is a proclitic and attaches to the verb on its right. In (8) above the clitic pronoun σου /su/ 'your'

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<sup>23</sup> This would be more accurately translated as "destroyed (your) desk to your detriment". The clitic σου /su/ 'your' in reading B does not necessarily denote possession of the noun γραφείο /grafio/ 'desk' but it is denoting either benefactive or anti-benefactive (in this case clearly the latter) attributes to the action of the verb. Sometimes this type of clitic is referred to as an ethical dative.

starts with a /s/ and the preceding noun ρομπότ /robot/ ‘robot’ ends in a /t/. A sequence of /t+s/ across word boundaries and when not separated by a prosodic phrase break as in (10) can perhaps surface as the phoneme /t<sup>s</sup>/, an affricate in Greek according to Botinis et al. (2003). Twelve sentences with this type of ambiguity were constructed; six of them included the pronoun σου /su/ ‘your’ and thus were sites for affricativization of /t+s/ and another six sentences were constructed with the pronoun του /tu/ ‘his’ and thus offered another site for identical adjacent consonant degemination as in Tserdanelis (2003), but this time not between fricatives but between two stops /t+t/ as in /to ro<sup>h</sup>bottu ka<sup>h</sup>testrepse to γra<sup>h</sup>fio/ ‘the robot-his, destroyed the desk.’

There were thus a total of 24 sentences created for these three different types of ambiguities. Six sentences had a PP-attachment ambiguity in them, six had an Adjective scope ambiguity in them, and twelve had a clitic attachment ambiguity in them, six of them with a /t+s/ sequence and six with a /t+t/ sequence at the juncture between noun and clitic. Finally, speakers were asked to read a list of words (three times in carrier phrases) with underlying initial, medial and word-final [z], [s], and [ts] sounds in order to use these recordings as a baseline for comparison between these sounds as the result of sandhi and as underlying phonemes. Appendix A provides a complete list of all three different types of ambiguous sentences and selected words which served as the reading materials for the production experiment along with English translations.

### 2.2.2 Speakers

The participants in the experiment were five undergraduate students from Athens, Greece. Two of them studied at the Aristotle University in Thessaloniki, Greece and had lived in Thessaloniki for 1 and 2 years respectively. Three of them were students at the University of Macedonia in Thessaloniki and had lived in the city for about one and a half years. There were three female and two male speakers. All five speakers were in their early twenties and they were recorded in Thessaloniki, Greece. They were all native speakers of Standard Athenian Greek and appeared to have no distinct regional accent. All speakers also spoke some English and French to a varying degree of fluency. None of the speakers reported any speech or hearing problems. They were all volunteers.

### 2.2.3 Procedure

The recording took place in a quiet room in the Phonetics Laboratory of the English Language department, at Aristotle University in Thessaloniki, using a CDR 3000 Marantz Compact Disk recorder and an AKG head-mounted cardioid condenser microphone. The speakers read the test phrases from typed cards three

times each, in pseudo-random order. Each card had one sentence written on it in Greek. Under each sentence there was a short paraphrase of the sentence similar to the ones listed below the example sentences in the previous sections above. In addition to the written paraphrases the ambiguity for each of the three different types of sentences, PP-attachment, Adjective-Scope and Clitic-Attachment, was explained to the speakers verbally prior to the recordings.

There were two recording sessions. In the first session the speakers were asked to read each of the sentences within a set of sentences with the intention to render one of its two alternate meanings. The order of the two possible interpretations within a session was pseudo-randomized so as not to give any bias across the speakers due to the order of presentation. In the second session they were asked to read each of the same sentences with the intention to render the other alternate meaning. This was done in order to avoid confusion between the two possible interpretations and to help speakers to concentrate on one reading for each sentence during a recording session across the different sentences with the same type of ambiguity.

The speakers were instructed not to pause between words and to read the sentences in a natural and relaxed manner at a comfortable speaking rate and loudness level but also making sure to try to convey the one of the two alternative readings of the sentences they had to read during each session. All speakers were given some time to practice the sentences before the recordings so as to make sure

they had understood the task and especially the ambiguity involved in the three different types of sentences. Each speaker read the 24 test sentences three times with one reading in mind during the first recording session and after a short break, another three times with the alternate meaning in mind for a total of 144 sentences per speaker. For each type of ambiguity the order of presentation of the ambiguous sentences was varied across and within speakers so as to avoid any confounding bias effects due to the ordering of the presentation of the two types of ambiguities. The two recording sessions combined for each participant lasted for about an hour, including the presentation and signing of a consent form, the oral and written explanation and instructions for the task, the break between the sessions and a short debriefing about the purpose of this experiment after the completion of the recordings.

#### 2.2.4 Measurements.

The recordings were saved as stereo digital files sampled at 44.1KHz directly onto a compact disk and then transferred to a PC as mono 16-bit WAV 44.1KHz files. Segmental durations were measured from waveforms and spectrograms using the speech analysis program, Praat, freely distributed by the Institute of Phonetic Sciences in Amsterdam and developed by Paul Boersma and

David Weenink. As shown in figure 2.2 below, Praat can generate a waveform display, a wide band spectrogram and a pitch track in an editor window where phonetic transcriptions and prosodic annotations can be inserted on separate tiers. Each annotation is associated with one or two time markers depending on whether the tier is defined as a set of labeled time points (as in the first tier in Fig. 2.2) or as a sequence of labeled time intervals (the other three tiers in Fig. 2.2). The labels and time points are recorded in text files that the program generates in order to store the information inserted by the transcriber in the various tiers. Each sentence was intonationally transcribed using the GRT<sub>o</sub>BI annotation system discussed in chapter 1 (tier 1) and phonetically transcribed using the International Phonetic Association (IPA) alphabet (tier 2). Durations for the target consonant and vowel sequences were measured by calculating the duration between the two interval boundaries for each segment on the IPA tier.

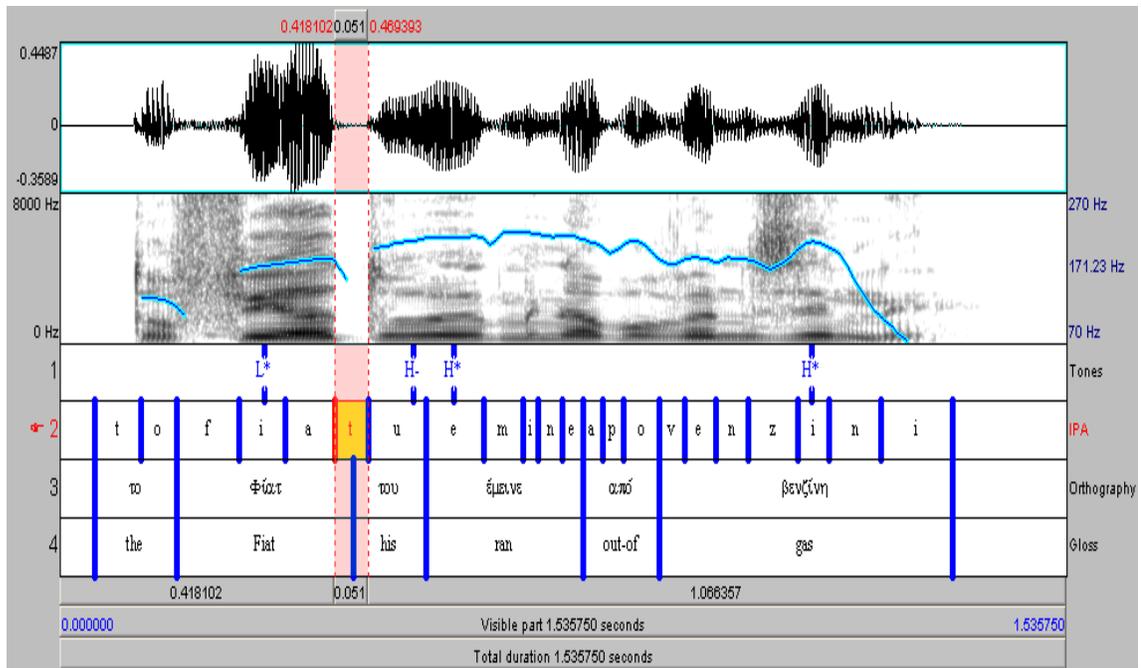


Figure 2.2. The acoustic analyses editor in Praat.

For the stop consonant /t/ the duration was measured from the offset of the preceding vowel, that is the disappearance of any periodic oscillation in the waveform display, until just before the release of the consonant. Because voiceless stops in Greek are not normally aspirated (Arvaniti, 1999) the Voice Onset Time was not included in the total duration of the stop, only the stop closure. However, one speaker who did use considerable aspiration and two speakers who often paused after the release of the first stop in stop-stop and stop-fricative sequences. The segmentation and duration measurement for stops is illustrated in figures 2.4 through 2.7. Figure 2.5 shows a sequence of two stops where the first is not released while figure 2.7 is an example of a sequence where the first stop was

released, yielding a percept of subsequent pausing (of course this “pause” cannot be distinguished acoustically from the second stop closure).

For the fricatives, three types of acoustic measurements were made. The first two measurements were of the total duration and of the proportion of the constriction with voicing of the target fricative /s/. Following Pincas and Jackson (2004), the duration was measured from the offset of the higher formant resonances in the preceding vowel and simultaneous start of turbulent noise (the frication onset time) to the onset of the following vowel (or nasal) which was defined as the point where there was no longer any turbulent noise (the frication offset time). These frication onset and offset points were marked at the visual appearance and subsequent disappearance on the waveform display of any noticeable high frequency frication noise, whether or not this was superimposed on aperiodic oscillations. As illustrated in figure 2.3 the onset and offset of voicing was marked from the appearance and subsequent disappearance of any periodic low frequency oscillation. However, as it will be evident later in the results section, there were no cases observed where there was voicing only during the first part of the fricative. Thus the proportion of voicing was always 0% or 100% unlike in Smith’s (1997) study of English or Jun’s (1993) study of Korean. Thus the fricative interval was not divided into an “[s]-voiced” interval and an “[s]-voiceless” interval but it was simply noted in the IPA tier whether the fricative

interval was voiced or not, as seen in figures 2.8 (for voiceless /s/ = [s]) and 2.9 (for voiced /s/ = [z]).

In addition to the temporal and voicing measurements, spectra were made of the /t/ release in the sentences where /t/ was followed by a /s/ in the clitic /su/ ‘your’ in the last set of materials with the clitic attachment ambiguity. This was done in order to see whether the [t] was released directly into the following fricative. Thus the spectra could be used to check for the possible rounding effect on the [t] release of the vowel following the [s] which was always the high back rounded vowel [u] in the clitics used in the test sentences. The reasoning was that presence of an unrounded [t]-burst phase that is independent of the following fricative can be interpreted as evidence of non-affrication, that is since /s/ before /u/ in Greek is rounded (as shown in Fig. 2.7). FFT spectra were taken from the release of the [t] closure into the fricative constriction of the following [s] from a 25ms long windowed (Hanning) selection from the release of the stop closure, as shown in figure 2.4.

The target vowel duration in the test sentences with potential vowel degemination was measured from the onset of periodic oscillation after the release of the preceding stop consonant (or from the end of aperiodic noise when the consonant preceding the target vowel was a fricative) to the point of complete cessation of periodic oscillation before the stop closure or onset of frication of the following consonant. The segmentation points for vowels can also be seen in the

various vowels displayed in the waveforms of figures 2.3 for vowel fricative sequences and 2.4 for vowel stop sequences.

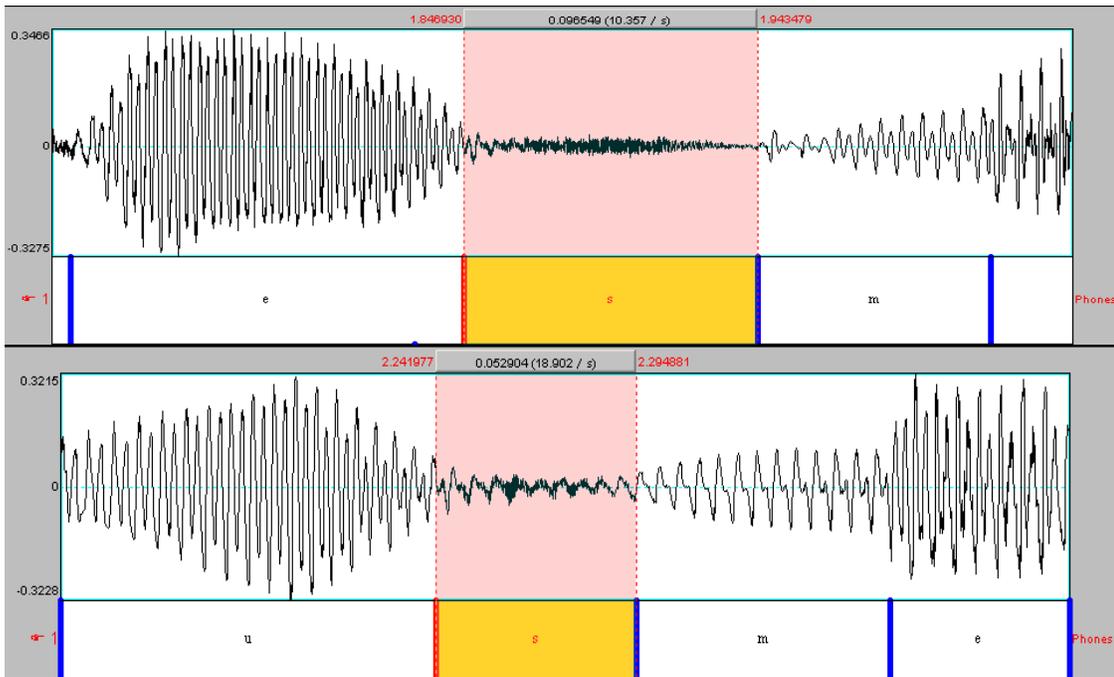


Figure 2.3. Segmentation for fricative /s/. The highlighted region in the upper waveform displays a voiceless [s] and in the lower a fully voiced [z]. Both fricatives occur in the same context, between a vowel and a nasal.

A final set of measurements involved the presence or not of the tonal marker for a prosodic phrasal boundary between the words containing the sandhi target segments and its exact location when present. This phrasal boundary in Greek is phonetically marked by a rising tone that usually aligns with the last syllable of the phrase-final prosodic word, so that the target for the end of the rise is a tonal marker of the phrase edge. In the GRTtoBI annotation system it is called an intermediate phrase boundary (ip) and it is denoted by the symbol H-. A

fundamental frequency contour was generated and the peak F0 value, or the center of an F0 high plateau, was taken as the location of the phrasal boundary with regard to the end of the syntactic phrase. In figure 2.5 the prosodic break is realized early on the final vowel of the noun /pla'kat/ 'placard' signaling thus the end of the prosodic phrase at the end of the noun to the exclusion of the following clitic /tu/ 'his' which belongs to the following prosodic phrase.

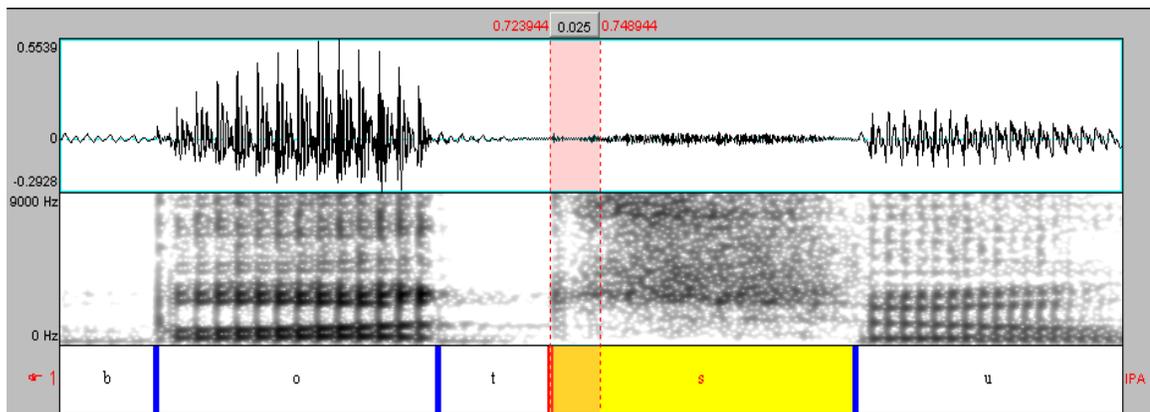


Figure 2.4. Segmentation for [t] stop closure duration and selection of [t] release (25 milliseconds) for FFT spectrum calculation.

Conversely, in picture 2.6 the prosodic boundary is realized on the vowel of the clitic /tu/ signaling thus its inclusion to the prosodic phrase which coincides with the noun phrase /ta pla'kat tu/ 'his placards'.

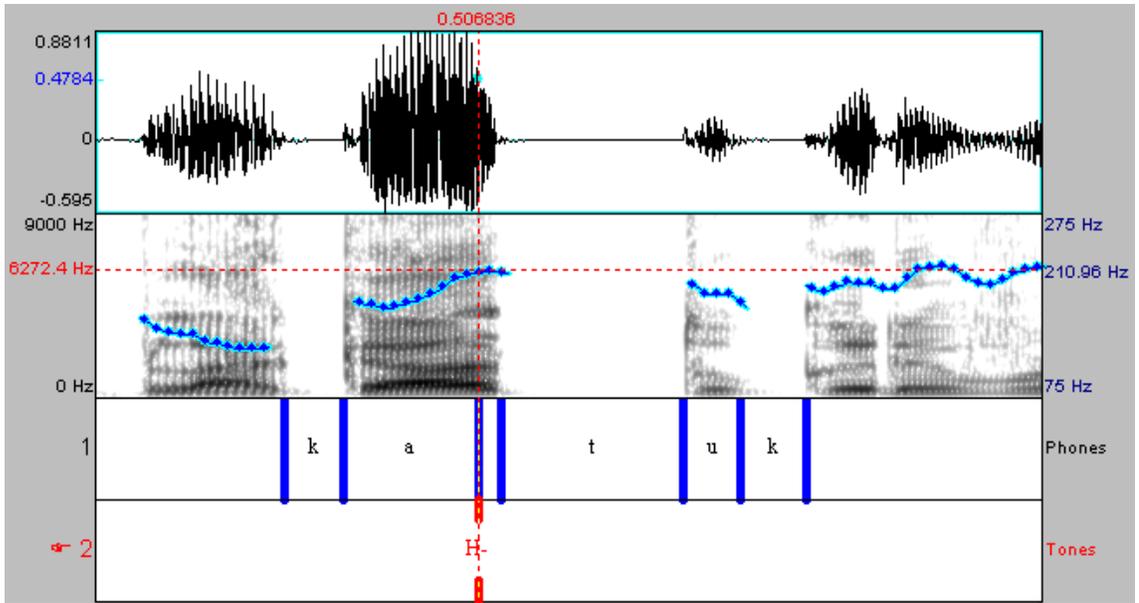


Figure 2.5 Early alignment of prosodic break [H-] on the final vowel [a] of the noun /pla'kat/ 'placards'. Speaker did not release the final [t] nor did he pause after the H-phrase boundary tone.

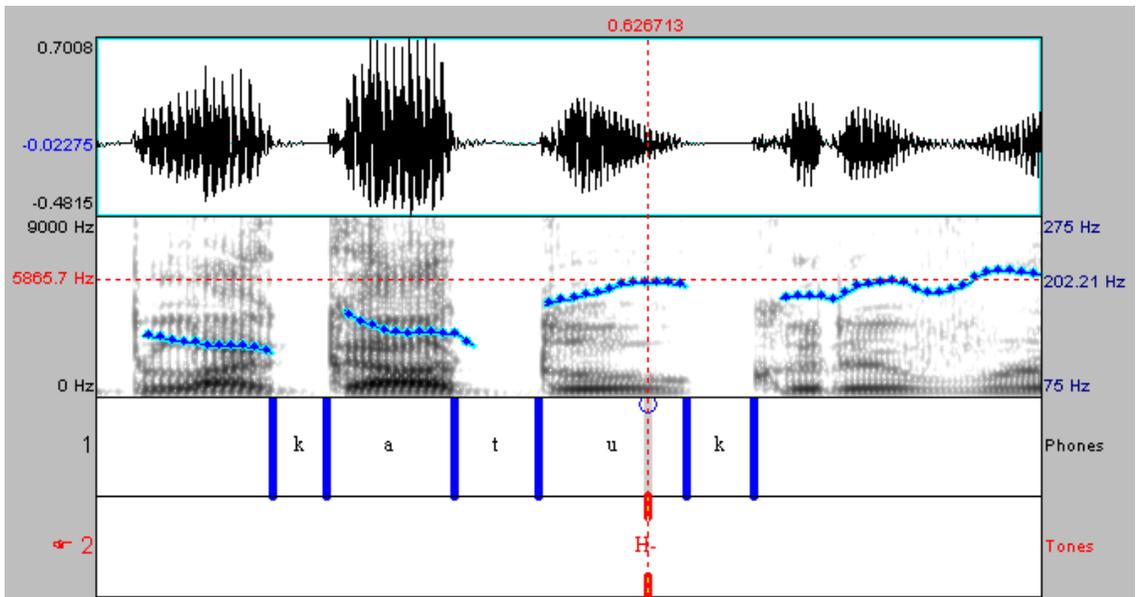


Figure 2.6 Late alignment of prosodic break H- on the vowel [u] of the clitic /tu/ 'his'.

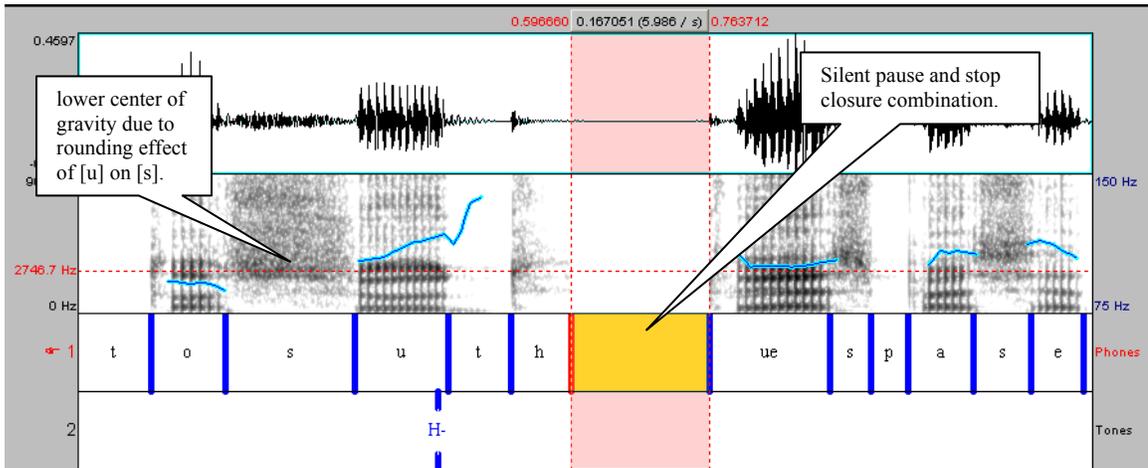


Figure 2.7. Token from speaker 1 with a release of final [t] of the word /sut/ 'shot' and silent pause before the stop closure and release of the following [t] of the clitic /tu/ 'his' which is part of the VP /tu 'espase/ 'to-him broke'

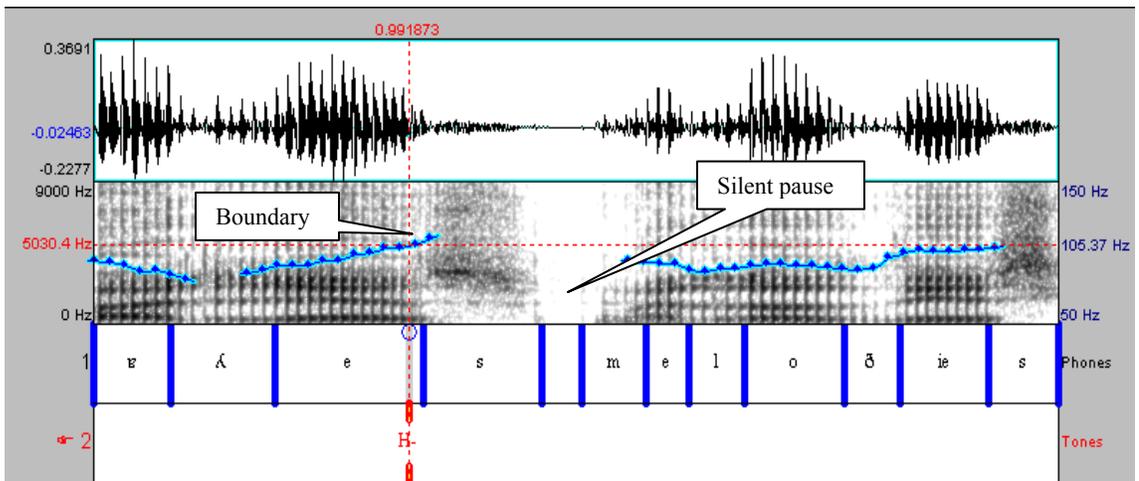


Figure 2.8 Prosodic break at the end of /pa'lies/ 'old' and /melo'dies/ 'melodies' in the sentence /a'kusane pa'lies melo'dies ke madi'naðes/ '(they) heard old [melodies and rhyming couplets]' produced with wide scope.

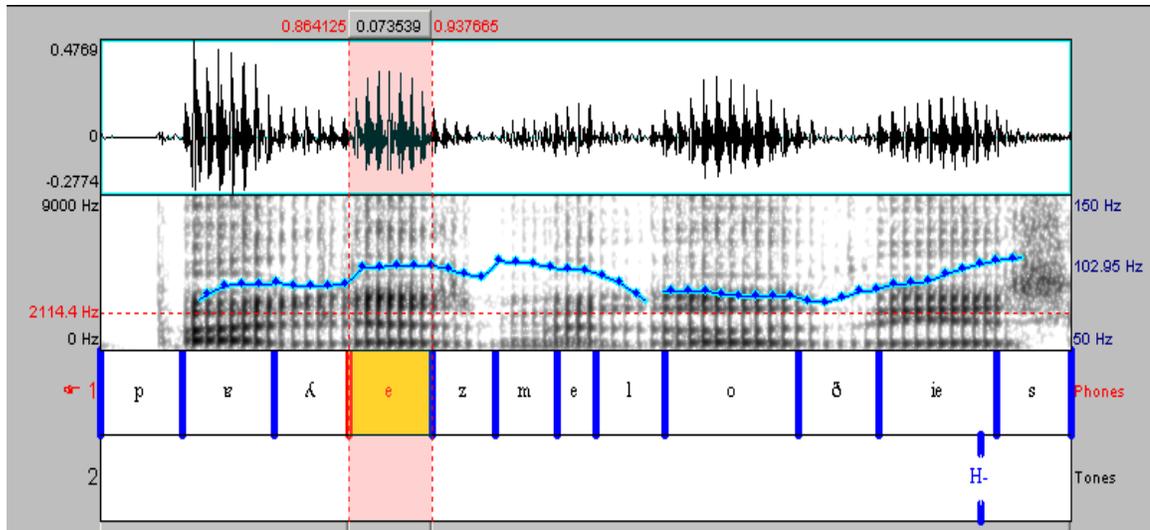


Figure 2.9 Absence of prosodic break at the end of /pa'lies/ 'old' and /melo'dies/ 'melodies' in the sentence /a'kusane pa'lies melo'dies ke madi'naðes/ '(they) heard [old melodies] [and rhyming couplets]' produced with narrow scope.

## 2.3 Results.

### 2.3.1 Intonation

Speakers varied the intonation on their production of the test sentences according to the desired meaning elicited during each sentence's recording. As reported in the experimental method section, speakers were guided toward producing one particular reading as opposed to the other of a given ambiguous test sentence by being given the selected meaning (out of the two possible) of each test sentence in an appropriate paraphrase. Table 2.1 tabulates the number of

tokens in which the speakers produced a tonally marked ip-boundary between the target segments in each of the two readings. The first column in each pair is for the reading where no boundary was expected and the second is for the reading when it was expected for the speakers to insert a prosodic boundary as a disambiguation mechanism. In table 2.1 the results per speaker are shown. For each condition in the Prepositional Phrase (PP) attachment and Adjective (Adj) scope ambiguity sentences speakers were asked to read each of the 6 sentences, three times with one reading in mind and three with the other.

In the readings of the test sentences in the first column- i.e. when the prepositional phrase was supposed to attach to the noun phrase in the first set, the adjective was supposed to modify only the first noun (narrow scope) in the second set<sup>24</sup>, and the clitic was supposed to be part of the noun phrase in the third set (a possessive pronoun)- speakers 1, 3 and 4 consistently did not insert a prosodic break between the words that contained the target segments.

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<sup>24</sup> Speakers 2 and 5 occasionally put a prosodic break after the first noun in the readings of some of these sentences, but this didn't have an effect since there was no possible segmental sandhi in the test sentences between the end of the first noun and the beginning of the conjunction *καί* /ke/ 'and'.

<b>Sandhi:</b>	/s/ voicing		V Degemination		C Degemination		t-resyllabif.	
<b>Ambig:</b>	PP_attachment		Adj_scope		Cl_attachment			
<b>Spkr</b>	<b>low</b>	<b>high</b>	<b>narrow</b>	<b>wide</b>	<b>en-</b>	<b>pro-</b>	<b>en-</b>	<b>pro-</b>
S1	11%(2)	39%(7)	6%(1)	17%(3)	0%(0)	83%(15)	0%(0)	100%(18)
S2	0%(0)	17%(3)	0%(0)	22%(4)	0%(0)	88%(16)	0%(0)	100%(18)
S3	6%(1)	28%(5)	11%(2)	33%(6)	0%(0)	100%(18)	0%(0)	100%(18)
S4	0%(0)	11%(2)	0%(0)	17%(3)	0%(0)	94%(17)	0%(0)	100%(18)
S5	0%(0)	11%(2)	6%(1)	22%(4)	0%(0)	100%(18)	0%(0)	88%(16)
<b>Total:</b>	3%(3)	21%(19)	4%(4)	18%(16)	0%(0)	91%(82)	0%(0)	98%(88)

Table 2.1 Percent of tokens in which there was a H- phrase tone marking the presence of a prosodic phrase boundary between the target segments for each sandhi type in each of the two readings. Number in parentheses is the number, out of 18 per speaker or out of 90 total.

Speakers varied the intonation in their productions of the test sentences according to the meaning elicited by the paraphrases that they read just before producing the token. As shown in Table 2.1, with a few exceptions, speakers consistently produced no phrase boundary in the more closely conjoined readings -- i.e., in the low-attached reading of the verb-object-PP sequences, the narrow-scope reading of the adjective-noun-noun sequences, and the enclitic (possessive pronoun) reading of the noun-clitic-verb sequences. In the other reading of each type, by contrast, every speaker produced at least a few tokens in which the disjuncture was marked by an H- phrase tone. This marking was most consistent in the two sandhi types targeted in the clitic-attachment sets, where three out of the five speakers always produced an intonationally marked prosodic phrase boundary and the other two speakers produced only four tokens in total where there was no intonational

marking of the disjuncture. The marking was considerably less consistent in the other two sets, ranging from a low of only 11% of tokens (for S4 and S5 for the VP-attached reading of the PP cases) to a high of 39% of cases (for S1 in this set).

All five speakers were thus successful in the majority of their production in producing two intonationally distinct versions of the same test sentence in the third set of materials that involved clitic attachment ambiguity. On the other hand, they were not so successful in disambiguating test sentences with either an adjective scope ambiguity or a prepositional phrase attachment ambiguity. That is, in about 80% of the these cases they did not produce a boundary tone [H-] between the words that contained the juxtaposed target segments as shown in figure 2.5. Additionally, whenever they did produce a prosodic break it was often accompanied by a brief pause between the target words as shown in figure 2.7 between [s] and [m].

These results have implications for older theories of deterministic syntax-to-phonological-phrasing models of Selkirk (1984), Nespor & Vogel (1986), and others. That is, while the phrasing rules might be stated in some way as to get the results for the clitic-attachment cases, the variation in the high-attached PP reading and the wide-scope adjective modification reading would be problematic for a theory that says that the intermediate phrase (a.k.a. "phonological phrase") is a layer in a universal hierarchy of prosodic types that is read off of the syntax, with

languages differing only in whether the rules refer to the left or the right edge of the relevant syntactic level. This does not seem to be the case in Greek.

## 2.3.2 Sandhi

### 2.3.2.1 Identical consonant degemination

The hypothesis laid out in chapter 1 predicted that two identical stop consonants across word boundaries will degeminate in the absence of a prosodic break between the target words. This prediction was verified by the data collected in this experiment: the temporal characteristics of the stop consonants in the test sentences patterned according to the degemination hypothesis whenever there was no prosodic boundary inserted by the speakers in the third set of materials that involved the two possible clitic attachments. The converse was also true: whenever there was a prosodic break between the two target words (noun and clitic) the duration of the stop closure between the /t/-final noun and the /t/-initial clitic was, with only a few exceptions, usually twice as long as or even longer than when there was not one. In other words, whenever there was a phrasal boundary between the noun and the clitic /tu/ the identical consonant degemination sandhi did not apply. Figure 2.9 shows very clearly that stop closure durations for speakers 2, 4 and 5 cluster around the  $y=2x$  line, as one would predict if the 18

tokens with the proclitic readings and the H- tone break were all geminates and the 18 tokens with the enclitic reading and no H- break were all categorically degeminated.

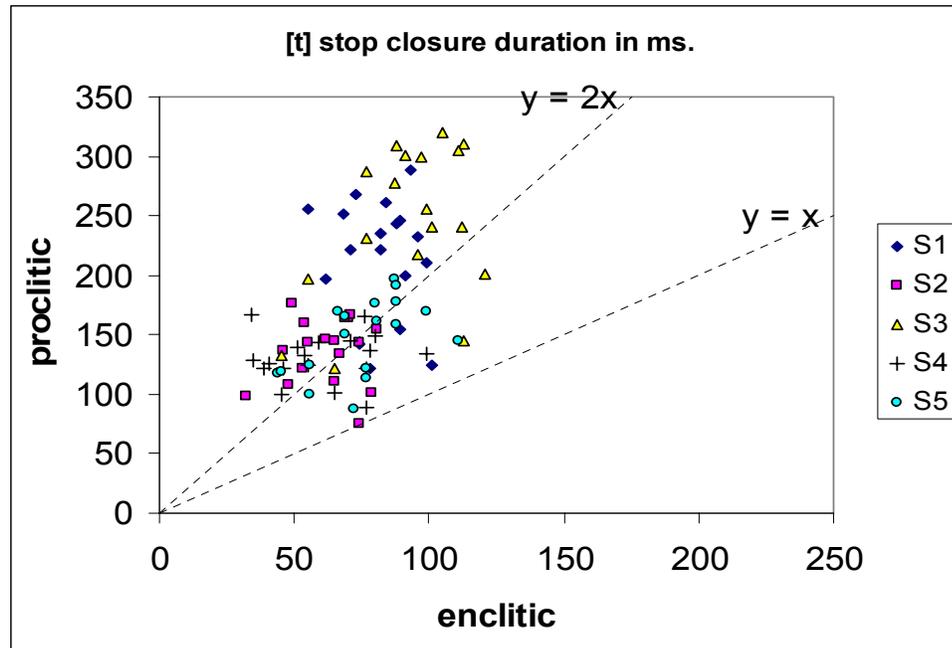


Figure 2.10. [t] stop closure duration by speaker (S[1-5]). Each data point on the chart represents the stop closure duration for each speaker for each of the three repetitions of each sentence with (proclitic condition) and without a prosodic break (enclitic condition) between the target words.

Moreover, the majority of the data points for S1 and S3 who often released the first of the two stops, lie well above the  $y=2x$  line, indicating that they produced a pause after the release of the first stop in most cases (cf. Figure 2.7). Since speakers 1 and 3 tended to release the first stop whenever they inserted a prosodic

break (H-) between the target words the /t/ closure duration in their data actually includes the silent pause after the release phase of the word-final /t/ of the noun and the subsequent stop closure for the initial /t/ of the following clitic /tu/. Since the silent pause is acoustically indistinguishable from the stop closure for the following /t/ we cannot be sure about the duration of the pause in these speakers' productions. Speakers 2, 4 and 5, however, did not release the first stop, and their stop closure intervals were consistently longer (36% longer on average) in their productions when they produced a prosodic break than when they did not.

Speakers 1 and 4 in a very small number of their productions did not insert a prosodic break between the noun and the clitic in the condition where it was predicted as in <sub>NP</sub>[to sut] <sub>VP</sub>[tu espase ta jalia] 'the shot, to-him broke the glasses' (see table 2.1). The duration of /t/ stop closure in these productions was somewhere between those speakers' production of a /t/ stop closure when there was no prosodic break predicted by the test sentences and the ones where they did produce a prosodic break. This means that they produced a /t/ stop closure that was shorter than the /t/ stop closure they produced when they did insert a prosodic break between the noun and the clitic when it was predicted that they would (the overwhelming majority of their productions) but longer than the ones where it was not predicted that they would, and nobody did. Since there were very few such tokens produced (three by Speaker 1 and only one by speaker 3) one can attribute them to either a slight confusion in their disambiguation effort during the reading

of the materials or perhaps are indicative of only a quasi-categorical effect for these speakers with regard to the prosodic disambiguation of clitic-attachment ambiguities.

### 2.3.2.2 Identical vowel degemination

For the vowel degemination sandhi there was no clear pattern in the durational differences between the sequences of the two identical vowels across word boundaries in the two readings of the ambiguous test sentences. The results were not clear due to two main reasons: (i) the failure of the speakers to intonationally disambiguate between the two readings of the test sentences constructed to test the vowel degemination sandhi (Narrow vs. Wide scope and Low vs. High Attachment) and (ii) the fact that it was difficult to measure the total vowel duration in sequences of two identical unstressed front vowels /i/ in many cases due to devoicing and deletion of the entire sequence when there was no intervening tonal break or pause. As seen in table 2.1 only 16 out of 90 productions of the test sentences (17.7%) contained a prosodic break between the vowel-final adjective and vowel-initial noun when the adjective was supposed to have wide scope over both following nouns. Many speakers also followed a prosodic break with a short silent pause or by inserting a glottal stop or a series of glottal stops (or creaky voice) in many cases as shown in Fig. 2.8. The continuous

variation in the vowel duration in the cases where there was no pause or creaky voice between the vowels (which was the overwhelming majority) showed no patterning according to the underlying syntactic structures of the two renditions of the ambiguous sentences.

Even though the results from this experiment are not clear, it is evident that there is no direct mapping from syntactic structure to either intonational or segmental events. In the case of ambiguous sentences with and adjective-scope ambiguity, prosody and sandhi are not categorically determined by a simple syntax to phonology model à la Nespor and Vogel (1986). At the same time, however, Greek vowel degemination, unlike consonant degemination does not seem to be categorically determined by prosody either, contra Jun (1993).

### 2.3.2.3 /s/ voicing (PP-Attachment)

For the /s/ voicing sandhi the results were similar to those of the vowel degemination. That is, most speakers only sporadically differentiated intonationally between the two readings of the ambiguous test sentences. However, whenever in the productions that they did insert a prosodic boundary, /s/ voicing was blocked. As noted in table 2.1, these productions, were relatively rare. Moreover, the prosodic breaks were almost always accompanied by a silent pause

between the target words. By contrast when, there was no prosodic breaking, voicing was categorical: voicing extended throughout the frication interval, and it did so in every case. That is, there were no clear cases of partial voicing of /s/ whenever there was no prosodic break. We do not rule out that speakers could have made a distinction between the surface [z] that resulted in the two conditions which could perhaps be detected by EGG and airflow data. However, this seems unlikely given the durations of the “voiced cases” when compared to underlying /z/. A post-experiment short recording by each speaker was made of a Greek word<sup>25</sup> with an underlying /z/ word-final phoneme in order to compare those underlying [zm] sequences to the ones that were the result of sandhi. There were no durational or voicing differences between the two sequences. In the few cases that speakers did not apply the /s/-voicing sandhi, [s]-duration was significantly longer than [z]-duration, which could be attributed either to inherent durational differences between /s/ and /z/ in Greek -which was indeed the case in the [z] vs. [s] sounds produced in the word list readings- or to phrase-final lengthening or to a combination of both factors.

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<sup>25</sup> The word was /i plaz/ ‘the beach’. It was read three times in isolation and three times in the phrase /i plaz mu/ ‘my beach’ by each speaker.

### 2.3.2.4 Affricate formation

In chapter 1 we hypothesized that when a word ends in a final /t/ and the following word begins with an /s/ the two segments could be combined by speakers so as to be pronounced as a sequence that patterns acoustically with the underlying /ts/ affricates reported in Fourakis et al. (2004). This never-before-reported sandhi process was predicted to occur when the segmental context was appropriate across word boundaries, unless a prosodic break intervened between the target words. The temporal measurements for the /t/ and /s/ in the two prosodic conditions are shown in table 2.2.

<i>Speaker</i>	<i>[t]</i> duration		<i>[s]</i> duration	
	<i>NP</i>	<i>VP</i>	<i>NP</i>	<i>VP</i>
S1	23(9)	48(12)	111(23)	82(21)
S2	36(11)	43(13)	116(17)	93(11)
S3	54(17)	67(21)	121(9)	88(15)
S4	39(14)	55(11)	81(16)	77(11)
S5	62(22)	87(25)	156(39)	113(21)
<b>Mean:</b>	42(15)	60(16)	117(21)	90(15)

Table 2.2. Mean duration in milliseconds of [t] stop closure and [s] frication (standard deviations are shown in parentheses) in two conditions (i) NP: No prosodic break between /t/ and /s/ and (ii) VP: H- ip boundary tone between /t/ and /s/.

As it is shown in table 2.2 mean stop closure duration was longer when /t/ was produced before a prosodic break in the VP condition. As for /s/, the durational difference was in the opposite direction. When /s/ was produced within the NP it

was longer than when it was initial to the following VP and typically after the prosodic break. Figure 2.11 shows this discrepancy between a short /t/ and long /s/ in the NP (enclitic) condition contrasting with a longer /t/ and a shorter /s/ in the VP (proclitic) condition. This is true of all speakers with the possible exception of speaker 4 who did not show a difference in /s/ duration in the two readings.

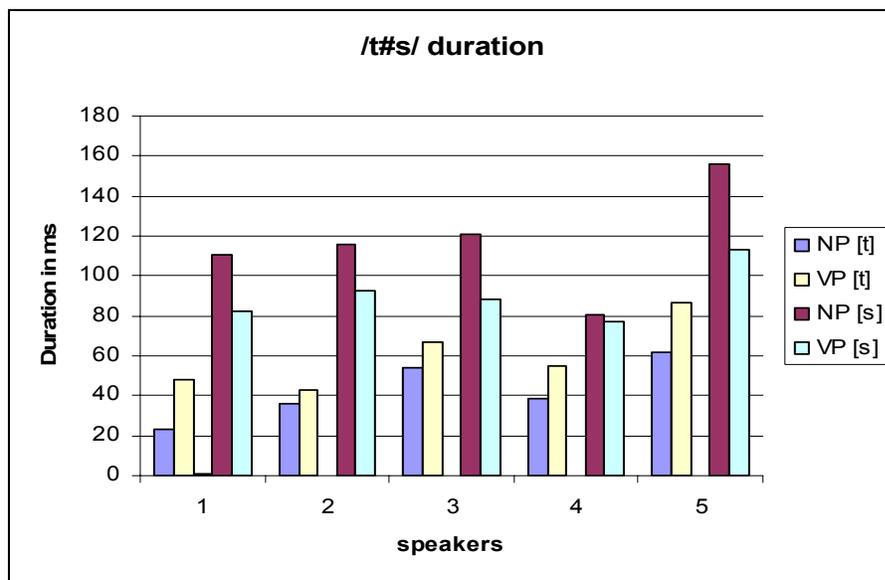


Figure 2.11. Average durations for /t/ closure and /s/ in /t#/s/ sequences within (NP) and across (VP) phrases breaks.

The average stop closure duration (42ms) and /s/ duration (117ms) for the NP condition, when affrication was predicted to occur, are close to the results of Fourakis et al. (2004) for the mean duration of /t/ closure (77ms) and /s/ duration (82ms). Even though Fourakis et al. measured these /t+/s/ sequences word

initially whereas the durational results in this experiment are not from word-initial sequences the durations of /t/ and /s/ in the NP condition are similar to their data. There is further evidence for resyllabification of the /t/ from its spectral release into the following fricative. The nature of the release can be interpreted as indicative of whether this segment has been resyllabified with the following /s/ to form a complex onset of the following syllable. The following syllable contained the vowel /u/ in all the sentences since the clitic /su/ ‘your’ was kept constant. Average spectra of the release of [t] in the two conditions show indeed an effect of

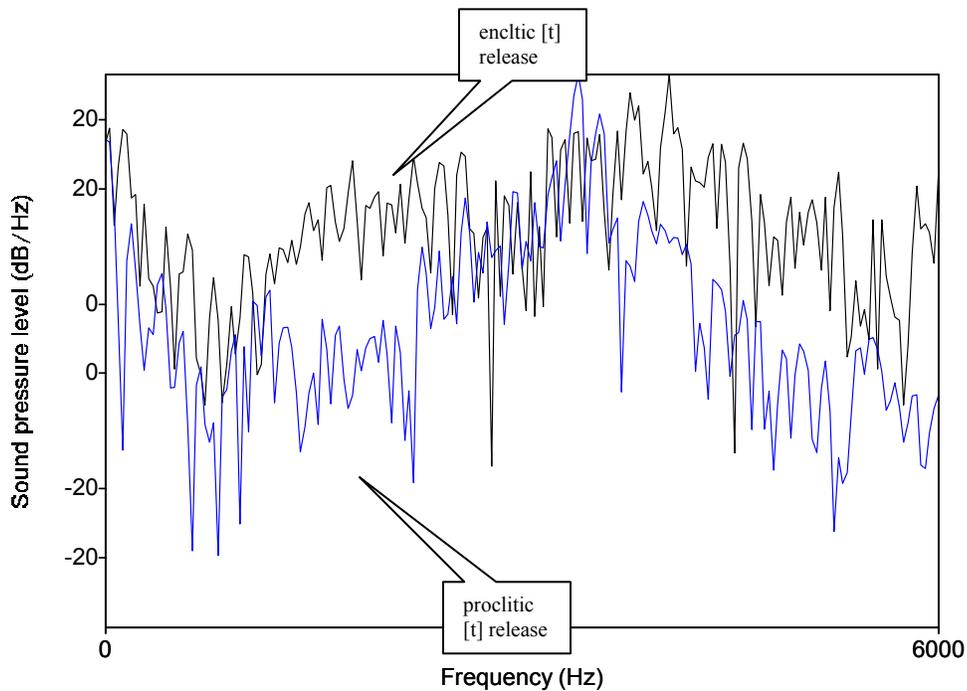


Figure 2.12. Average FFT spectra of [t] release when /su/ ‘your’ was part of the NP (dark, upper plot) and when it was part of the following VP (lighter, lower plot).

rounding when the [t] was not before a prosodic break (in the NP condition in table 2.2). In figure 2.12 we can observe that the higher intensity in the lower frequencies for the [t] release into the frication noise of [s] when there was no prosodic break between /t/ and /s/ is indicative of the rounding effect of the following /u/ vowel. This rounding effect is evident in the different spectral qualities of /s/ before round vowels than before non-round vowels in Greek. This effect of rounding would lend support to the analysis proposed—i.e. that there is resyllabification of [t] into a syllable onset affricate /ts/ in these cases. Temporally however, these sequences pattern differently than either non-tautosyllabic /t+/s/ sequences as in the VP condition in this experiment or the underlying word initial /ts/ affricates like the ones reported by Fourakis et al (2004). That is, the /t/ closure is similar to an underlying /ts/ affricate in the enclitic condition, and the /s/ duration is more similar to an underlying /ts/ affricate in the proclitic condition.

## 2.4 Discussion.

The first production experiment examined the occurrence of segmental sandhi in ambiguous sentences with the expectation that different prosodic conditions would influence its application. This prediction was partially verified in the third type of ambiguity employed in the test sentences, that of clitic

attachment. In the other two types of ambiguities, the adjective scope and prepositional phrase attachment cases, speakers did not consistently disambiguate the sentences by either intonational or segmental means. That is, in both renditions of these sentences speakers tended to apply the segmental sandhi of /s/ voicing and identical vowel degemination whenever the segmental context was present, without a consistent mapping of the process onto different syntactic structures hoped-for by the paraphrases of the test sentences. Furthermore, the output of the segmental sandhi in these cases could not be reliably compared between two different prosodic conditions since at the same time, and perhaps even more importantly, all five speakers failed to consistently disambiguate the sentences by means of an intonational boundary. One cannot be certain though that especially the /s/-voicing sandhi results in non-continuous neutralization between underlying /z/ and voiced /s/ phonetic output since additional aerodynamic measurements (such as airflow, electroglottography, palatography etc.) could perhaps point to different articulatory gestures in the two cases.

In the case of identical consonant degemination and affricate formation though, the data from this experiment seem to support the hypothesis that speakers can use segmental as well as intonational cues in order to disambiguate ambiguous sentences. All speakers successfully disambiguated the sentences with a clitic ambiguity through the use of an intonational boundary between the words containing the target segments. This allowed for more direct comparisons between

the two prosodic conditions. The output of consonant degemination, for at least the three of the five speakers who did not pause between the stops, showed evidence for continuous variation between the two prosodic conditions in the phonetic realization of /t/. Stop closure for the “geminate” [t] when there was a prosodic break between the two underlying /t/ segments was on average longer than either a singleton /t/ as reported in Fourakis et al. (2004) or a “degeminated” /t/ when there was no prosodic break between the two /t/ underlying segments. At the same time, a “degeminated” was also on average slightly longer by (~30ms), than the singleton /t/ stop closure duration of (~120ms) reported in Fourakis et al. That is there was no complete neutralization to a singleton /t/ as the output of the degemination sandhi. At the same time the temporal characteristics of a tautosyllabic /t+/s/ sequence seem to fall between the heterosyllabic /t+/s/ (with a prosodic break between them) presented here and the underlying /ts/ affricates in Greek as reported in Fourakis et al. That is, again, the output of this sandhi seems to be non-categorical, but continuous, since stop closure duration and release duration are intermediate between underlying /ts/ phonemes and sequences of /t+s/.

## CHAPTER 3

### THE PERCEPTION EXPERIMENT

#### 3.1 Introduction

All healthy human language users are both speakers and listeners. In the previous chapter we saw how speakers may apply external segmental sandhi in order to disambiguate some syntactic ambiguities. In this chapter, results from a perception experiment are presented that was designed to test how listeners might exploit the presence or absence of segmental sandhi in parsing correctly the intended (by the speaker) meaning of a syntactically ambiguous sentence. Scott and Cutler (1984) found that English listeners can indeed exploit segmental cues (such as flapping and palatalization) in order to correctly identify the presence or not of a phrasal boundary in certain ambiguous sentences.

The results of the production study presented in the previous chapter indicated that at least the segmental sandhi of identical stop degemination is not normally applied across a prosodic boundary in Greek. However, there were a few

productions where there was no clear intermediate phrase boundary at all between the Noun Phrase and the Verb Phrase. Three such sentences were produced by Speaker 1 and two sentences by Speaker 2 when a prosodic break was expected between the noun and the clitic (see table 2.1). Additionally, there were a few more productions by all speakers with no clear prosodic break when the prosodic break was expected between the clitic and the Verb.

As for the other two types of ambiguities, involving the Adjective Scope and PP attachment, speakers did not consistently disambiguate the two different readings of the sentences by means of a prosodic break. In an ideal situation, we would have liked to have productions by the speakers where intonational markings and segmental events varied orthogonally. That is a sentence fragment that was produced four different ways by the speakers: (i) with a boundary tone and no segmental sandhi, (ii) without a boundary tone but with segmental sandhi, (iii), with both a boundary tone and segmental sandhi and (iv) without either a boundary tone or segmental sandhi. From the production experiment results, the closest to filling these four different possibilities was the sentences produced by speakers of the test materials designed to elicit identical consonant (/t/) degemination sandhi in the clitic attachment ambiguity condition. In the NP condition, sentences of type (ii) were the norm, and in the VP condition, sentences of type (i) predominated. However, there were a few productions in the VP condition where an intonationally-marked prosodic break (ip boundary tone [H-])

was present at the same time that the /t/ stop closure duration was short in absolute value. For example, Speaker 2 produced a sentence *with* a prosodic break and /t/ stop closure duration of 108ms whereas Speaker 5 produced a sentence *without* a prosodic break and /t/ closure duration of 101ms. This means that, in absolute duration values of stop closure, their productions were comparable even though these were intended to be integrated as opposite readings of the ambiguous sentence, and were marked as different in different ways in terms of the different alignment of the prosodic break (early, at the sandhi site for speaker 2 and late, after the sandhi site for speaker 5). That is, there was an intonational contrast but their stop closures when compared directly were similar. This overlap in absolute stop closure duration in the two different prosodic conditions across speakers, but not within speakers is shown in figure 2.9 (especially for Speakers 2, 4 and 5). Of course, each individual speaker as shown in the plot in Figure 2.9 clearly differentiated in terms of stop closure duration between their two readings, but the absolute value overlap is fortuitous in order to “artificially” generate a 2x2 design where segmental sandhi (in absolute stop closure duration values) and intonational boundaries could be varied orthogonally in a perception test.

In order to avoid confounding “application or not of the sandhi rule” with inter-speaker variation in speaking rate it is necessary to establish first that the “long” durations in type (iv) were not long because these speakers were just slower and the “short” durations in type (iii) were not short because these speakers

were just faster. In order to do this it is necessary to show that there is no real difference in speaking rate across the speakers. This is evident in figure 3.1 in which /t#t/ duration is plotted against the duration of the vowel [o] in the definite article /to/ ‘the NEUT’ which is constant in the beginning of 4 out of the 6 stimuli senteces (See Appendix A).

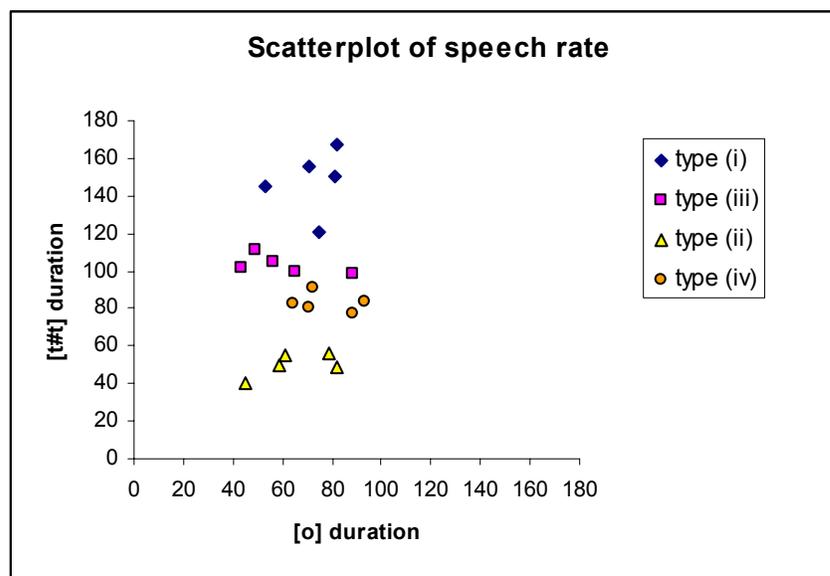


Figure 3.1 Duration of /t#t/ closure plotted against duration of constant interval in speakers productions for the four different types of sentences selected.

There is perfect overlap in [o] duration as produced by speakers 2, 4 and 5 between all four groups of /t/ closure duration (from the same speakers) that were selected as stimuli for the perception experiment. The duration of the vowel [o] ranged from 40 to about 90 milliseconds between all three speakers. By selecting

sentences from different speakers with or without a prosodic break and with long or short stop closure intervals, sentences of type (i) through (iv) could be used in a perception test in order to see what may be the functional role of segmental sandhi in the correct parsing of ambiguous sentences.

## 3.2 Method

### 3.2.1 Materials.

From the total number of 740 sentences produced by the five speakers in the production experiment a subset consisting of 20 sentences repeated 5 times each in a pseudo-randomized order (so as to avoid consecutive presentation of the same sentence with different prosodic or segmental cues). All 20 stimuli sentences were selected from the third set of materials of the production experiment that were designed to elicit identical stop /t/ degemination in sentences with a clitic attachment ambiguity. The 20 stimuli sentences were selected according to the criteria shown in Table 3.1.

With a Prosodic Break	Without a Prosodic Break
<b>Type (i):</b> No Sandhi (long /t/ ~150ms)	<b>Type (ii):</b> Sandhi (short /t/ (~50ms)
<b>Type (iii):</b> Sandhi (“short” /t/, ~100ms)	<b>Type (iv):</b> No sandhi (“long” /t/ (~80ms)

Table 3.1 Types of stimuli sentences for perception experiment. Types (iii) and (iv) contained “pseudo-sandhi”. That is “short” and “long” in absolute values. Mean durations in milliseconds (ms) of /t/ stop closure for each type are also shown.

In Table 3.1, sentences from “fast” and “slow” speakers were juxtaposed. That is speakers for whom, when they applied the /t/ degemination rule, their stop closure duration was similar to the absolute stop closure durations in productions by speakers who did not apply the degemination rule. Five sentences of each type were selected from the production materials of the clitic ambiguity test sentences (see Appendix A) produced by all speakers in the No Break condition, but only from Speakers 2, 4 and 5 only in the Prosodic Break condition. Productions from Speakers 1 and 3 in the Prosodic Break condition were not included because they consistently released the first stop. There were also 50 filler sentences, also taken from the production experiment that contained the two other kinds of segmental sandhi tested in the production study (/s/ voicing and identical vowel degemination). These sentences were not matched for presence or absence of sandhi or prosodic break since the results of the production study were not conclusive. Sentences with possible affricate formation were not included in the

stimuli sentences. Thus, there were  $20 \times 5 = 100$  target sentences and 50 filler sentences for a total of 150 sentences that were heard by each participant.

### 3.2.2 Participants

There were a total of 14 listeners who participated in the perception experiment. 12 of them were tested in Thessaloniki, Greece, where they were undergraduate students at the Aristotle University, and 2 were tested in Larissa. All participants were originally from Athens and they either lived or studied in Thessaloniki and Larissa. All listeners were native speakers of Standard Modern Greek with no distinct regional accents. There were 8 females and 6 males, and all the listeners were in the twenties and thirties. None of them reported any speech or hearing problems. They were all volunteers.

### 3.2.3 Procedure.

The 14 listeners were asked to listen individually to the stimuli sentences over headphones. They were given answer sheets which included paraphrases of the two possible meanings of the test sentences (see appendix A). The listeners were provided with typewritten paraphrases of the two possible meanings and they had to check the one they thought most closely corresponds to their interpretation

of the aurally presented sentences. For example, one of the four types (i-iv) of the sentence in (1) was heard by the participants over headphones.

- (1) Τα πλακάτ του κρύβουνε τον ήλιο.  
/ta pla'kat tu 'krivune ton 'ilio/  
'the placards his/to-him hide the sun'

And then on the sheet of paper they had to circle one of the following two possible paraphrases of (1):

- a. Τα δικά του πλακάτ, κρύβουνε τον ήλιο στον κόσμο.  
/ta ði'ka tu pla'kat krivune ton ilio ston kosmo/  
'his own placards hide the sun from the people/'
- b. Κάποια πλακάτ, τα οποία δεν είναι δικά του, κρύβουνε τον ήλιο από αυτόν.  
/kapia plakat, ta opia ðen ine ðika tu, krivune ton ilio apo afton/  
'some placards which are not his, hide the sun from him'

The order of paraphrases (a) and (b) was balanced across sentences so as not to bias the listeners' responses. The 150 sentences were divided into three blocks and their order varied between participants. For each block the 50 sentences contained both target sentences (with /t/ degemination sandhi and clitic ambiguity) and fillers with the other two types of sandhi and ambiguities. The sentences were played over headphones at a constant amplitude level and each listener heard each sentence only once without the possibility of playback. They were given the answer sheets and a pencil and they were asked to decide on the paraphrase that best matched their interpretation of the heard sentence as quickly as possible. The pace of the presentation of the stimuli sentences over headphones was controlled

by the experimenter. Each answer sheet contained the paraphrases of 10 stimulus sentences.

### 3.3 Results and discussion

The tabulated responses for the target sentences are shown in table 3.2. If a listener checked the paraphrase that matched the speaker's intention (as indicated to him or her during the recording by the same paraphrase) for the sentence heard, it was counted as a correct response. If the listener did not choose the intended meaning then it was counted as an error. Under the assumption that there would be an equal likelihood for both meanings of the ambiguous sentences without any auditory information, then the probability of correctly guessing each speaker's intention can be expected to be influenced solely by the different prosodic and segmental cues contained within the spoken productions of these sentences.

	<b>long /t/</b>	<b>short /t/</b>
<b>H-</b>	<b>Type (i)</b> 97% correct	<b>Type (iii)</b> 89% correct
<b>no H-</b>	<b>Type (ii):</b> 91% correct	<b>Type (iv)</b> 94% correct

Table 3.2. Percent correct of responses.

From the first row of results in table 3.2 we can see that listeners made fewer errors when, in addition to the presence of a tonally marked prosodic break between the noun and the following clitic, sandhi was blocked as in type (i). That is the combination of a clear tonally marked prosodic boundary with the absence of segmental sandhi (= long /t/ stop closure) yielded the most correct responses (97%). By contrast, when despite the presence of a prosodic break, sandhi was “not blocked”- that is the /t/ closure duration was comparatively somewhat short as in type (iii)- there were the fewest correct responses (89%).

From the second row of results, we can see that when there was no prosodic break, listeners were slightly more accurate (94%) when “canonical” sandhi was present- that is /t/ stop closure duration was very short as in type (ii)- by comparison to when sandhi “was blocked,” that is /t/ stop closure duration was somewhat longish as in type (iv) (91%).

Results from this experiment lend support to the hypothesis of the potential functional role that segmental sandhi can play in the processing of ambiguous speech. This of course does not mean that a gestural overlap account à la Browman and Goldstein (see discussion in section 2.1.1) of segmental sandhi is not still valid, but that once such gestural overlap takes place between adjacent segments across word boundaries listeners can use it as a reliable cue to the prosodic organization of a sentence. The continuous output of certain segmental sandhi, such as identical stop degemination in Greek, can especially be re-

interpreted dynamically by listeners in their attempt to successfully resolve a potential ambiguity when other more salient cues, such as an intonational boundary tone or a strong semantic, morpho-syntactic or pragmatic bias, are lacking. These persistent mental categorizations of continuous output of optional phonological rules could perhaps lead over time to their eventual non-optional or non-phonological nature such as, for example, in the case of Celtic consonant mutations, where in the absence of the initial conditioning environment such processes have become grammaticalized and independent of phonetic context (Awbery, 1986).

## CHAPTER 4

### SECOND PRODUCTION EXPERIMENT

#### 4.1 Background

Chapters 2 and 3 reported production and perception data regarding the frequency and nature of segmental sandhi in Greek scripted ambiguous sentences collected in a laboratory setting. This chapter looks at the frequencies of occurrence of segmental sandhi in adult spontaneous (non-scripted) speech. This second production experiment was conducted in order to see whether the frequencies of sandhi in two different speech styles were different. The two different speech styles tested in this experiment were (i) adult speech directed towards other adults (AD speech) and (ii) adult speech directed towards young children between the ages of 10 and 18 months old (CD speech).

There is evidence from the literature (e.g. Malsheen 1980) that suggests that the type of speech addressed to children is acoustically more distinct and better specified with regard to segmental phonology than that addressed to adults.

At the same time, other studies (Shockey and Bond, 1980) have found the application of optional phonological rules such as palatalization and /ð/ deletion in English to be more common in child-directed (CD) speech than in adult-directed (AD) speech. Ratner (1984), however, claimed the exact opposite results for such optional phonological processes in English. Ratner found these processes to be used much less frequently by mothers in CD speech rather than AD speech.

With such conflicting results from the literature on these English processes, it would be interesting to see how some of the segmental sandhi processes discussed so far pattern in Greek CD and AD speech.

## 4.2 Method

### 4.2.1 Participants.

Three mother-infant dyads were recorded in Thessaloniki, Greece. The mothers were all native speakers of Greek in their late twenties and early thirties and the infants were 11, 14 and 17 month-old girls. The mothers were all volunteers and a small gift was given to them for the child at the end of the experiment.

#### 4.2.1 Procedure

The three mother-infant dyads were recorded separately while interacting with their child. The recording took place at each participant's home during play or feeding time. Mothers wore a Phillips cardioid lavalier microphone and were recorded on a CDR 3000 Marantz Compact Disk recorder. The recordings were saved as stereo digital files sampled at 44.1KHz. Each mother was recorded for about 30 minutes interacting with her daughter. Each mother was instructed to assume her normal routine and to speak to her daughter in a normal way as she would in everyday life activities such as playing, feeding, cleaning etc. After the end of the CD speech recording, the experimenter interviewed each mother for an additional 30 minutes approximately in order to elicit some spontaneous AD speech for comparison purposes. The AD speech was a casual conversation where the experimenter asked some questions about the CD speech recording session and answered questions that the mothers had about the purpose of the study.

#### 4.2.2 Analyses.

Each recording session was transferred onto a computer and each utterance was transcribed by using Praat (see Chapter 2 for transcription methods). The

presence of sandhi was noted on a separate tier as seen in Figure 4.1. Label conventions for different sandhi phenomena were used to annotate the recordings at the sites in the utterances where sandhi occurred. Sites of possible sandhi were also noted when sandhi did not apply. As it can be seen in figure 4.1 each utterance was phonemically transcribed and tagged as to whether it was part of AD speech [ADS] or CD speech [CDS].

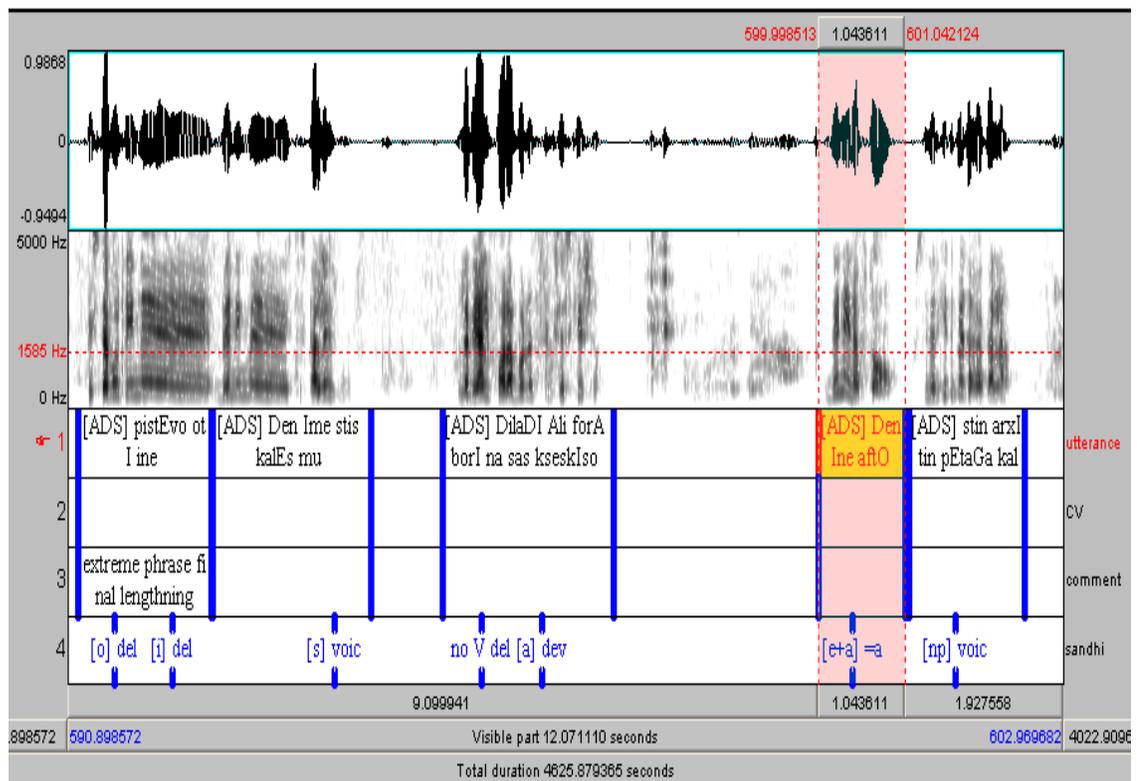


Figure 4.1 Segmentation and annotation of AD speech.

The different sandhi phenomena noted were grouped into two major categories: (i) Sandhi that affected vowels and (ii) sandhi that affected consonants. For the vowel sandhi the two most common processes were vowel deletion and vowel devoicing. With vowel deletion the vowel deleted was noted in square brackets, or sometimes when the output of a vowel-vowel sequence was indeterminate, a notation such as the one highlighted in Figure 4.1 was used ([e+a]=a). This means that by judging impressionistically, and without detailed acoustic analyses such as the ones used by Baltazani (2003) for vowel-vowel coalescences, the vowel deletion was perceived to result in a vowel indeterminate between [e] and [a] but closer to an [a]. With vowel devoicing the vowel devoiced was also noted in square brackets.

For the consonant sandhi, the most common process was post-nasal voicing, a sandhi process not tested in the first production experiment. The second most common process was consonant weakening— ie. stops pronounced as fricatives or glides, and the third was consonant deletion. Deletions were mostly of word final nasals before fricatives and sonorants, but there were also deletions of other stops and fricatives. The two consonantal segmental sandhi tested in the first experiment in sentences with clitic ambiguities -identical stop degemination, and /ts/ affrication- were not very common in this experiment due to the fact that very few words in Greek end in stops. However, /s/ voicing, a process included in the first experiment in sentences with adjective or adverb scope ambiguity was another quite frequent process. As in the first experiment, /s/ voicing in this study

was completely categorical in its application and showed a non-continuous output of fully voiced [z], except when it too was deleted or severely undershot, in both AD and CD speech.

#### 4.3 Results and discussion.

The results from the frequency calculations of segmental sandhi in CD and AD speech are shown in table 4.1. As far as vowel sandhi, the difference in frequency between CD and AD speech was not significant ( $\chi^2= 0.1171$ ,  $p<1.0$ ). With regard to consonant sandhi however, there was a clear difference between CD and AD speech in the probability of its application given the right segmental context ( $\chi^2= 4.2083$ ,  $p<.05$ ). In the case of CD speech sandhi applied in only 62% of the possible times where sandhi could have applied. By contrast, in the case of AD speech it was applied 92% of the time, a difference of 30% in its probability of application, under the assumption of equal likelihood in both styles of speech.

Dyad	CDS		ADS	
	V-Sandhi	C-Sandhi	V-Sandhi	C-Sandhi
1	87% (67/78)	64%(35/55)	87%(77/89)	93%(43/46)
2	80%(44/55)	59%(23/39)	85%(33/39)	93%(27/29)
3	88%(49/56)	63%(31/49)	94%(65/69)	92%(49/53)
Total	85%(160/189)	62%(89/143)	89%(175/197)	93%(119/128)

Table 4.1. Instances of V(owel)-Sandhi and C(onsonant)-Sandhi in CD and AD speech. The first number in each column represents the number of times sandhi was observed and the second number indicates the number of segmental environments identified in the data in which this sandhi could apply.

The interesting result is that mothers tended to avoid consonantal sandhi in their speech to their daughters more than in their speech to the adult experimenter. The most common environment that C-Sandhi could apply but was not applied by the mothers was that of consonant weakening and/or deletion. This could be perhaps the result of speaking at a faster rate when addressing an adult, which could compress many gestures required for the clear articulation of many stop consonants in Greek especially in weak prosodic positions (most notably as syllable codas).

## CHAPTER 5

### GENERAL DISCUSSION AND CONCLUSION

#### 5.1 Summary of dissertation

This dissertation examined the effect of a number of segmental sandhi phenomena on the parsing of ambiguous sentences in Greek. The production experiments in chapters 2 and 4 investigated the phonetic realization of these phenomena with regard to the prosodic structure of Greek in these speech styles- i.e. scripted lab speech and non-scripted AD and CD speech, and the perception experiment in chapter 3 examined their role in the disambiguation of morpho-syntactically ambiguous sentences.

## 5.2 General Discussion

This dissertation has argued for a functional interpretation of segmental sandhi in the production and perception of speech. Phonological rules showing gradience in their application and with continuous phonetic output, such as some of the segmental sandhi in Greek examined here, offer the possibility of taking a synchronic glimpse at the very processes of generation of new phonetic patterns in a spoken language. The phonological material at the edges of words is particularly vulnerable to slight modifications that can arise from the interaction between various underlying segments not normally adjacent in word-internal positions. For example, the phonotactically impossible sequence /sm/, not found in any word in Greek, despite the orthography of some of them such as *κόσμος* /kozmos/ ‘world’, is a very common sequence across word boundaries. It occurs whenever a /s/-final word –and there is a very large number of such words in the lexicon of Greek- is followed by a not infrequent /m/-initial word (similarly for other sequences of /s/ and other quite frequent sonorant-initial words, where /s/ is normally voiced). The categorical application of /s/-voicing sandhi and its non-continuous invariably voiced output are thus not surprising since the sequence /sm/ is not attested anywhere in the lexicon whereas the output of other sandhi rules usually is found in different contexts too. However, when the need arises in a pressed situation to try to disambiguate between two competing interpretations of the same sentence

speakers can and do produce a voiceless [s] before a sonorant [m], as seen in Figure 2.3. Admittedly, these productions were erratic and not used as a consistent cue to prosodic disjuncture, but suppression of voicing did occur in some instances for at least one speaker in the production study.

### 5.3 Conclusion.

The exact nature and scope of the various sandhi rules require carefully controlled investigations of the precise segmental, prosodic and morpho-syntactic environments in which they occur. In this study, attempts were made to design methodologies for the careful description and analysis of segmental sandhi using scripted laboratory speech and a small corpus of naturally occurring speech. The results from these experiments indicate that speakers and listeners can employ segmental sandhi, whether they are the result of “automatic” phonetic implementation due to overlapping articulatory gestures or of categorical post-lexical rules, as a phonetic enhancement to other prosodic cues in the generation and parsing of speech. Furthermore, it was found that the phonetic outcome of segmental sandhi in Greek is not uniform in the nature of its output across the different sandhi processes investigated here. The fact that some processes such as /s/-voicing seem to result in non-continuous outputs- i.e. a fully voiced [z], is due

to possible inherent non-linearities in the mapping from articulation to acoustics and to other aerodynamic characteristics of the production of voiced and voiceless fricatives. It is not articulatorily easy to start out with a voiceless fricative [s] and have it partially voiced to a [z] before a following sonorant. The opposite is very likely though, that is, for a voiced [z] to become partially devoiced to a [s] towards the end of its production. This happens because maintaining glottal frication and oral frication when the pressure is equalized above and below the larynx is articulatorily and aerodynamically difficult.

Finally, it is evident from the data collected in the second production experiment involving non-scripted spontaneous speech that segmental sandhi is very frequent in spoken Greek. It is a characteristic of the language that is not merely stylistic, but one that is part of the phonological grammar of standard Greek as shown by the presence of sandhi in the speech collected even in formal experimental interviews. If one were to assume that, in the case of adult-directed speech collected under a formal interview setting, more intense self-monitoring of speech would result in a less casual, more formal style, or at least more careful than that when addressing children, then the presence of sandhi in interviews would support its importance in the phonological grammar of the language. In other words, “Sunday” Greek, meaning the very formal register assumed by many speakers under many non-casual (hence “Sunday”, as in the expression *to wear one’s Sunday’s (best) clothes*) communicative situations reported by Kazazis

(1968) is not a stranger to sandhi. One would expect sandhi to be turned off in “Sunday” Greek, and indeed speakers can produce “spelling” pronunciations, undoing many of the natural sandhi processes, but the data collected in this thesis do not support this expectation. Moreover, if one were to assume that the reading of scripted sentences in the first experiment and the production of adult-directed speech in the third experiment are closer to what Kazazis called “Sunday” or formal Greek than the child-directed speech produced in the third experiment, the fact that there is more sandhi in the formal adult-directed style than in the child-directed style makes “Sunday” Greek a more likely style for sandhi to be applied than child-directed Greek. However, as Kazazis notes, hypercorrections are frequent in “Sunday” Greek and, even though none were found in this study, further investigations of “Sunday” versus casual speech styles and segmental sandhi are needed in order to firmly claim that “Sunday” Greek does not systematically avoid sandhi, and that native speakers will not block sandhi in environments where there are no alternations (word-internally) or alternatively apply it where the prosodic context should block it.

Further cross-linguistic investigations of segmental sandhi, in various speech styles and in spontaneous speech, are needed in order to establish a complete sandhi typology and to define in more detail its functional role in the generation and parsing of speech. I leave that as a task for the future.

## APPENDIX A

### STIMULI SENTENCES

#### **English Translations:**

##### **Sentences for production experiment 1.**

1. They saw many women with confidence.
2. They heard many people with poise.
3. They saw many men with anger
4. They saw many opponents with conceit.
5. They consulted many tour guides with earnestness
6. They confronted many enemies with passion

##### **Sentences for production experiment 2.**

1. We saw black goats and hens in the village.
2. They heard new melodies and serenades at the party
3. They sold new stocks and insurance today.
4. We saw many new lawyers and judges at the reception.
5. We bought Japanese adaptors and computers
6. They brought fancy garlands and ribbons for the wedding.
  
7. They saw fast airplanes and ships
8. We ate some lambs and chickens
9. They picked wild shrubs and herbs in the forest.
10. New employees and owners came to the meeting.
11. Devout supplicants and visitors came to the temple.
12. Rich Italians and Russians sat in the first rows.

### **Sentences for production experiment 3.**

1. Your placards are obstructing the sun.
2. Your mascot ruined the party.
3. Your Fiat ran out of gas.
4. Your yacht blocks the view.
5. Your robot destroyed the desk.
6. Your shot broke the glasses.

1. His placards are obstructing the sun.
2. His mascot ruined the party.
3. His Fiat ran out of gas.
4. His yacht blocks the view.
5. His robot destroyed the desk.
6. His shot broke the glasses.

### **Greek Originals:**

Set 1.

Υλικό 1. (PP attachment ambiguity).

Αρχεία: GL\_ppatt\_vp[1-6].wav

#### **1. Γνωρίσαμε πολλές γυναίκες, με αυτοπεποίθηση.**

(δηλαδή, εμείς είχαμε αυτοπεποίθηση, όταν γνωρίζαμε τις γυναίκες).

#### **2. Ακούγαμε πολλούς ανθρώπους, με σιγουριά.**

(δηλαδή, εμείς ακούγαμε με σιγουριά, τους ανθρώπους)

#### **3. Είδαμε κάποιους άντρες, με θυμό.**

(δηλαδή εμείς ήμασταν θυμωμένοι όταν είδαμε αυτούς τους άντρες)

#### **4. Νικήσαμε πολλούς αντιπάλους, με όπλα.**

(δηλαδή χρησιμοποιήσαμε όπλα για να νικήσουμε τους αντιπάλους)

**5. Συμβουλευτήκαμε πολλούς ξεναγούς, με λεξικά.**

(δηλαδή χρειάστηκε να χρησιμοποιήσουνε λεξικά για να συμβουλευτούμε τους ξεναγούς)

**6. Αντιμετωπίσαμε πολλούς εχθρούς, με πάθος.**

(δηλαδή εμείς είχαμε πάθος όταν αντιμετωπίζαμε τους εχθρούς).

Αρχεία: GL\_ppatt\_np[1-6].wav

**1. Γνωρίσαμε, πολλές γυναίκες με αυτοπεποίθηση.**

(δηλαδή εμείς γνωρίσαμε κάποιες γυναίκες και οι γυναίκες αυτές είχανε αυτοπεποίθηση. Γνωρίσαμε κάποιες γυναίκες που είχαν αυτοπεποίθηση).

**2. Ακούγαμε, πολλούς ανθρώπους με σιγουριά.**

(δηλαδή ακούγαμε ανθρώπους που ήτανε σίγουροι· που είχανε σιγουριά)

**3. Είδαμε, πολλούς άντρες με θυμό.**

(δηλαδή ακούγαμε πολλούς θυμωμένους άντρες· άντρες που ήτανε θυμωμένοι).

**4. Νικήσαμε, πολλούς αντιπάλους με όπλα.**

(δηλαδή νικήσαμε πολλούς οπλισμένους αντιπάλους· οι αντίπαλοί μας είχανε όπλα).

**5. Συμβουλευτήκαμε, πολλούς ξεναγούς με λεξικά.**

(δηλαδή συμβουλευτήκαμε ξεναγούς που κρατάγανε λεξικά· οι ξεναγοί είχανε λεξικά).

**6. Αντιμετωπίσαμε, πολλούς εχθρούς με πάθος.**

(δηλαδή οι εχθροί μας είχανε πάθος· αντιμετωπίσαμε πολλούς παθιασμένους εχθρούς).

## Υλικό 2. Adjective scope ambiguity.

Αρχεία: GL\_adjCC\_first[1-6].wav

### 1. είδαμε άσπρες γάτες, και κότες στο χωριό.

(δηλαδή είδαμε γάτες που ήτανε μύρες και κάποιες κότες που μπορεί να ήτανε οποιοδήποτε χρώμα).

### 2. ακούσαν παλιές μελωδίες, και μαντινάδες στο πάρτυ.

(δηλαδή ακούσανε μελωδίες που ήτανε παλιές και κάποιες μαντινάδες που μπορεί να ήτανε από οποιαδήποτε χρονολογία).

### 3. πουλήσαμε καινούργιες μετοχές, και ασφάλειες σήμερα.

(δηλαδή πουλήσαμε μετοχές που ήτανε καινούργιες και ασφάλειες που μπορεί να ήτανε από οποιαδήποτε χρονολογία).

### 4. είδαν πολλούς νέους δικηγόρους, και δικαστές στη δεξίωση.

(δηλαδή είδαμε δικηγόρους που ήτανε νέοι, και δικαστές γενικώς· απροσδιόριστης ηλικίας).

### 5. αγοράσαμε ιαπωνικούς μετασχηματιστές, και υπολογιστές.

(δηλαδή οι μετασχηματιστές ήτανε από την Ιαπωνία και οι υπολογιστές γενικώς, δηλαδή μπορεί να ήτανε και από άλλες χώρες)

### 6. φέραν περίτεχνες γιρλάντες, και κορδέλλες για το γάμο.

(δηλαδή οι γιρλάντες ήτανε περίτεχνες, και οι κορδέλλες μπορεί να ήτανε και απλές).

Αρχεία: GL\_adjCC\_both[1-6].wav

**1. είδαμε μαύρες, γίδες και κότες, στο χωριό.**

(δηλαδή και οι γίδες και οι κότες ήτανε μαύρες)

**2. ακούσανε παλιές, μελωδίες και μαντινάδες, στο πάρτυ.**

(δηλαδή και οι μελωδίες και οι μαντινάδες ήτανε παλιές).

**3. πουλήσαμε καινούργιες, μετοχές και ασφάλειες, σήμερα.**

(δηλαδή και οι μετοχές και οι ασφάλειες ήτανε καινούργιες).

**4. είδανε πολλούς νέους, δικηγόρους και δικαστές, στη δεξίωση.**

(δηλαδή και οι δικηγόροι και οι δικαστές ήτανε νέοι).

**5. αγοράσαμε ιαπωνικούς, μετασχηματιστές και υπολογιστές.**

(δηλαδή και οι μετασχηματιστές και οι υπολογιστές ήτανε ιαπωνικοί).

**6. φέρανε περίτεχνες, γιρλάντες και κορδέλλες, για το γάμο.**

(δηλαδή και οι γιρλάντες και οι κορδέλλες ήτανε περίτεχνες).

Αρχεία: GL\_adjVV\_first[1-6].wav

**7. είδαμε όμορφα αμάξια, και μηχανάκια στην έκθεση.**

(δηλαδή μόνο τα αμάξια ήτανε όμορφα)

**8. φάγαμε νόστιμα ακτινίδια, και πεπόνια στο χωριό.**

(δηλαδή μόνο τα ακτινίδια ήτανε νόστιμα).

**9. μαζέψαμε όμορφα αγκάθια, και βότανα στο δάσος.**

(δηλαδή μόνο τα αγκάθια ήτανε άγρια).

**10. ήρθαν νέοι υπάλληλοι, και ιδιοκτήτες στη συγκέντρωση**

(δηλαδή μόνο οι υπάλληλοι ήτανε νέοι)

**11. έρχονται άσπνοι, ικέτες και επισκέπτες στο ναό.**

(δηλαδή μόνο οι ικέτες ήτανε άσπνοι)

**12. καθήσαν άοπλοι Ιταλοί, και Ρώσοι στις πρώτες θέσεις.**

(δηλαδή μόνο οι Ιταλοί ήτανε άοπλοι).

Αρχεία: GL\_adjVV\_both[1-6].wav

**7. είδαμε όμορφα, αμάξια και μηχανάκια στην έκθεση.**

(δηλαδή και τα αμάξια και τα μηχανάκια ήτανε όμορφα).

**8. φάγαμε νόστιμα, αρνάκια και κοτόπουλα, στο χωριό.**

(δηλαδή και τα αρνάκια και τα κοτόπουλα ήταν νόστιμα).

**9. μαζέψαμε άγρια, αγκάθια και βότανα, στο δάσος..**

(δηλαδή και τα αγκάθια και τα βότανα ήταν άγρια).

**10. ήρθαν νέοι, υπάλληλοι και ιδιοκτήτες, στη συγκέντρωση**

(δηλαδή και οι υπάλληλοι και οι ιδιοκτήτες ήταν νέοι).

**11. έρχονται σεβάσμιοι, ικέτες και επισκέπτες, στο ναό.**

(δηλαδή και οι ικέτες και οι επισκέπτες ήταν σεβάσμιοι).

**12. καθήσαν πλούσιοι, Ιταλοί και Ρώσοι, στις πρώτες θέσεις.**

(δηλαδή και οι Ιταλοί και οι Ρώσοι ήταν πλούσιοι).

Υλικό 3. Clitic Ambiguity

Αρχεία: GL\_cITS\_np[1-6].wav

**1. τα πλακάτ σου, κρύβουνε τον ήλιο από τον κόσμο.**

(Τα δικά σου πλακάτ, τα πλακάτ που ανήκουνε σε σένα, κρύβουνε τον ήλιο από τον κόσμο).

**2. η μασκώτ σου, χάλασε το πάρτυ της Μαρίας.**

(η δικιά σου μασκώτ χάλασε το πάρτυ)

**3. το φιάτ σου, έμεινε από βενζίνη όταν το οδήγησα.**

(το δικό σου φιάτ έμεινε από βενζίνη)

**4. το γιωτ σου, κόβει τη θέα στους περαστικούς.**

(το δικό σου γιωτ κρύβει τη θέα).

**5. το ρομπότ σου, κατέστρεψε το γραφείο τους.**

(το δικό σου ρομπότ κατέστρεψε το γραφείο)

**6. το σουτ σου, έσπασε τα γυαλιά του Ηρακλή.**

(το δικό σου σουτ, του έσπασε τα γυαλιά).

Αρχεία: GL\_cITS\_γρ[1-6].wav

**1. τα πλακάτ, σου κρύβουνε τον ήλιο.**

(κάποια πλακάτ σε εμποδίζουνε να δεις τον ήλιο).

**2. η μασκώτ, σου χάλασε το πάρτυ.**

(κάποια μασκώτ που δεν σου ανήκει, χάλασε το πάρτυ σου.)

**3. το φιάτ, σου έμεινε από βενζίνη.**

(το φιάτ και όχι το νισσάν που οδηγούσες έμεινε από βενζίνη).

**4. το γιωτ, σου κόβει τη θέα.**

(ένα γιωτ σε εμποδίζει να δεις).

**5. το ρομπότ, σου κατέστρεψε το γραφείο.**

(ένα τυχαίο ρομπότ κατάστρεψε το γραφείο σου).

**6. το σουτ, σου έσπασε τα γυαλιά.**

(ένα σουτ των αντιπάλων στο πρόσωπό σου έσπασε τα γυαλιά σου).

Αρχεία: GL\_cITT\_ηρ[1-6].wav

**1. τα πλακάτ του, κρύβουνε τον ήλιο από τον κόσμο.**

(Τα δικά του πλακάτ, τα πλακάτ που ανήκουνε σε αυτόν, κρύβουνε τον ήλιο από τον κόσμο).

**2. η μασκώτ του, χάλασε το πάρτυ της Μαρίας.**

(η δικιά του μασκώτ χάλασε το πάρτυ)

**3. το φιάτ του, έμεινε από βενζίνη όταν το οδήγησα.**

(το δικό του φιάτ έμεινε από βενζίνη)

**4. το γιωτ του, κόβει τη θέα στους περαστικούς.**

(το δικό του γιωτ κρύβει τη θέα).

**5. το ρομπότ του, κατέστρεψε το γραφείο τους.**

(το δικό του ρομπότ κατέστρεψε το γραφείο)

**6. το σουτ του, έσπασε τα γυαλιά του Ηρακλή.**

(το δικό του σουτ, έσπασε τα γυαλιά του Ηρακλή).

Αρχεία: GL\_clTT\_vr[1-6].wav

**1. τα πλακάτ, του κρύβουνε τον ήλιο.**

(κάποια πλακάτ τον εμποδίζουνε να δει τον ήλιο).

**2. η μασκώτ, του χάλασε το πάρτυ.**

(κάποια μασκώτ που δεν του ανήκει, χάλασε το πάρτυ του.)

**3. το φιάτ, του έμεινε από βενζίνη.**

(το φιάτ και όχι το νισσάν που οδηγούσε έμεινε από βενζίνη).

**4. το γιωτ, του κόβει τη θέα.**

(ένα γιωτ τον εμποδίζει να δει).

**5. το ρομπότ, του κατέστρεψε το γραφείο.**

(ένα τυχαίο ρομπότ κατέστρεψε το γραφείο του).

**6. το σουτ, του έσπασε τα γυαλιά.**

(ένα σουτ των αντιπάλων στο πρόσωπό του έσπασε τα γυαλιά του).

Words:

πες την λέξη μάζα ξανά.

πες την λέξη μάσα ξανά.

**Ματσάρα**

**Σάρα**

**Ματσούκι**

**Πλαζ (μου)**

**Ματς (σου)**

**Τσούζει**

**Ζάρα**

**πας**

## APPENDIX B

### SAMPLE CONSENT FORM

#### INFORMED CONSENT

**Title of the Study: The Role of Segmental Sandhi in the Parsing of Speech:  
Evidence from Greek**

**Description of the Study:** This experiment has been designed to look at variation in the pronunciation and perception of certain sounds and sound sequences when produced in words that belong to ambiguous sentences (sentences with more than one possible interpretation). The purpose of this study is to find out what kind of variation in pronunciation exists in spoken language when speakers need to make clear one meaning as opposed to another of an ambiguous sentence and how listeners use this type of variation to resolve ambiguities. The examination of variation in pronunciation and perception could give us important clues about how speakers internalize and use the sound system of their native language.

**Location:** All of the procedures will take place at your home.

**Procedures:** You will be recorded onto a compact disk recorder while wearing a head-mounted microphone. Your task will be to you will have to listen to some sentences with more than one possible meaning over headphones and then choose from the two possible meanings that will be given to you typed on a sheet of paper. You will have to decide which of the two paraphrases of the sentence you heard more closely describes your interpretation of it. You will listen to approximately 60 short sentences over headphones. The whole experiment will be about and hour in duration.

**Risks and Benefits:** There appear to be no risks involved in your participation in this study outside the inconvenience of the time taken from your usual routines. The major benefits of this study will be in the future and will relate to a better understanding of the

way speakers and listeners of language use variation in pronunciation in order to understand more efficiently spoken language.

**Confidentiality:** Your confidentiality will be preserved at all times. To preserve confidentiality, we will use a number instead of your name. Only the experimenters will have access to the participants' names. Thus, the confidentiality of the participants will be preserved. No information about you will be made available to others without your expressed written permission.

**Rights:** You have the right to have any questions regarding the research or your participation in this study answered now or in the future. The principal investigators are Brian Joseph, who is a Linguistics Professor at The Ohio State University, and Georgios Tserdanelis, who is a Ph.D. candidate at The Ohio State University. You can reach Georgios Tserdanelis at (614) 292-8878. You may withdraw from the study at any time.

I have read and understood the above description of the procedures, risks, and benefits of this study as well as my rights. All of my questions have been answered satisfactorily and I understand that any further questions will be answered. I voluntarily consent to participate in the described research study. A copy of this consent form has been given to me.

\_\_\_\_\_  
Signature of participant

\_\_\_\_\_  
Date

**Thank you for participating in this study**

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