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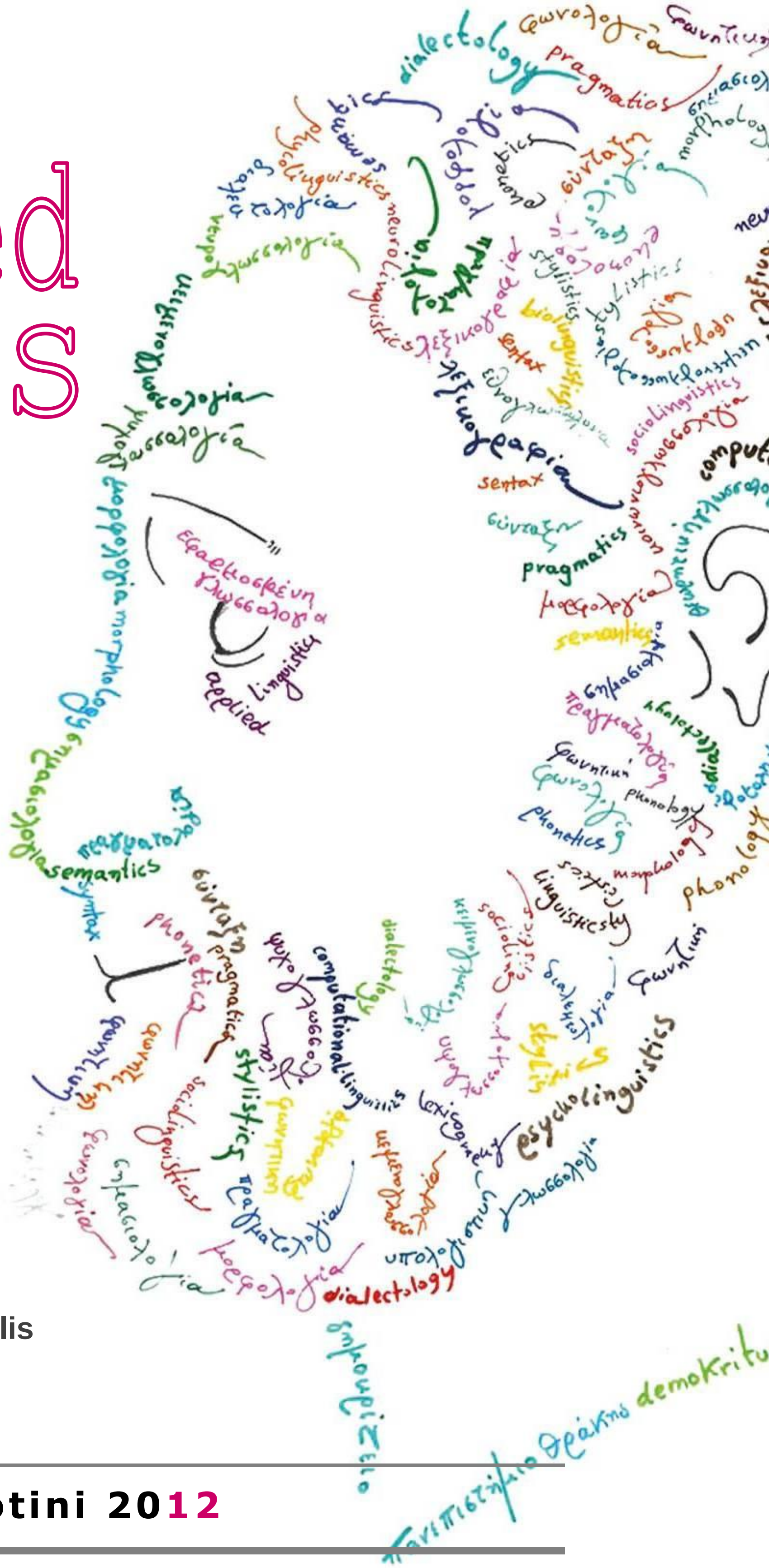

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The Acoustics of Post-nasal stop voicing in Standard Modern Greek

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ABSTRACT

This paper reports on a production and a perception experiment investigating post-nasal stop voicing in Greek with two goals: (i) to establish whether the process is categorical, and (ii) to identify the type of effect exercised by prosodic boundary strength on it. It is shown that the phenomenon is categorical, and is influenced categorically by boundary strength (it only occurs within the lowest domain of the prosodic structure). Variation is evident across lexical items, whereby some items undergo voicing more frequently than others. Experimental results are also presented on the acoustics of voiceless and voiced stops of Standard Modern Greek; voiceless stops have shorter closure duration, longer release duration and smaller amplitude within the closure and the release than voiced stops.

1. Introduction

Sandhi phenomena of Standard Modern Greek have gained a substantial amount of interest over the last years, as shown by several impressionistic and acoustic analyses investigating their application (e.g. for acoustic analyses Pelekanou and Arvaniti 2001, Baltazani 2006, Baltazani 2007, Kainada 2007, in press, Tserdanelis 2004, and for impressionistic analyses, Nespor and Vogel 1986, Condoravdi 1990, among many other studies in the area). Research interest on sandhi phenomena is mainly derived from the need to understand two different sides of their nature; first, their acoustic manifestation, and second the regulating factors of their application. This paper addresses both issues; using a perception and a production experiment it examines the acoustics of SV in Greek, compares it to those of voiceless and voiced stops, and investigates prosodic boundary strength effects on its application.

Results show that SV applies categorically, i.e. its acoustic manifestation is clearly divided in voiceless and voiced instances. Perceptually, SV is a very prominent process, since speakers of SMG classify voiceless vs. voiced instances with distinctive ease and high inter-rater agreement. Acoustically, SV instances are similar to those of voiced stops of SMG. Finally, results show that the prosodic structure exercises a categorical effect on SV application in that it is only allowed within the lowest post-lexical domain of the structure, while within that domain the phenomenon is optional and varries in frequency across different lexical items. Importantly, this paper compares, for the first time to my knowledge, the acoustics of voiceless and voiced stops in SMG.

1.1 Phonology and phonetics of post-nasal stop voicing

SV is a process whereby a voiceless stop assimilates in voice to the preceding nasal, as in example (1) from Modern Greek.

(1) τον πατέρα /ton pa'teɾa/ 'the father' → [toba'teɾa][1]

This is a phenomenon that has been attested in many languages, such as Modern Greek (Newton 1972), Japanese (Ito & Mester 1986) and others (see Hayes & Stivers 2000). In Modern Greek, the

[1] There is a question as to whether the voiced stop is preceded by a nasal, if the nasal is deleted or if it is retained as prenasalisation. This is not part of the current investigation (but see Arvaniti and Joseph 2000). In the example shown here the nasal is deleted.

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phenomenon can be found both lexically and post-lexically. Lexically, it is obligatory and can appear word-initially or word-medially, e.g. ντάμα (‘checkers’) (which can be produced as either ['dama] or ['^{n}dama], whereby prenasalisation is optional and is influenced by social factors and style, e.g. Arvaniti and Joseph 2004). Post-lexically voicing is optional, and again speakers have the option of prenasalisation (Arvaniti 1999). The present paper only deals with *post-lexical post-nasal stop voicing.*

The phonological/prosodic conditions that allow for the application of SV post-lexically are not clear. Nespor and Vogel (1986) proposed that prosodic structure regulates SV, in the sense that it will occur within a clitic group (henceforth CG), but will be blocked across CGs. In a somewhat circular reasoning, the authors proposed the existence of the CG as a domain of the prosodic hierarchy, on the basis that SV is disallowed across two of those domains. According to this analysis, SV is obligatory within prosodic words, optional within the clitic group, and is blocked across clitic groups ([-cont] → [+voice] / […[…[+nas]]ω[__...]ω…]$_{C}$). Examples (2a) and (2b) (Nespor and Vogel 1986:158-9) show two constructions, whereby in (2a) voicing is allowed, while in (2b) blocked the reason being, according to the authors, that the two words in 2a belong in the same CG, while the two words in 2b are two CGs.

(2a) δεν πειράζει → [ðembi'ɾazi]
(2b) όταν πας → *['otambas]

Malikouti-Drachman and Drachman (1988), on the other hand, refute that SV depends on prosodic constituency and propose that the distribution of its application can be analysed on the basis of syllabification. According to their analysis, SV takes place when the preceding nasal is syllabified with the onset of the syllable containing the stop, while when it is placed as the coda of the preceding syllable SV is not allowed.

Additionally to the above conflicting approaches, there is one overall point of criticism that has emerged in recent research regarding the treatment of sandhi phenomena. It has been shown that not all sandhi phenomena have a categorical outcome, as one would expect from their phonological description (e.g. Arvaniti 2007). For example, an acoustic analysis by Zsiga (1997) showed that vowel hiatus in Igbo is not resolved categorically via complete assimilation, as traditional phonological analyses would have it, but rather has a gradient output. Similarly, Pelekanou and Arvaniti (2001) and Baltazani (2007) have shown that /s/-voicing in SMG is a gradient process while Baltazani (2006) and Kainada (2007, and in press) have shown that vowel hiatus resolution is also a gradient process in SMG. All the above clearly showcase the need to link phonological analyses to acoustic studies, at least in the case of sandhi phenomena. The present paper aims at filling a gap in research by examining the acoustics of SV in SMG, specifically by testing whether SV applies categorically or gradiently and how boundary strength affects its application.

1.2 Phonology and phonetics of voiceless and voiced stops of SMG

Phonologically speaking, Modern Greek employs voiceless and voiced stops (Mirambel 1961, Mackridge 1985, Philippaki-Warburton 1992, Arvaniti 2007). Voiceless stops are unaspirated (Fourakis 1986b, Botinis, Fourakis & Prinou 1999, Arvaniti 2001, Nicolaidis 2002); voiced stops are fully voiced, i.e. voicing appears well before the burst and continues throughout the closure. While past research has examined the durational characteristics of voiceless stops in Greek (Fourakis 1986a, Arvaniti 2001, Nicolaidis 2001, Nicolaidis 2002) we are lacking studies examining the acoustic characteristics of voiced stops. In a recent study looking at the acquisition of voiced stops by greek children, Kong, Beckman and Edwards (2007) reported that durational and amplitude differences can distinguish between the two categories, but this was based on a single adult speaker[2]. Botinis et al. (1999) showed that closure duration was longer in voiced than voiceless stops and that VOT was longer in voiceless than voiced stops (see also Antoniou et al. (2011) regarding VOT as produced by bilingual speakers). In what follows, the acoustics of voiceless and voiced stops in SMG will be presented and compared, since the two categories will act as baselines against which SV instances are compared in Experiment 2 (§3.2.3).

[2] Panagopoulos (1974) also investigated voiced stops, but the presentation and methodology used for the acoustic and articulatory measurements makes it somewhat difficult to compare to current experimental acoustic analyses.

2. Experiment 1 – Voiceless and voiced stops

2.1 Method

2.1.1 Participants

Five native speakers (2 male, 3 female) of SMG, all in their twenties, were recorded. Recordings took place in an isolated recording booth at the University of Edinburgh. None of the participants had spent more than one year in the UK.

2.1.2 Materials

Speakers produced sentences containing the voiceless and voiced stops of Modern Greek in five prosodic positions (i.e., the strength of the boundary at the vicinity of which they appeared was gradually stronger, see Appendix A for template of constructing materials and for an example). These boundary conditions will henceforth be referred to as BC1-5, with BC1 having the weakest and BC5 the strongest boundary. In addition to materials for voiceless and voiced stops of SMG this production experiment included materials for SV. Clusters of 'nasal+stop' were placed at the exact same boundary conditions[3]. Moreover, one extra condition was created specifically for SV, named BC0. Items for this condition can be seen in Table 1. I focus on this final construction since, as we will see in §3.2.1, it is the only condition within which SV takes place. In addition, this is the domain designed to further probe Nespor and Vogel's (1986) analysis (see §1.1), since materials include words like /'otan/ and /ðen/.

Particle
/'otan/ 'when'
/an/ 'if'
/ðen/ 'not'
/min/ 'not'
/ton/ 'him'

+

Verb
/pace'taɾis/ 'pack'
/taksi'ðevis/ 'travel'
/kata'ɟelis/ 'denounce'

Table 1 Materials used for the lowest prosodic condition examining SV

Speakers produced a total of 850 instances [voiceless vs. voiced stops: 5 speakers*6 items*5 boundary conditions*2 repetitions = 300 plus for 'nasal+stop' sequences: 5 speakers*8 items*5 boundary conditions*2 repetitions = 300 items plus for BC0 of 'nasal+stop' sequences: 5 speakers*3 items*1 condition*2 repetitions*5 particles = 150].

2.1.3 Acoustic measurements

A. *Duration of Closure and Release*: release refers to the time taken from the release of the closure to the beginning of vocal fold vibration of the *following* vowel (it, therefore, cannot be equated to VOT).

B. *Relative Amplitude of Closure and Release*: the amplitude at the mid-point of the closure and release was measured, as shown in Figure 1. Measurements were performed automatically in PRAAT using a minimum pitch value of 100Hz (that is, the resulting window frame over which the analysis for amplitude is performed is 18ms, with 9ms on each side of the point of measurement). These raw measurements were then normalised by subtracting the mid-point amplitude measurement of the pre-boundary vowel from the measurement of the closure and the release:

Relative Amplitude = dB of Closure/Release (midpoint) - dB of Vowel (midpoint)

[3] Notice that while the production experiment for voiceless and voiced stops of SMG includes the design and elicitation of SV instances, these are analysed in §3.2.3, and not in this section.

Given that vowels have higher amplitude than the closure and release of stops, negative values are expected, and lower absolute values indicate higher amplitude (e.g. a value of -8 in comparison to -11 means that the first sound has a higher amplitude than the second).

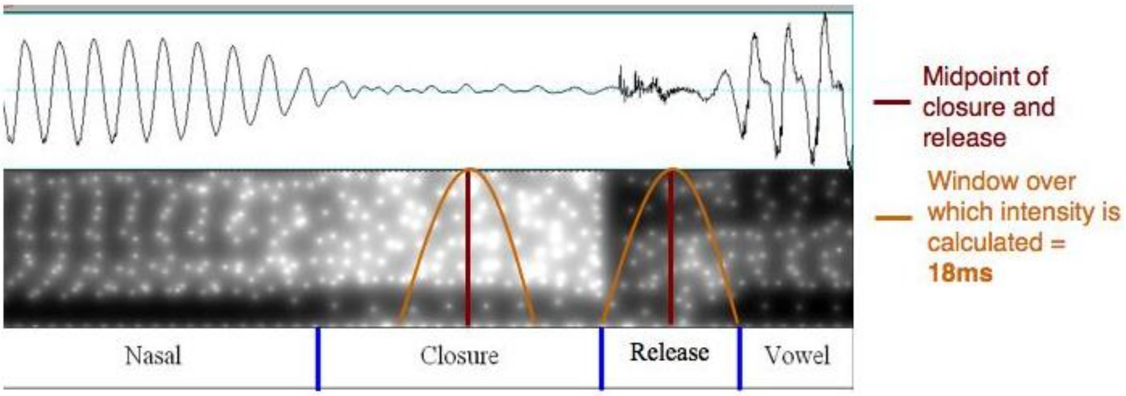

Figure 1 Example of segmentation of closure and release depicting the window for amplitude measurements

2.2 Results

Four Univariate ANOVAs are performed, testing the effect of Stop category (voiceless vs. voiced) on duration of closure, duration of release, relative amplitude of closure and relative amplitude of release. The effect of Stop category is significant in all four ANOVAs (Table 2). The closure of voiceless stops is 20% shorter than that of voiced stops ($F(1,271)=45.521$, $p<.001$) and the duration of the release for voiceless stops is 42% longer than for voiced stops ($F(1,285)=150.290$, $p<.001$). The amplitude of the closure and of the release are significantly lower for voiceless than for voiced stops (82% difference for the closure and 80% for the release ($F(1,247)=563.993$, $p<.001$, and $F(1,258)=295.8$, $p<.001$ respectively[4]). Table 3 shows the results for each place of articulation separately (asterisks indicate a difference between the voiceless and voiced stop).

	Voiceless	Voiced	Significance
Closure duration	51ms	64ms	*<.001
Release duration	24ms	14ms	*<.001
Closure amplitude	-17dB	-3dB	*<.001
Release amplitude	-10dB	-2dB	*<.001

Table 2 Mean duration and relative amplitude of voiceless and voiced stops in SMG

	p	t	k	b	d	g
Closure duration	63	44	45	65	70*	58*
Release duration	18	23	23	11*	13*	16*
Closure amplitude	-18	-14	-19	-3*	-2*	-3*
Release amplitude	-9	-10	-12	-1*	-1*	-4*

Table 3 Mean duration and relative amplitude of voiceless and voiced stops in all places of articulation (asterisks indicate statistical difference between voiceless and voiced rendition)

A Binary Logistic Regression analysis tested which of the four variables is the most important predictor for the voiceless-voiced classification. The most important predictors are the duration and

[4] All boundary conditions have been pooled in these results, which means that mean results stem from a variety of prosodic contexts. For a breakdown of the results in each boundary condition, see Appendix B.

amplitude of the closure, while those of the burst do not significantly contribute to the model. A discriminant analysis showed that by using only the duration and amplitude values of the closure, 98.4% of the data can be correctly classified as voiceless or voiced. While this suggests that the acoustic characteristics of the closure are very important in the voicing distinction, it is not to be taken that they alone contribute to that, since a discriminant analysis testing the predictive power of only the acoustic characteristics of the release showed that 88.1% of the data can still be correctly classified.

2.3 Summary

Experiment 1 showed that the duration and amplitude of voiceless and voiced stops in SMG differ significantly. In terms of their amplitude, as expected, voiced stops have higher values. Interestingly, in terms of their duration, there is an interplay between the duration of the closure and that of the release, whereby the closure is longer for voiced stops than voiceless, and conversely the release longer for voiceless than voiced stops. Finally, the acoustic characteristics of the closure emerged as the most significant factors in distinguishing statistically between the voiceless and voiced categories.

3. Experiment 2 – Perception and acoustics of post-nasal stop voicing

A perception experiment was performed with the goals of (i) investigating the domain within which SV occurs, and (ii) on the basis of speakers' classifications as to which instances of 'nasal+stop' have undergone voicing, to compare their acoustic characteristics to those from voiceless and voiced stops in Experiment 1.

3.1 Methodology

Three raters, native speakers of SMG, classified all items from Experiment 1, i.e. both 'nasal+stop' sequences and phonologically voiceless and voiced stops (baselines). The nasal was located at the end of the word and was followed by a stop at the beginning of the next word. To avoid lexical bias, raters only listened to the syllables preceding and following the word boundary. Each rater heard the same number of items [272 bilabials, 268 palatals/velars and 206 alveolars] with different randomizations across speakers. The experiment was run in PRAAT (Boersma 2001). The raters were asked to listen to the items and decide whether they heard a voiceless or voiced stop[5]. Each rater did the experiment three times – one for each place of articulation.

3.2 Results

3.2.1 Prosodic boundary strength effects on post-nasal stop voicing application

Inter-rater agreement is first quantified using the *kappa statistic.* This statistic evaluates whether agreement has reached an acceptable level (Siegel and Castellan 1988), taking into consideration chance agreement between raters. Its output varies between -1 (no agreement) and 1 (full agreement), therefore expected results should lie between 0 (chance agreement) and 1. The level above which agreement is considered satisfactory is not uniformly agreed upon by researchers but a number above 0.65-0.70 is generally considered adequate for further analyses (personal communication with Dr. J. Carletta, and see Carletta 1996).

The results show very high inter-transcriber agreement for all three places of articulation, specifically k=0.888 for alveolars, k = 0.845 for bilabials, and k = 0.901 for velars], indicating that voicing judgments were easy for raters.

Figure 2 shows how often raters classified a 'nasal+stop' cluster as voiced or voiceless across all boundary conditions. It can be seen that SV is allowed in BC0 and blocked in all other conditions, indicating that the phenomenon is confined within the lowest domain of the hierarchy. Moreover, there

[5] Four options were actually made available to the speakers; voiced or voiceless with the sub-categorisation of them being preceded by a nasal component. Those were collapsed to only two categories for the purposes of the analyses.

is an approximately 60-40% divide between SV applying vs. not applying, suggesting that the rule is optional. In the following section, its behavior within this domain is examined in detail.

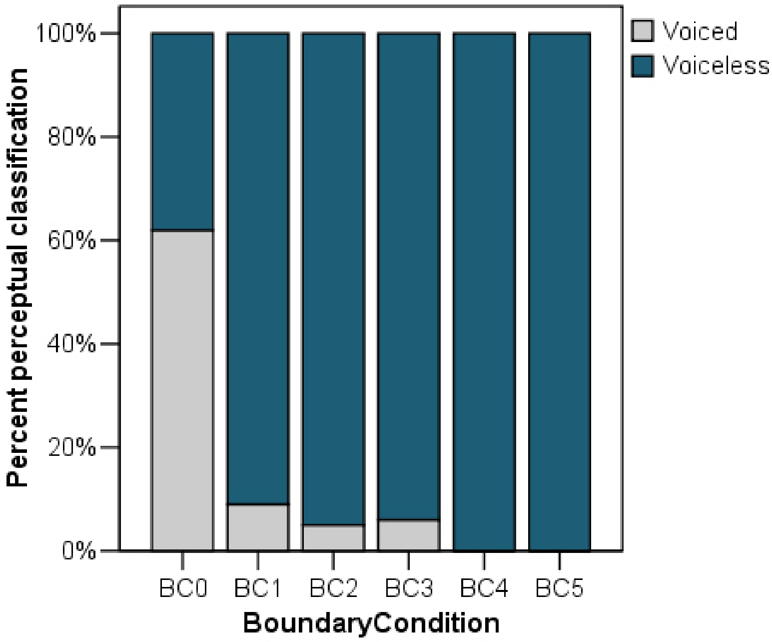

Figure 2 Percentage perceptual classification of 'nasal+stop' clusters as voiced or voiceless

3.2.2 Gradience within the same domain

When designing the lowest condition for the perception experiment, the items created entailed a variety of lexical items such as negation and temporal particles, subjunctive particles etc (see Table 1). This was done with the goal of probing potential differences across items within the same domain, and testing different expectations from analyses by Nespor and Vogel (1986) and possibly Malikouti-Drachman and Drachman (1988). For example, /ðen/ and /'otan/ according to Nespor and Vogel (1986) form different CG constructions (although the reasons for that are not clear), generating the hypothesis that the two items should behave differently in our experiment (/'otan/ should never voice and /ðen/ should voice). With respect to Malikouti-Drachman and Drachman's (1988) analysis we might be able to form a prediction for /ðen/, /ton/ and /min/, in that in terms of syllabification they should not differ. The generated hypothesis would therefore be that all three lexical items should be optionally voiced following similar trends. Table 4 shows the amount of times each item was classified by the raters as voiced or not, broken down by item.

	Voiceless	Voiced	No Agreement
/ðen/ ('not') *(9430,8)*	-	19	5
/ton/ ('him') *(8677,8)* /tin/ ('her') *(18625,8)*	5	17	5
/min/ ('not') *(696,2)*	8	11	9
/an/ ('if') *(2520,1)*	12	5	5
/'otan/ ('when') *(1514,2)*	10	3	7

Table 4 Number of times each 'nasal+stop' cluster from each lexical item was classified as voiceless or voiced by all raters, and number of times classification did not reach agreement across raters. Numbers in italic parentheses show frequency of the lexical type in a million (Protopapas et al in press)

What is notable from Table 4 is that in BC0 there are indeed differences across lexical items in how often they are classified as voiceless and voiced; while the negation particle /ðen/ always undergoes voicing, the other negation particle /min/ is split almost in half, with many instances of disagreement across raters, and at the other end temporal and subjunctive particles /'otan/ and /an/ are classified as voiced only a few times. Interestingly, this variability is gradient; /ðen/ is always voiced, /ton/ follows with many instances of SV, and then /min/ with less SV instances and more instances of no agreement between raters, while /'otan/ and /an/ appear to be mostly voiceless. Therefore, the hypothesis on the basis of Nespor and Vogel's (1986) analysis is half-met, in that /'otan/ behaves differently to /ðen/ (but is still voiced a few times), while the second hypothesis regarding /ðen/, /min/ and /ton/ is not met at all, since the behavior of the three items differs.

The frequency of each lexical item from Protopapas et al's (in press) corpus is shown in Table 4 in italic parentheses in the first column. The most frequent item (/ðen/) always voices, while the least frequent items (/'otan/ and /an/) voice the least frequently, and /ton/ lies in between in terms of both lexical and voicing frequency. However, this interesting pattern does not pertain to /min/, an item that voices often, but which appears the least frequently in the language.

3.2.3 Acoustics of post-nasal stop voicing

Two issues are addressed in this section with respect to SV: (i) the acoustic characteristics of instances of 'nasal+stop' classified as having undergone voicing, and (ii) their comparison to the acoustics of voiceless and voiced stops of SMG, as seen in Experiment 1[6].

Four Univariate ANOVAs are performed, testing the effect of Stop category (this time instances *classified as* voiceless vs. voiced) on duration of closure, duration of release, relative amplitude of closure and relative amplitude of release. The effect of voicing is significant on all dependent variables (pooling all prosodic conditions: Closure Duration: $F(5, 20) = 5.989$, $p<.01$, Release duration: $F(5, 20) = 6.694$, $p<.01$, Relative Amplitude of Closure: $F(5, 20) = 4.365$, $p<.01$, Relative Amplitude of Release: $F(5, 20) = 4.433$, $p<.01$). This suggests that 'nasal+stop' clusters classified as voiced are statistically different to those classified as voiceless.

Moreover, the same pattern as in §2.2 is replicated (Table 5); the duration of the release of the voiceless items is longer than for the voiced and amplitude is higher for voiced than voiceless renditions both in the closure and the release. However, the duration of the closure of the voiceless items is also longer than that of the voiced, contrary to what was found in §2.2. This mismatch stems from the fact that almost all instances classified as voiced are derived from BC0, the lowest condition. Taking into consideration that boundary strength exercises lengthening effects in the preceding and following syllables and sounds (Fougeron and Keating 1997, Kainada 2010b for SMG), it becomes clear that all instances from BC1-BC5 (which were in their majority voiceless) will have longer closure durations than BC0 (which included in its majority voiced stops). On the basis of post-boundary lengthening being more pronounced in the vicinity of stronger prosodic boundaries, it is therefore expected that BC0 will have shorter durations than BC1-BC5. Given that all of the voiced instances are within BC0, the comparison between voiceless and voiced 'nasal+stop' sequences with respect to the duration of closure is not reliable. To rectify this issue, the difference between voiceless and voiced stops only in BC0 was tested; voiceless stops indeed have shorter closure duration than voiced ones[7].

	Voiceless	**Voiced**
Closure duration	43	38
Release duration	24	15
Closure amplitude	-14	-8
Release amplitude	-18	-7

Table 5 Mean duration and amplitude of closure and release for all 'nasal+stop' sequences classified as voiceless and voiced

[6] Remember that the production of all 'nasal+stop' sequences was performed in Experiment 1 and are analysed here. The reason for that is that first we need to perceptually classify which instances have undergone SV, before examining their acoustics. Therefore, the perception experiment is needed before any acoustic analyses are performed.

[7] Instances of 'No Agreement' between raters were also investigated and were found to have acoustic characteristics similar to the items classified as voiceless, and statistically different to those of instances classified as voiced. It is not clear why those instances did not reach agreement. A spectrographic analysis was also performed by the author, confirming them visually as voiceless.

3.3 Summary

Experiment 2 showed that SV applies at the lowest domains of the prosodic structure. Importantly, there is variation in SV application within that domain, in that some lexical items are voiced more often than others, and the process appears to be optional. Acoustically, SV instances share the same durational and amplitude characteristics as voiced stops of SMG, and are statistically different to voiceless renditions. All the above show that SV applies categorically and is influenced by prosodic boundary strength in a categorical manner too.

4. Discussion

This paper set out to answer two questions. First, whether SV is categorical and, second, how is SV influenced by boundary strength. Acoustically, SV is categorical, i.e. the duration and amplitude of instances having undergone SV are distinct (both perceptually and statistically) to those of instances that have not undergone voicing. Moreover, SV instances were acoustically similar to voiced stops of SMG, and statistically dissimilar to voiceless stops. This is interesting because much acoustic research on sandhi phenomena in several languages over the past decade reports that such phenomena do not fit in acoustically distinct categories, but vary in a continuum of possible acoustic values. In fact, such findings have led to questioning whether sandhi phenomena are the result of a phonological rule or of coarticulation. The results of this paper clearly indicate that SV in SMG is a categorical process whose application seems to be the result of phonological planning and whose occurrence needs to be explained phonologically and not in terms of coarticulation. With respect to the boundary strength on the application of SV it was shown that SV is influenced categorically by prosodic boundary strength; SV is allowed only within the lowest domains of the prosodic hierarchy.

The second issue addressed concerns the way SV applies within the lowest domains of the prosodic structure. It was shown that frequency of voicing varied across lexical items, with /ðen/ emerging as always voiced, and /'otan/ and /an/ being the items with the least amount of voicing. According to Nespor and Vogel’s (1986) analysis this can be explained on the basis of different CGs; /'otan/ and /an/ form CGs on their own, and therefore SV is blocked across them. However, this does not explain why these items were still classified as voiced in some instances, nor does it explain the phonological or other characteristics of /'otan/ and /an/ that force them to form CGs (in comparison to items such as /ðen/ or /ton/). Finally, Nespor and Vogel’s (1986) analysis cannot account for the gradient variation found across lexical items, whereby /ðen/ is always voiced, /min/ and /ton/ are sometimes voiced, and /'otan / and /an/ are almost never voiced (especially so for /ðen/ and /min/ which are both negation particles, unstressed, monosyllabic, and followed by the exact same verbs). Malikouti-Drachman and Drachman’s (1988) analysis on the basis of syllabification cannot account for the findings either. All particles included in the experiment were followed by the exact same verbs, thus giving rise to the same syllabification conditions. Even if the nasal is optionally attached at the onset of the following syllable or at the coda of the preceding, we need an explanation as to why, for example, negative particles /ðen/ and /min/ behave differently, and why the object-clitic /ton/ is less frequently voiced than the negation particle /ðen/.

One possible explanation for the described variation could be the frequency of the words involved in the overall language. It was shown in §3.2.2 that a correlation could be loosely identified between the frequency of the lexical item in the language and the amount of times it exhibited SV, but this correlation did not pan out for all items under investigation (/min/ did not fit the pattern). This may indicate a process currently in progress in SMG whereby some items (the most frequent ones) undergo SV more often than others, but this is speculative and does not seem to apply to all items investigated. If this is the case, SV in SMG would prove an excellent test bed to test articulatorily how the process evolves, which could give insights into the link between coarticulation and sandhi phenomena.

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APPENDIX A

Example of construction of boundary conditions for Exp.1. The boundary was always placed between an adjective and a noun (see Kainada 2010a for reasons on using these constructions).

BC1 [a'po a'ftin tin **ci'notopi # ko'pela**, to pe'ɾimena]
'From this common girl, I expected it'.
BC2 [me em'fanisi **ci'notopi, # ko'pela** ðen θa vɾi]
'With a common appearance, he will not find a girl'.
BC3 [a'fu 'eçis em'fanisi **ci'notopi # ko'pela** ðe θa vɾis/
'Since you have a common appearance, you will not find a girl.'
BC4 [a'fu 'eçis ka'ta ʝeni'ci omolo'ʝia em'fanisi **ci'notopi # ko'pela** ðe θa vɾis xo'ɾis ɾizi'ci ala'ʝi]
'Since everyone agrees that you have a common appearance, you will not find a girl without radical change.'
BC5 ['eçis ka'ta ʝeni'ci omolo'ʝia em'fanisi **ci'notopi # ko'pela** ðe θa vɾis xo'ɾis ɾizi'ci ala'ʝi]
'Everyone agrees that you have a common appearance. You will not find a girl without radical change.'

APPENDIX B

Voiceless							
	BC1	**BC2**	**BC3**	**BC4**	**BC5**	**Significance**	**Bonferroni**
Duration closure	45	49	52	54	60	.016	1,2<5
Duration release	22	24	24	24	25	-	-
Amplitude closure	-13	-13	-16	-17	-21	<.001	1,2,3,4<5
Amplitude release	-8	-11	-11	-11	-7	-	-

Voiced							
	BC1	**BC2**	**BC3**	**BC4**	**BC5**	**Significance**	**Bonferroni**
Duration closure	56	60	66	70	69	.002	1<4,5
Duration release	13	14	14	13	14	-	
Amplitude closure	-3	-3	-4	-4	-1	<.001	1,2,3,4<5
Amplitude release	-3	-2	-2	-2	-1	.13	1,2,3,4<5

Mean duration and amplitude of closure and release of voiceless and voiced stops in SMG in varying boundary strength conditions [BC1=weakest boundary, BC5=strongest]