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Coda aspiration and incomplete neutralisation in Eastern Andalusian Spanish*

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Abstract

This paper focuses on the aspiration of word-internal codas in the dialect of Spanish spoken in the eastern Andalusian provinces of southern Spain (henceforth EAS). S-aspiration usually refers to the deletion of an underlying, syllable-final /s/ accompanied by breathy voicing/aspiration of the preceding vowel and, word-internally, by gemination of the following onset consonant. For example, the word /kasta/ 'caste' would typically be realised as [ka^{h}t.ta] in EAS.

Although much attention has been paid to s-aspiration because of its role in preserving morphological information word-finally, there has been little focus on whether other contrasts are also maintained when coda aspiration is implemented. Given that s-aspiration can occur with any obstruent in coda position, and not just word-final /s/, we might expect to find homonyms present in EAS that do not appear in standard peninsular Spanish. For example, the underlying minimal pair /kasta/ and /kapta/ 's/he captures' might be expected to undergo neutralisation in EAS, resulting in the single, non-contrastive form [ka^{h}t.ta].

In this paper, we present evidence from two controlled, eleven subject production study that indicates that this contrast is not in fact fully neutralised. Rather, we find a subtle yet consistent production pattern distinguishing forms derived from an underlying /s/ and those derived from an underlying voiceless stop (/p/ or/k/). Anticipating our results, we find that aspirating an /s/ results in a longer duration of aspiration, while aspirating a /p/ or /k/ results in more medial consonant gemination, though both types robustly exhibit each of the cues mentioned above when compared to words without medial coda obstruents.

Our results inform four larger areas of discussion. First, they add to the growing body of data on the fine-grained nature of language-particular phonetics. Second, they call to the limitations and dangers inherent in an approach to phonology which relies exclusively on impressionistic transcription. Third, our findings lead us to speculate on the nature of the phonetics/phonology interface. In particular, we suggest that an adequate understanding of this phenomenon requires a model of phonetic implementation that does not blindly interpret the output of a categorical phonology. We propose two possibilities for accounting for the kind of phonetic knowledge under discussion here. One involves wholesale incorporation of finely grained phonetic features into the phonology, while the other allows for a more traditional phonetics/phonology interface with the proviso that phonetic implementation can also be informed by underlying feature specification. Finally, our data can be usefully viewed in the context of the literature on near mergers, as the subtle nature of the differences we find may be indicative of the nature of the phonetic differences in cases of near mergers.

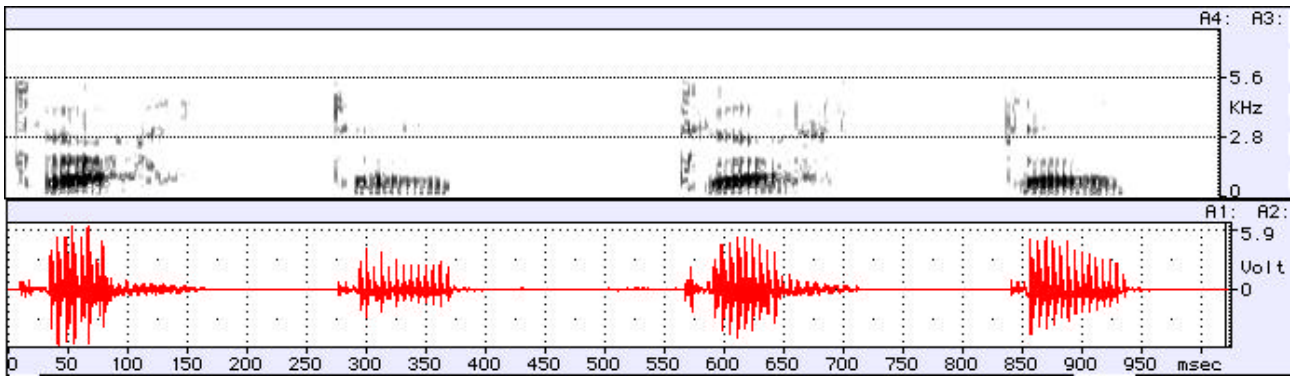
Keywords: Andalusian Spanish, s-aspiration, neutralisation

1. Introduction

This paper focuses on the aspiration of word-internal codas in the dialect of Spanish spoken in the eastern Andalusian provinces of southern Spain (henceforth EAS). The phenomenon of s-aspiration in many dialects of Spanish has been well documented in the literature (see, for example, Rodríguez Castellano and Palacio 1948, Alarcos Llorach 1958, Zamora Vicente 1969, Goldsmith 1981, Zamora Munné and Guitart 1982, Guitart 1985, Hualde 1987, Mondéjar 1991, and Romero 1989, 1995), and usually refers to the deletion of an underlying word-final /s/ accompanied by breathy voicing on and sometimes aspiration of the preceding vowel. Word-final s-aspiration has been the subject of many studies. This is due to the potential morphological consequences resulting from the loss of final /s/, which signals both plurality for nouns and the second person singular informal of verbs. In this sense, s-aspiration provides a means of preserving the morphological contrasts that are potentially lost due to s-deletion. Thus, where standard peninsular Spanish (SPS) produces the form [mesas] 'tables,' dialects with s-aspiration produce [mesa^{h}].[1]

More recent work has investigated this phenomenon as it applies to other coda obstruents in EAS (Gerfen 2001, forthcoming). Essentially, word-internal coda aspiration refers to the process whereby a coda obstruent is 'deleted' (or fails to be licensed) but 'leaves behind' phonetic cues that continue to distinguish the syllable as closed. The most robust of these cues are 1) breathy voicing or aspiration on the preceding vowel and 2) gemination of the following onset consonant. For example, the word /kasta/ 'caste' would typically be realised as [ka^{h}t.ta] in EAS.

Although much attention has been paid to word-final s-aspiration because of its role in preserving semantic contrasts, there has been little focus on whether other contrasts are also maintained when coda aspiration is implemented. Given that s-aspiration can occur with any obstruent in coda position, and not just word-final /s/, we might expect to find homonyms present in EAS that do not appear in SPS. Gerfen (forthcoming), for example, simply assumes that there is a lack of contrast for obstruents in coda position in the syllable in EAS (1)—that the coda obstruent is in effect neutralised, though the broader contrast between words with underlying medial codas and those without them is maintained by the aspiration itself. Thus, the SPS minimal pair /kasta/ and /kapta/ 's/he captures' would appear to undergo neutralisation in EAS, resulting in the single, neutralised form [ka^{h}t.ta] for each. As an example, consider Figure 1, which shows two tokens produced by a native female speaker of EAS.



[k a ^{h} t: a] [k a ^{h} t: a]

Figure 1: Apparent neutralisation of /kasta/ and /kapta/, speaker BH

At first glance, the forms in Figure 1 appear to be neutralised; there is aspiration of V1 and gemination of the medial stop in each token, and there are no other obvious phonetic cues as to which is which. The form on the left is a token of /kasta/, while the

one on the right is from /kapta/, but this is not immediately obvious from examining the individual spectrograms.

In this paper, we present evidence from two controlled production studies[2] that indicates that this contrast is not in fact fully neutralised. Rather, we find a consistent production pattern distinguishing forms derived from an underlying /s/ and those derived from an underlying voiceless stop. Anticipating our results, we find that aspirating an /s/ results in a longer duration of aspiration, while aspirating a voiceless stop results in more medial consonant gemination, though both types robustly exhibit each of the cues mentioned above when compared to words without medial coda obstruents.

The rest of this paper is organised as follows. In §2 and §3, we describe the experiments and report the results. In §4, we discuss the implications of our findings for a number of issues, including the limitations phonological analyses based solely on impressionistic transcription, the phenomenon of neutralisation in phonology, and the phonetics/phonology interface. In §5, we summarise the findings and present conclusions.

2. Experiment 1

2.1 Experimental design

Experiment one focuses on a set of three minimally distinct words with the underlying forms /CVCV/, /CVSCV/, and /CVPCV/, which would syllabify in SPS as [CV.CV], [CVS.CV], and [CVP.CV]. These are shown in (1).

(1)

cata	/kata/	‘s/he samples, tastes’
casta	/kasta/	‘caste’
capta	/kapta/	‘s/he captures’

These words were placed in a larger list of 37 Spanish words, each of which was presented in the carrier sentence *dime* ____ *tío* ('say ____ pal'). The 37-word list was randomised 15 times and read by 11 native speakers of EAS (7 female and 4 male), for a total of 11 speakers * 15 repetitions * 3 words. All participants were native speakers of EAS, having been born and raised in eastern Andalusia, and all used EAS as their primary dialect on a daily basis. All were college educated and between the ages of 30 and 38 years old. The instructions to the subjects were only that a study was being conducted of how people in Granada speak, and they were asked to use a normal, relaxed speaking voice, as if they were speaking to family or friends at home. Because EAS is a non-prestige variety of Spanish, we anticipated that the reading task might cause subjects to slip into a more 'proper' register, that is, to read the sentences in a fashion more similar to the non-aspirated standard. While a few tokens were in fact read without aspiration (see section 2.2.1 for more discussion), speakers were in general highly comfortable with the task. Two factors may have contributed to this comfort level. Following Gerfen (2001, forthcoming), the frame used for the sentences is highly informal. *Tío*, literally meaning 'uncle' but more colloquially translated as 'pal' or 'dude,' is often used in the most informal registers of speech in Spain. Secondly, the high education level of all the subjects may have helped them feel more confident when asked to perform a reading task in their dialect.[3] Recordings were made by the first author in Granada, Spain, during the summer of 2000 in a quiet room with a Shure SM10A, close-talking dynamic, unidirectional, head-mounted microphone on a Marantz PMD 222 cassette recorder. The data were then digitised on a PowerMacintosh 8600 at 22 kHz with 16-bit sampling and analysed in SoundScope.

2.2 Data measurement

In analysing the data, we made the following three measurements: 1) duration of the voiced portion of V1, which we will refer to for convenience as 'V1 duration,' 2) duration of aspiration (relevant for the aspirated forms only), which we identified as the period of aspiration following the offset of V1 voicing and prior to the onset of medial stop closure; and 3) medial stop closure duration. Figure 2 provides a sample waveform and spectrogram showing the placement of cursors for measuring V1 duration, aspiration duration, and closure duration.

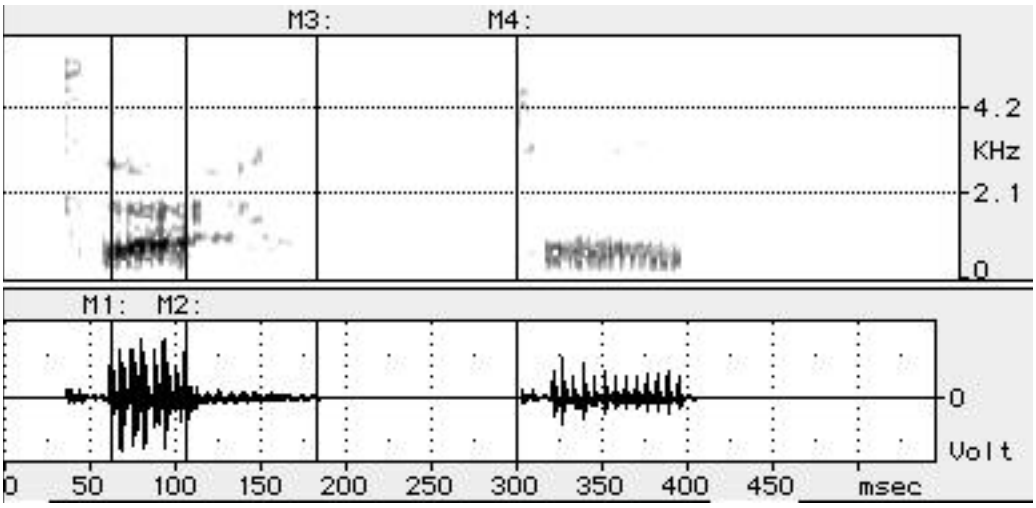


Figure 2: Landmarks for measurements

As this figure shows, the onset of vowel voicing (indicated by the first marker, M1) was located at the first glottal pulse after the release of the word-initial stop. To determine the onset of aspiration, and thus the offset of the voiced portion of the vowel, both the waveform and the spectrogram were used. The most consistent and reliable indication was a sharp drop in amplitude and thus loss of the visible formant energy, as seen by the second marker (M2) in Figure 2, which was placed on the last clear glottal pulse of the vowel preceding the onset of visible aspiration. The offset of aspiration was

determined by the lack of energy in the waveform, indicating the onset of stop closure, as shown by the waveform alone. M3 is placed at this point in Figure 2. Finally, closure duration was measured from the onset of stop closure (i.e., the offset of the aspirated portion of the vowel) to the release burst of the stop (M4).

If /s/ and /p/ are in fact neutralised in EAS, then the null hypothesis predicts that there should be no significant difference in the duration of any of these variables for /kasta/ and /kapta/. (Note, of course, that such results would only be compatible with the null hypothesis, given that we cannot know if some other acoustic measure would serve to distinguish the two words.) If, on the other hand, neutralisation is incomplete, then we should find a consistent, significant difference in at least one of these measurements, indicating that the two words are not produced identically.

2.2.1 Data excluded from analysis

As indicated in Table 1 below, some /CVCCV/ forms were produced without aspiration. Because this study examines only the difference between /s/-aspirated and /p/-aspirated words, the tokens in which the underlying consonant was realised are not relevant to the analysis. Such forms were thus discarded. Excluded tokens were identified by listening for a medial [p] or [s] and by comparing the waveforms and spectrograms of aspirated and non-aspirated forms. Figure 3 shows the first vowel and following transition of three tokens from speaker VE. The first one is a non-aspirated or standard pronunciation of the form [kapta], which shows no clear period of aspiration, and whose second formant is falling at V offset, as expected in the context of a following bilabial closure gesture. The second form is an aspirated token from underlying /kapta/. This form has a period of aspiration and formant transitions that are not indicative of a following bilabial. Note, in

fact, the similarity between this token and the third one, which shows the initial aspirated vowel for a token of /kasta/. Also note that only speakers VE, BS, and AL produced any tokens in which the underlying medial coda obstruent surfaced, and even they did not do so in the overwhelming majority of cases.

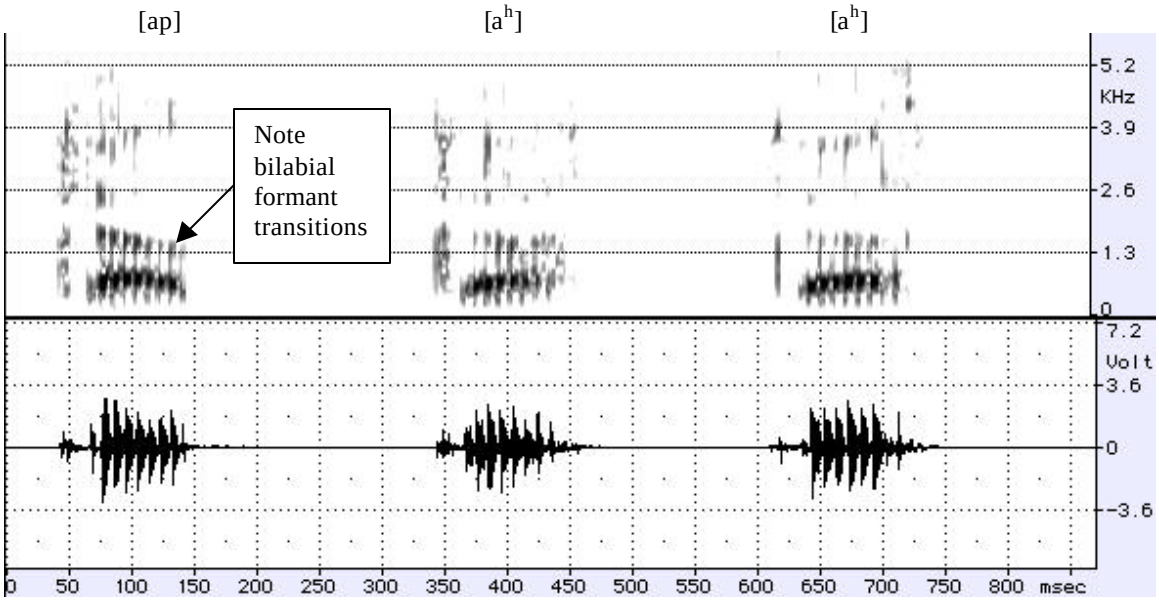


Figure 3: Comparison of non-aspirated /kapta/, aspirated /kapta/, and aspirated /kasta/ tokens

Speaker	**/kasta/**	**/kapta/**	**Total by Speaker (30 = 100%)**
CR	15	15	30
JP	15	15	30
VE	15	**11**	26
BH	15	15	30
UR	15	15	30
ER	15	15	30
BS	15	**11**	26
PP	15	15	30
IN	15	15	30
AL	15	**14**	29
RM	15	15	30
Total by Word (165 = 100%)	165	156	321

Table 1: Number of aspirated forms by speaker and by word, /kasta/ vs. /kapta/

2.2.2 Statistical analysis

Following Max and Onghena (1999), we employed a multivariate analysis of variance for repeated measures designs (MANOVA) to compare the above-mentioned duration measures of /kasta/ and /kapta/, using the SAS System (v. 8.01) for Windows as our statistical analysis package. Also following Max and Onghena (1999), prior to analysis we averaged the duration of each of our variables and computed our statistics over the means for each subject (see Max and Onghena's Table 4, p. 269). Before running the tests, we selected the standard significance level of $\alpha = .05$.

2.3 S-aspiration: the general picture

Although the focus of this study is the comparison of the surface realisations of /kasta/ and /kapta/, respectively, it is descriptively useful to first compare these two forms with a third member of the minimal triplet, /kata/. As mentioned above, so-called s-aspiration occurs with all coda obstruents and results in aspiration of the vowel and gemination of the medial consonant. Broadly speaking, this effect was reproduced in our study, as both /kapta/ and /kasta/ exhibited aspiration and gemination in their surface forms, while /kata/ exhibited neither. For example, Figure 4 provides a column graph of vowel aspiration duration for each speaker in the three contexts. Notable, of course, is that there is no column for aspiration in the /kata/ context, as these forms were never aspirated.

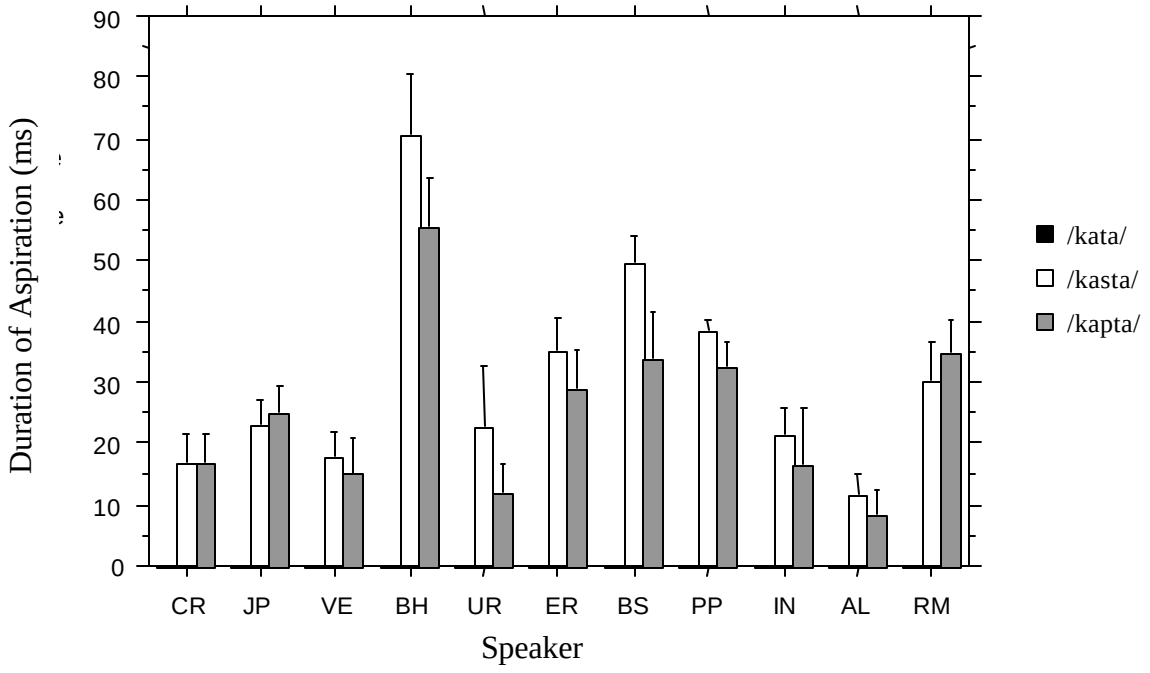


Figure 4: Aspiration duration by word and by speaker, /kata/ vs. /kasta/ vs. /kapta/

Similarly, Figure 5 provides a graph of closure duration by speaker for surface medial [t] in all three contexts. Note the large two-way split between the two /CVCCV/ forms and the much shorter closure duration in the /CVCV/ form.

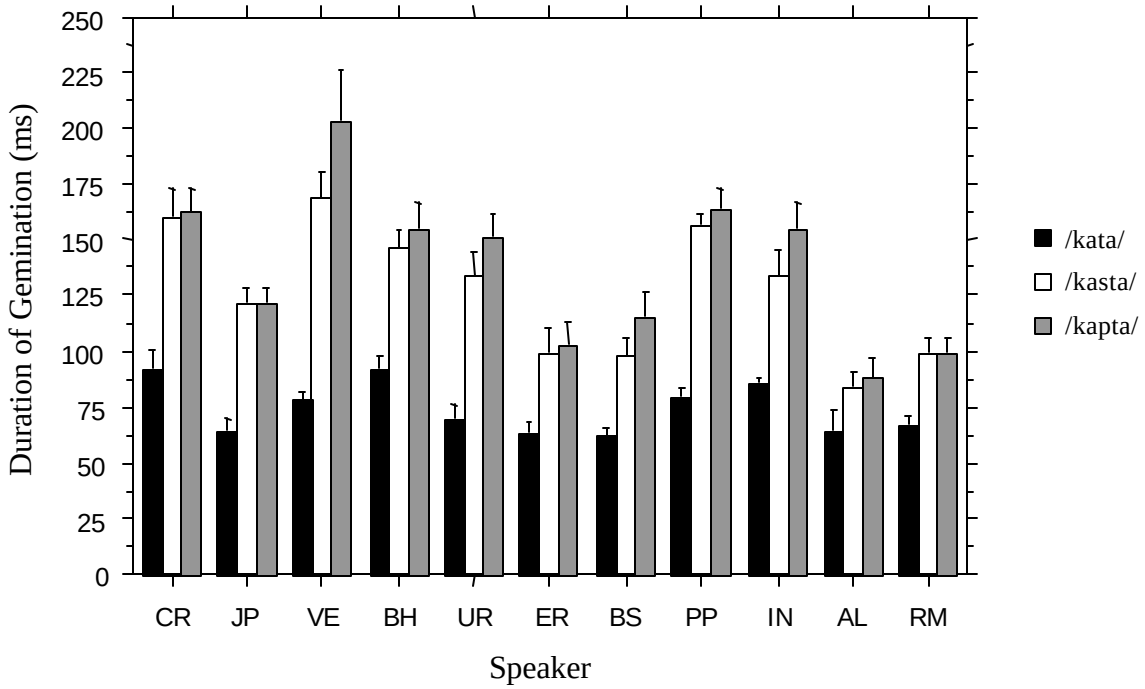


Figure 5: Closure duration by word and by speaker, /kata/ vs. /kasta/ vs. /kapta/

We return to the issue of fine-grained differences between /kasta/ and /kapta/ below, but Figures 4 and 5 give a clear picture of the basic situation: the 'aspiration' of coda obstruents includes the general features of aspiration and gemination, regardless of the quality of the underlying obstruent.

2.4 Results: comparing /kasta/ and /kapta/

We now turn to the basic question at hand, that is, whether there is neutralisation of the implementation of an /s/ and that of a /p/ in aspirating contexts. In §2.4.1, we examine vowel duration; in §2.4.2, we compare the duration of aspiration; and in §2.4.3, we consider the duration of stop closure in the two contexts.

2.4.1 Vowel duration

Table 2 gives the mean vowel durations (excluding aspiration) for all speakers, while Figure 6 shows a column graph of the average vowel durations (excluding aspiration) by speaker, broken down by word. Recall that by vowel duration, we refer here to the duration of the voiced portion of the vowel gesture, as described in §2.2 above.

Speaker	Mean Duration /kasta/ (ms)	Mean Duration /kapta/ (ms)	Difference: /kasta/- /kapta/ (ms)	Ratio: /kasta/ ÷ /kapta/	Percent Differences: /kapta/ - /kasta/
CR	72.874	66.515	6.359	1.096	**-9.56**
JP	65.893	63.915	1.978	1.031	**-3.095**
VE	83.81	68.712	15.098	1.22	**-21.973**
BH	53.799	60.68	-6.881	0.887	**11.34**
UR	72.139	70.794	1.345	1.019	**-1.9**
ER	42.978	56.834	-13.856	0.756	**24.38**
BS	60.06	68.567	-8.507	0.876	**12.407**
PP	71.193	74.437	-3.244	0.956	**4.358**
IN	56.937	59.534	-2.597	0.956	**4.362**
AL	43.084	51.179	-8.095	0.842	**15.817**
RM	67.761	62.667	5.094	1.081	**-8.129**

Table 2: Duration of vowel voicing

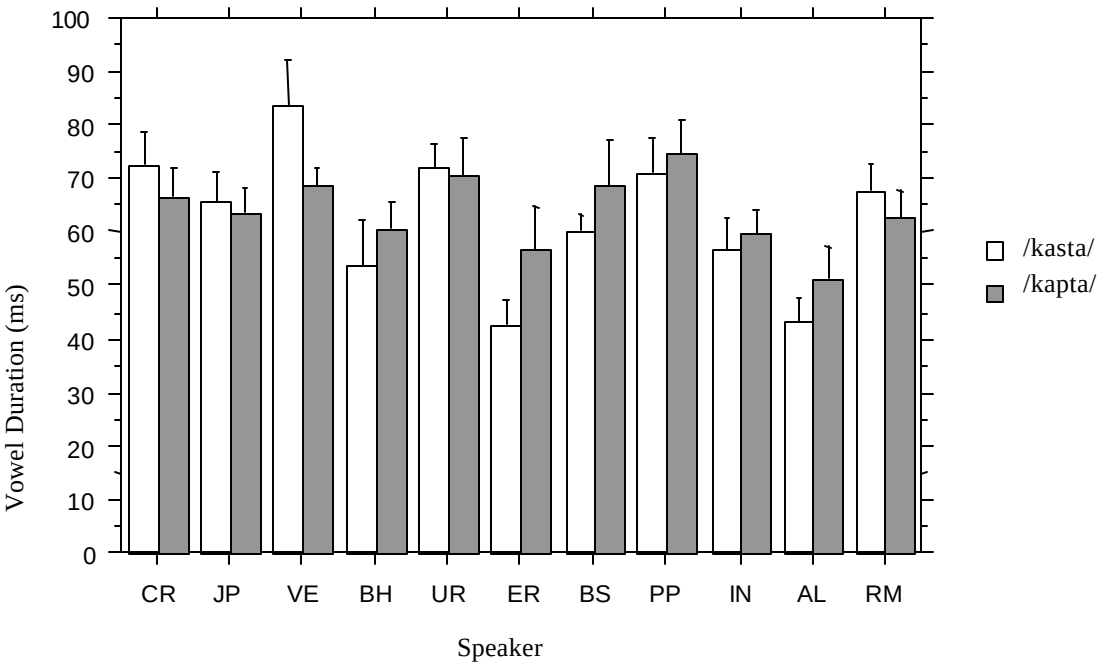


Figure 6: Vowel duration by word and by speaker

We observe considerable variation across speakers. Five speakers (CR, JP, VE, UR, and RM) produce a longer vowel in /kasta/ while the other six speakers have a longer vowel in /kapta/. A MANOVA indicates that there is no significant difference in vowel length [$F(1,10) = .24$; $p = .6367$]. The probability of these results happening purely by chance, $p = .6367$, is far above the critical value for statistical significance used here, $p < .05$. For this variable, then, our statistical test is compatible with the null hypothesis: vowel duration, as measured by the voiced portion of the vowel, is independent of the quality of the coda obstruent in the two aspirating contexts.

2.4.2 Aspiration duration

Turning now to the duration of aspiration in the two contexts, a different result emerges. Despite the variability reflected by the numbers in Table 3 , which provides the mean duration of aspiration for each of our speakers for the two contexts, Figure 7 clearly

shows a general pattern in which the duration of aspiration for /kasta/ is consistently greater than that for /kapta/.

Speaker	Mean Duration /kasta/ (ms)	Mean Duration /kapta/ (ms)	Difference: /kasta/- /kapta/ (ms)	Ratio: /kapta/ ÷ /kasta/	Percent Differences: /kasta/ - /kapta/
CR	16.937	16.831	0.106	0.994	**0.626**
JP	23.081	25.158	-2.077	1.090	**-8.999**
VE	18.077	15.003	3.074	0.830	**17.005**
BH	70.582	55.477	15.105	0.786	**21.401**
UR	22.978	12.254	10.724	0.533	**46.671**
ER	35.576	28.919	6.657	0.813	**18.712**
BS	49.744	33.898	15.846	0.681	**31.855**
PP	38.709	32.544	6.165	0.841	**15.927**
IN	21.412	16.423	4.989	0.767	**23.300**
AL	11.834	8.571	3.263	0.724	**27.573**
RM	30.479	34.742	-4.263	1.140	**-13.987**

Table 3: Duration of aspiration

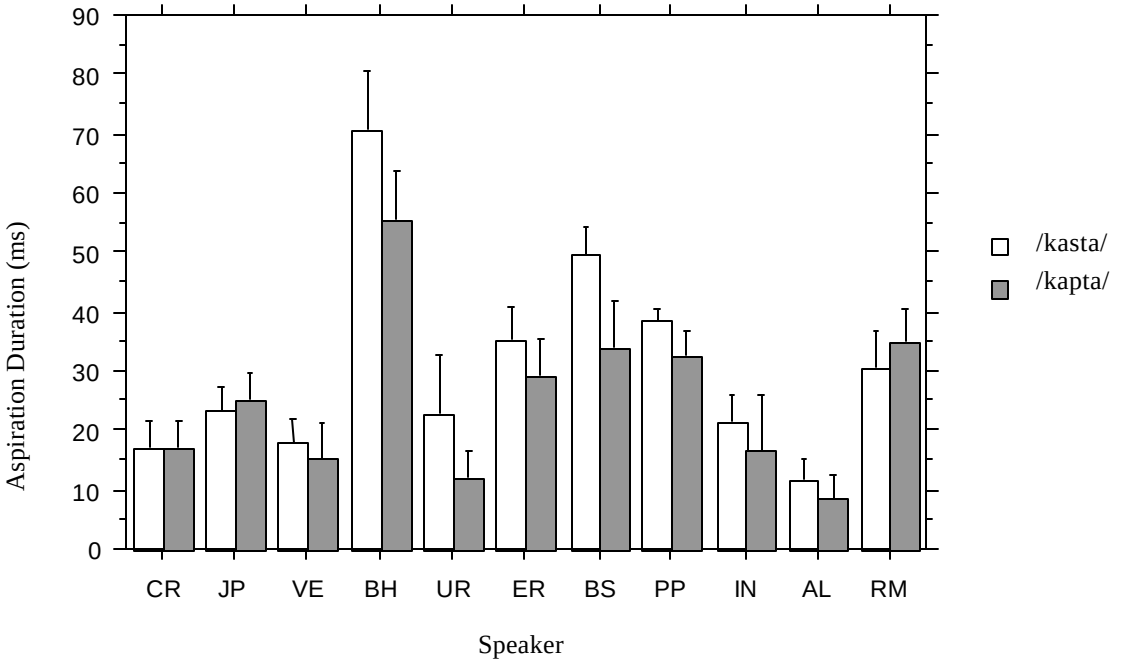
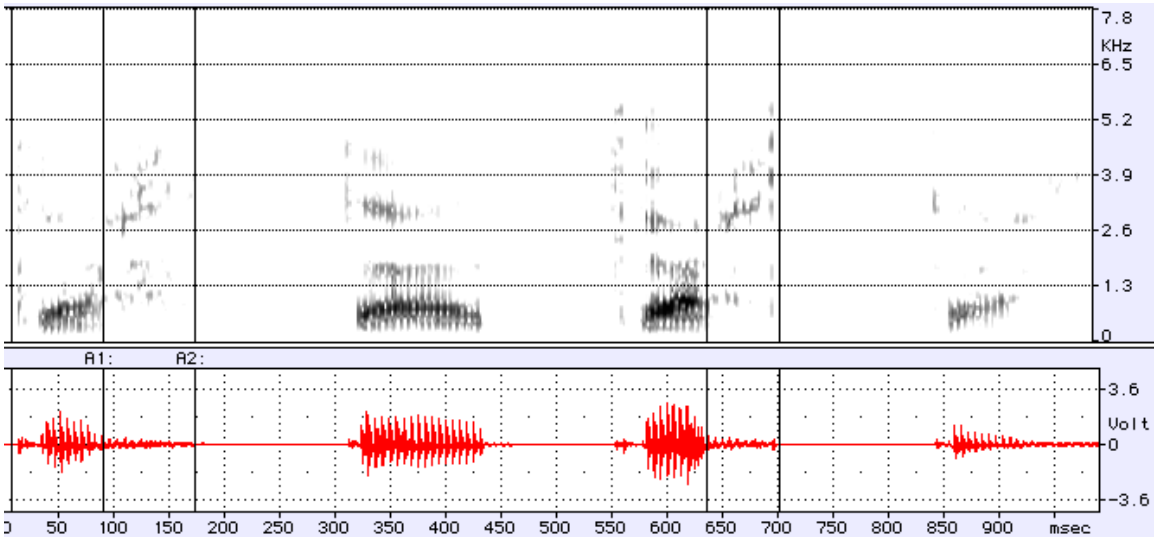


Figure 7: Aspiration duration by word and by speaker, /kasta/ vs. /kapta/

Only three speakers do not clearly exhibit the general pattern: two (JP and RM) show longer mean aspiration in /kapta/ than in /kasta/, and one (CR) uses an almost identical duration of aspiration for each word. A MANOVA yields a significant difference for the test population as a whole [$F(1,10) = 9.03$; $p = .0132$], indicating that the difference between underlying /s/ and /p/ is not actually neutralised under coda aspiration in EAS. That is, although both trigger aspiration of the preceding vowel, the duration of aspiration in the context containing the medial /s/ is significantly longer. Figure 8 gives example tokens showing waveforms and spectrograms for speaker BH, in which the duration of aspiration in /kasta/ and /kapta/, respectively, is indicated by the placement of markers(/kasta/ is on the left; /kapta/ is on the right).



[k a h t: a] [k a h t: a]

Figure 8: Comparison of aspiration duration, /kasta/ vs. /kapta/, for speaker BH

2.4.3 Medial stop closure duration

We have already seen that there is a longer period of aspiration in words with underlying /s/ than in words with underlying /p/, falsifying the null hypothesis of contrast neutralisation through coda aspiration. The next question is whether there is neutralisation in the closure durations of the medial consonants, that is, in the amount of gemination in the aspirated forms.

As noted in §2.2 above, closure duration was measured from the onset of stop closure to the release burst. The average closure durations for each speaker are given in Table 4. Once again, there is a clear pattern across speakers. In this case, despite variation in terms of actual duration of closure, ten speakers exhibit longer medial stop duration in /kapta/ than in /kasta/, and the exception (RM) has almost identical durations for both words. Figure 9 shows this general pattern in a column graph of closure duration in each context by speaker, which a MANOVA indicates is statistically significant [$F(1,10) = 10.50$; $p = .0089$].

Speaker	Mean Duration /kasta/ (ms)	Mean Duration /kapta/ (ms)	Difference: /kapta/- /kasta/ (ms)	Ratio: /kasta/ ÷ /kapta/	Percent Differences: /kapta/ - /kasta/
CR	160.578	162.763	2.185	0.987	**1.342**
JP	121.829	122.044	0.215	0.998	**0.176**
VE	169.334	203.368	34.034	0.833	**16.735**
BH	146.313	155.988	9.675	0.938	**6.202**
UR	134.225	152.145	17.92	0.882	**11.778**
ER	99.646	102.655	3.009	0.971	**2.931**
BS	98.386	115.861	17.475	0.849	**15.083**
PP	156.206	164.647	8.441	0.949	**5.127**
IN	134.222	154.854	20.632	0.867	**13.324**
AL	85.055	87.904	2.849	0.968	**3.241**
RM	99.426	99.22	-0.206	1.002	**-0.208**

Table 4: Closure duration

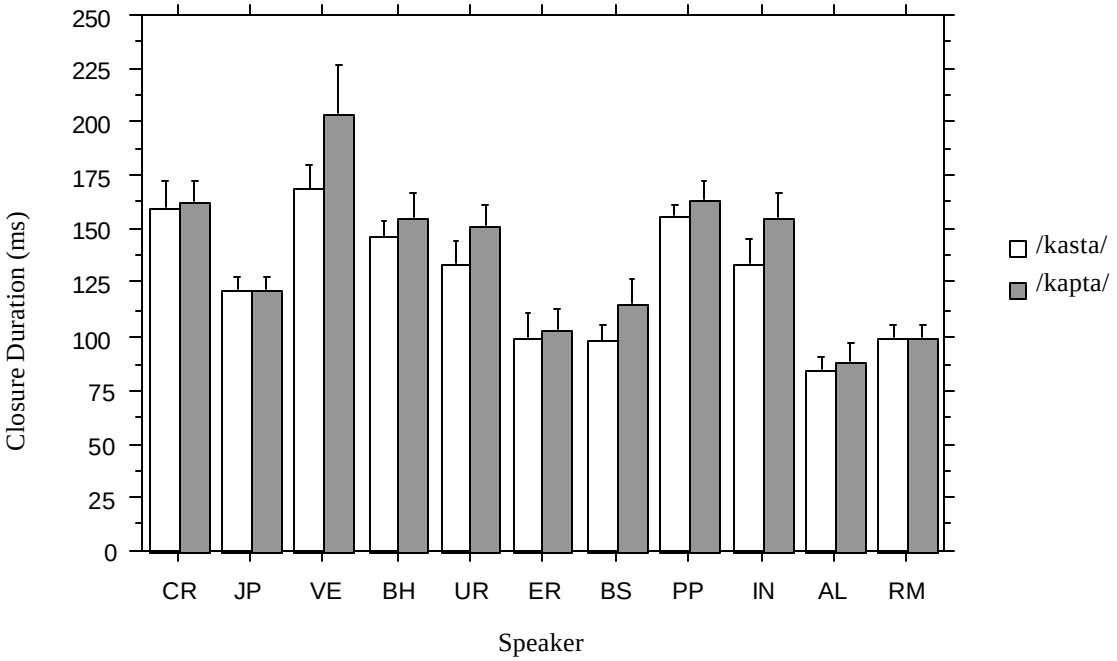


Figure 9: Medial stop closure duration by word and by speaker

Figure 10 shows waveforms and spectrograms for illustrative tokens. Here we see the shorter medial stop closure duration in /kasta/ on the left as compared to the longer medial stop closure of /kapta/ on the right for speaker VE.

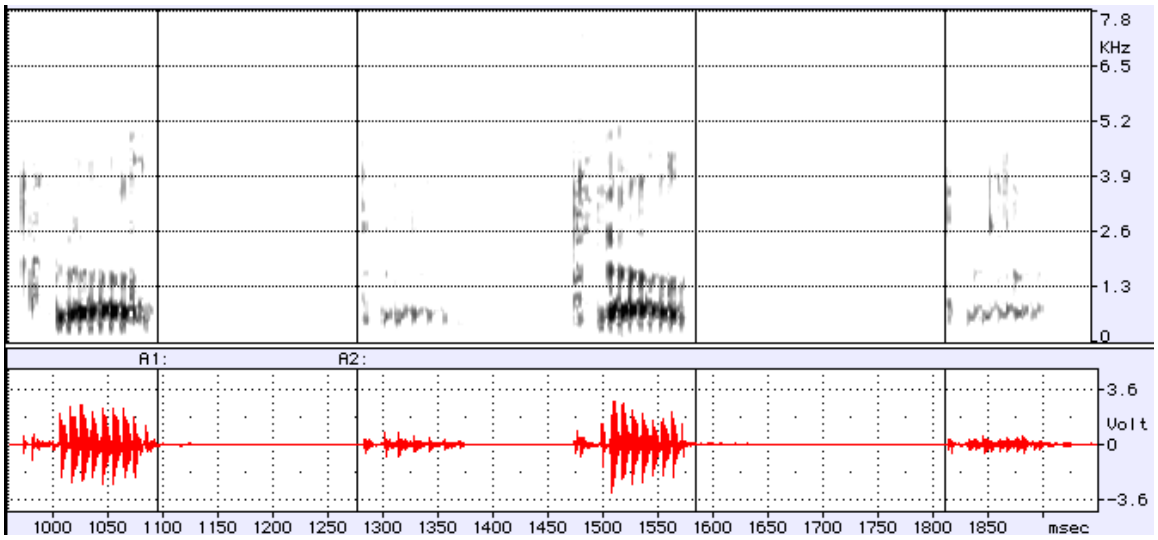


Figure 10: Comparison of closure duration, /kasta/ vs. /kapta/, for speaker VE

2.4.4 Summary of results

We have seen that for almost all speakers, coda aspiration in EAS does not result in the complete neutralisation of the underlying contrast between /kasta/ and /kapta/. Not only do aspirated forms as a general class contrast with non-aspirated /CVCV/ forms, but statistically significant distinctions can also be made among various aspirated forms. Specifically, we found that there are at least two significant differences between aspirated words with underlying /s/ in medial coda position and those with /p/: 1) the duration of aspiration is greater in words with /s/, while 2) the duration of consonant gemination is greater in words with /p/. Only one of our variables, the voiced portion of the vowel itself, does not exhibit a significant duration difference across the two contexts.

3. Experiment Two

3.1 Experimental design

The point of experiment two is to replicate and extend the statistically significant findings of experiment one. To do so, we employed an experimental design identical to that of experiment one, but one in which we focus on a different near-minimal pair of words. As mentioned in §2.1, the words in experiment one were embedded in a list of 37 Spanish words, all read by eleven native speakers of EAS. In addition to the words examined in experiment one, the list contained the forms /θesta/ 'basket' and /sekta/ 'sect.' These forms also undergo coda aspiration, yielding the surface EAS forms [θe^{h}t.ta] and [se^{h}t.ta]. This pair thus provides us with a test case for the results of experiment one, with one difference. In this case, we also have the opportunity to examine whether the differences in aspiration and gemination extend to comparisons between /s/ and coda obstruents other than /p/.

3.2 Data measurement and analysis

As the focus of experiment two is to replicate the differences in aspiration and gemination that were found in experiment one, we measured only the aspiration duration and the medial stop closure duration.[4] (See §2.2 for a discussion of how these durations were defined.) We used the same MANOVA test, described in §2.2.2, to test for statistical differences in the durations, again assuming a significance level of $\alpha = .05$.

3.2.1 Data excluded from analysis

As in experiment one, there were a few forms that were produced without aspiration, though again, the majority of the forms were in fact aspirated. Only two speakers produced any non-aspirated forms, as is shown in Table 5.

Speaker	/θesta/	/sekta/	Total by Speaker (30 = 100%)
CR	15	15	30
JP	15	15	30
VE	15	15	30
BH	15	15	30
UR	15	15	30
ER	15	12	27
BS	15	15	30
PP	15	15	30
IN	15	14	29
AL	15	15	30
RM	15	15	30
Total by Word (165 = 100%)	165	161	326

Table 5: Number of aspirated forms by speaker and by word, /qesta/ vs. /sekta/

3.3 Results: comparing /θesta/ and /sekta/

3.3.1 Aspiration duration

Looking first at aspiration duration, we see in Figure 11 a pattern that is strikingly similar to that in Figure 7. That is, despite the individual variation shown in Table 6, all but one speaker, IN, has a longer duration of aspiration in /θesta/ than in /sekta/.

Speaker	Mean Duration /sekta/	Mean Duration /θesta/	Difference: /θesta/- /sekta/	Ratio: /sekta/ / /θesta/	Percent Differences: /θesta/ - /sekta/
CR	16.05113	16.30813	0.257	0.984241	**1.601133**
JP	17.9106	26.101	8.1904	0.686204	**45.72934**
VE	11.31353	17.1488	5.835267	0.659727	**51.57776**
BH	36.81627	50.7904	13.97413	0.724867	**37.95641**
UR	4.3566	10.13271	5.776114	0.429954	**132.5831**
ER	11.58	12.35353	0.773533	0.937384	**6.679908**
BS	23.1926	25.78367	2.591067	0.899507	**11.17195**
PP	21.4208	28.38067	6.959867	0.754767	**32.49116**
IN	10.1197	8.901714	-1.21799	1.136826	**-12.0358**
AL	6.959867	8.931067	1.9712	0.779287	**28.32238**
RM	15.7852	23.0746	7.2894	0.684094	**46.1787**

Table 6: Aspiration Duration, /qesta/ vs. /sekta/

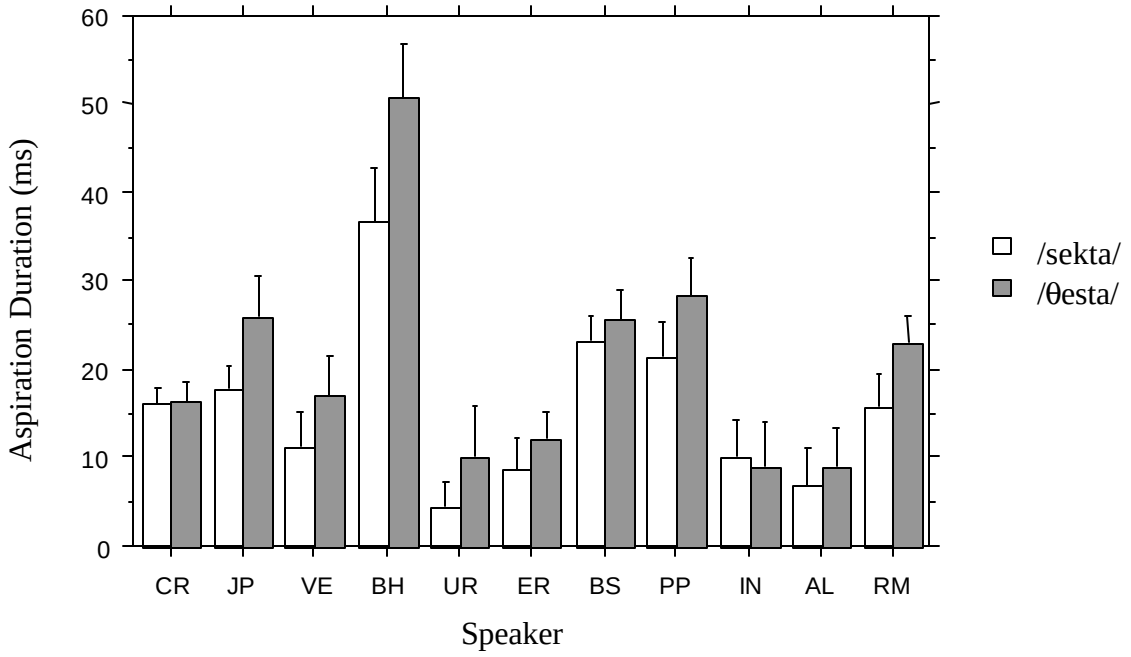


Figure 11: Aspiration duration by word and by speaker, /sekta/ vs. /qesta/

A MANOVA shows that this pattern is significant [F(1,10) = 12.83, p = .0050]. These results thus replicate those in experiment one; the form with an /s/ in coda position has longer period of aspiration than the form with a stop, in this case, /k/.

3.3.2 Medial stop closure duration

Next, we look at the closure duration of the medial stop. In both experiments, this stop was a geminate [t]. The average durations for each speaker are given in Table 7 and shown in the column graph in

Speaker	Mean Duration /sekta/	Mean Duration /θesta/	Difference: /sekta/- /θesta/	Ratio: /θesta/ / /sekta/	Percent Differences: /sekta/ - /θesta/
CR	170.1829	153.0764	17.10653	0.899481	**10.05185**
JP	118.0772	107.7704	10.3068	0.912711	**8.728866**
VE	191.8278	171.5253	20.30253	0.894163	**10.58373**
BH	154.5367	136.2027	18.334	0.881362	**11.86385**
UR	147.9726	144.0363	3.936314	0.973398	**2.660164**
ER	102.4265	105.5754	-3.1489	1.030743	**-3.0743**
BS	116.514	103.0749	13.43907	0.884657	**11.53429**
PP	166.9358	159.5433	7.392467	0.955717	**4.428329**
IN	148.8338	131.1015	17.7323	0.880858	**11.91416**
AL	73.28487	70.07087	3.214	0.956144	**4.385626**
RM	86.82713	91.4104	-4.58327	1.052786	**-5.27861**

Table 7: Closure Duration, /qesta/ vs. /sekta/

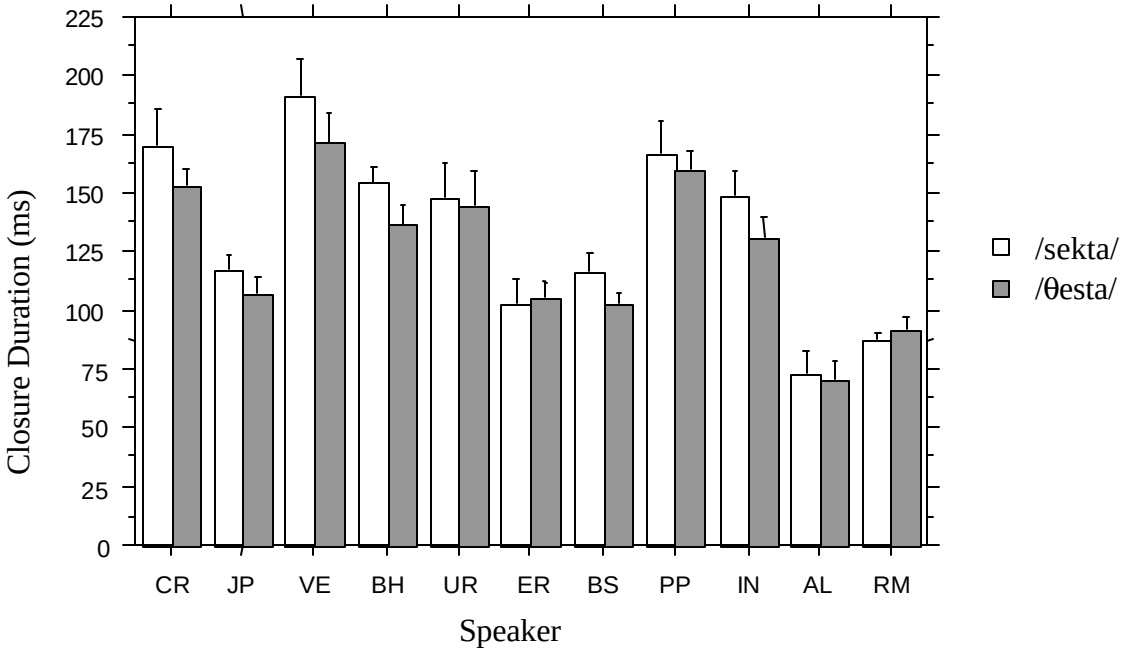


Figure 12: Closure duration by word and by speaker, /sekta/ vs. /qesta/

As in experiment one, there is a clear pattern for the sample population. Nine of the eleven speakers show a longer period of closure in /θesta/ than in /sekta/. A MANOVA indicates that this pattern is statistically significant [$F(1,10) = 12.73$, $p = .0051$]. Again, the form derived from an aspirating /s/ has a shorter medial geminate closure duration, while the one derived from an aspirating stop has a longer closure duration for its medial geminate consonant.

4. Discussion

In what context should we view the above results? We argue that they are best understood in the context of work in the growing area of laboratory phonology. In particular, many recent experiments have discovered extremely fine-grained phonetic details that must, nevertheless, be considered part of the linguistic grammar. As

Pierrehumbert (2000) notes, a key assumption of traditional generative linguistics is that phonological rules, which may be language specific, form the input to a universal phonetics that simply acts as a machine to implement various phonetic categories that are assumed to be the same cross-linguistically.

Numerous experiments have contradicted this traditional model, including Caramazza and Yeni-Komshian's (1974) study of European French, Canadian French, and Canadian English voice onset time, Keating's (1984) cross-linguistic study of what it means to be a 'voiced' or 'voiceless' stop, Flege and Hillenbrand's (1986) study of fricatives in French and English, and Bradlow's (1995) study of English and Spanish vowels, among others. All of these studies strongly suggest that there is no 'universal phonetics' in the traditional sense. (See Kingston and Diehl (1994) for further discussion of 'controlled' versus 'automatic' phonetics.) Rather, as Pierrehumbert et al. (2001) point out, 'there are no two languages in which the implementation of analogous phonemes is exactly the same' (9). Interestingly, our results show further evidence of finely grained phonetic knowledge. In this case, however, we do not approach the issue of coda aspiration cross-linguistically, but rather examine the implementation of coda aspiration within a single language. Specifically, we show that what it means to be an aspirated coda in EAS varies subtly according to the underlying quality of the lost segment—coda /s/ versus coda /p/ and coda /s/ versus coda /k/ aspirate differently, and thus do not undergo total phonetic neutralisation.

The rest of this discussion section is organised as follows. In §4.1, we address the issue of the magnitudes of the differences in our results. In §4.2, we discuss the implications of our results for phonological analyses based solely on impressionistic

transcriptions and for the relationship between phonology and phonetics. In §4.3, we address the issue of synchrony versus diachrony as it pertains to our data and to our discussion of the phonology/phonetics interface.

4.1 Magnitude of differences

Although aspiration is statistically non-neutralising, the subtle nature of the differences that we found warrants consideration. Consider, for example, the data in Table 3 (§2.4.2), Table 4 (§2.4.3), Table 6 (§3.3.1), and Table 7 (§3.3.2), which provide mean aspiration and closure duration measures for each subject by context. In Table 3, for the nine cases in which aspiration is longer in the /kasta/ context, we see that the mean differences are quite small, ranging from .106 ms for CR to 15.846 ms for subject BS. When viewed as ratios across the subject pool, however, the general magnitude of the difference is greater than what appears to be the case when considering only the mean differences. For example, for eight subjects there is at least a 15% or greater duration of aspiration in the /kasta/ context. Similarly, in Table 6, seven of the speakers with a longer aspiration duration in /θesta/ than in /sekta/ have percent differences of more than 15%.

Table 4 provides the mean closure duration differences for the /kasta/ and /kapta/ contexts. Here, again, the differences in the numbers are subtle. While it is the case that ten of eleven speakers exhibit longer closure duration in the /kapta/ context, six of these show mean differences of less than ten ms. In terms of ratios, only four speakers on average produce a medial stop closure that is greater by 10% or more. The results in Table 7 in §3.3.2, which shows the mean closure duration differences for the /sekta/ and /θesta/ forms, are similar to those in Table 4. The speakers show differences ranging

from about 3 ms to 20 ms, but only five speakers produced average closure durations that were at least 10% different.

The fine-grained nature of these differences leads us to address the question of whether our findings, though significant, are meaningful. Unfortunately, it is easier to test the null hypothesis statistically than to settle on a definitive answer to the more qualitative question of meaningfulness. We do, however, maintain that the results are meaningful, even if the differences emerge as statistically significant trends rather than clear distinctions between individual surface /kasta/ and /kapta/ or /θesta/ and /sekta/ tokens in EAS. It is notable, for example, that in contrast to the aspiration and gemination results, our statistical testing failed to falsify the null hypothesis with respect to the duration of vowel voicing. Consider the mean duration measures of the voiced portion of the vowel preceding the onset of aspiration in Table 5 (§2.4.1).

In this case, speakers are evenly split, with five subjects exhibiting longer mean vowel durations in the /kasta/ context and six patterning in the opposite fashion. Not surprisingly, the MANOVA failed to falsify the null hypothesis for vowel duration, as reported in §2.4.1 above. Clearly then, as a group the speakers are behaving systematically; i.e., there is a clear pattern with respect to the production of the aspiration and closure variables that we measured, while by contrast the data indicate that the differences in mean vowel duration are best attributed to chance.[5]

4.2 Implications for the phonetics/phonology interface

An interesting result of our experiments is that our findings reinforce work that has shown that the traditional, impressionistic transcriptions employed by phonologists and present in descriptive grammars are often insufficiently finely grained to reflect all of the

linguistically relevant characteristics of a form (see, for example, Port 1996). Having established that there are durational differences between the realisations of /kasta/ and /kapta/ and between /θesta/ and /sekta/ in EAS, we now turn to the questions of what speakers are doing and, in particular, why forms such as /kasta/ and /θesta/ exhibit greater duration of aspiration, while those such as /kapta/ and /sekta/ exhibit a longer closure duration for the medial stop. We hypothesise that the key to the issue lies in the aspiration question. Specifically, we claim that our measure of longer duration for aspiration in the underlying /kasta/ or /θesta/ context results from a subtle yet real tendency to aspirate forms containing underlying /s/ more heavily. Such forms can be thought of as the most prototypical cases, given that the overwhelming majority of aspirating forms in EAS are forms that contain [s] codas in SPS. It is most likely not by chance that the phenomenon is commonly called s-aspiration (and not consonant aspiration, or obstruent aspiration, or coda aspiration), and even linguistically naive speakers of EAS readily (if over-generally) characterise their dialect as one in which [s] is not pronounced.

We suggest that the greater duration of aspiration in the /kasta/ and /θesta/ contexts can be related to the well-known fact that voiceless fricatives are realised with greater glottal width than are voiceless stops (see, for example, Sawashima and Hirose 1968). Although it is clear that EAS realises neither a surface [s] nor a surface [p] in aspirated [ka^{h}tta] forms (nor a surface [s] or a surface [k] in the surface forms corresponding to /θesta/ and /sekta/), it is intriguing to consider the hypothesis that the longer duration of aspiration in the /kasta/ context may result from subtle timing differences related to the respective targets for glottal width, corresponding to the underlying /s/ versus the underlying /p/. To put this another way, let us assume that, phonologically, vowel

aspiration in both contexts can be characterised as the preservation of a [-voice] feature, i.e. a Faithfulness effect in Optimality Theoretic (Prince and Smolensky 1993, etc.) terms. What this suggests is that just as a [-voice] feature present at output is interpreted in a distinct fashion phonetically depending on whether it is a feature of a voiceless fricative or a voiceless stop, we might also conclude that it is not the same to preserve the [-voice] of an input /s/ than it is to preserve the [-voice] feature of an input /p/ or /k/. If this hypothesis is correct, then the results presented here would indicate that the wider glottal width target of the underlying /s/ is manifested as a longer duration of aspiration after the actual segment has been deleted.

Even if we are on the right track to place the aspiration difference at the core of the issue here, we are still left with the question of why medial stop closure duration is on average longer in forms corresponding to underlying /kapta/ or /sekta/. From an Articulatory Phonology standpoint (see, for example, Browman and Goldstein 1992), a slightly earlier onset of alveolar stop closure in the medial geminate consonant, timed with respect to the offset of vowel voicing, would have the result of reducing the duration of audible aspiration, i.e., would enhance the aspiration difference in the two contexts. If such a scenario is accurate, then we arguably predict that a statistical test of the duration of the mean aspiration+closure duration for each speaker in the two contexts should be compatible with the null hypothesis. That is, we expect that the average total aspiration+closure duration is neutralised in these two contexts, but that there is a trade-off relation between the closure duration and the aspiration. In order to compensate for the longer duration of the aspiration in forms corresponding to /kasta/ and /θesta/, ostensibly caused by the preservation of a wider glottal width target for the [-voice]

feature of underlying /s/, the closure duration is longer in the forms derived from /kapta/ or /sekta/. Interestingly, a MANOVA supports this hypothesis and indicates that there is no significant difference in the average sum of aspiration and closure duration in /kasta/ versus /kapta/ [$F(1,10) = 2.88$; $p = .1203$]; likewise, for /θesta/ versus /sekta/, a MANOVA yields a result of [$F(1,10) = 2.66$, $p = .1342$].[6]

If, broadly speaking, we are on track in our thinking about the trade-off between the aspiration duration and consonant closure duration above, then this raises interesting questions for the interface of phonology and phonetics as traditionally conceived. At least two obvious possibilities present themselves. As briefly mentioned above, traditional modular models treat phonology as 'feeding' phonetics: the output of the phonological system becomes the input of the language-particular phonetic implementation system (Keating 1990, Cohn 1993). A traditional view of categorical phonology would indicate that the aspiration process in EAS is one of neutralisation in coda position. If the input to the phonology is either /kasta/ or /kapta/, the input to phonetics is /ka^{h}t.ta/, and there is no way for the phonetics to differentiate between the two forms, because the underlying contrast has been lost.

One possibility would dispose of this split system and incorporate fine-grained phonetic knowledge directly into the phonology, thus eliminating the categorical nature of phonology. For example, rather than processes such as aspiration or gemination being considered binary, they could be thought of as continuous. A feature such as [-voice] would now correspond to a range of values for glottal width, instead of simply assuming a [-voice] valence of a binary [±voice] feature; phonological preservation of this feature would result in varying glottal width targets, as explained above. (See, for example,

Steriade 1997, Kirchner 1997, Flemming 1995 for models incorporating gradient features into an OT framework.)

An alternative idea would be a system in which the phonology remains categorical, but the phonetic implementation system is given more power. One way that this can be achieved is to allow the phonetics to be sensitive to the underlying representation, i.e., to endow the phonetics with the ability to 'look back' at the underlying form, so that the output of the phonology is no longer the only source of information for the phonetics. This would allow the system to maintain a kind of phonological neutralisation, in this case a phonology which bans obstruents from being independently licensed in coda position, thus accounting in a maximally general manner for the phenomenon of coda-aspiration in this variety of Spanish. This could, nevertheless, be distinct from a more finely grained (and hence total) phonetic neutralisation. Specifically, the phonetics could 'see' the quality of the segment from which the general phonological target of [-voice] originated, e.g. /s/ or /p/ or /k/, and adjust the glottal width (or its manifestation) accordingly, as sketched in Figure 13 below.

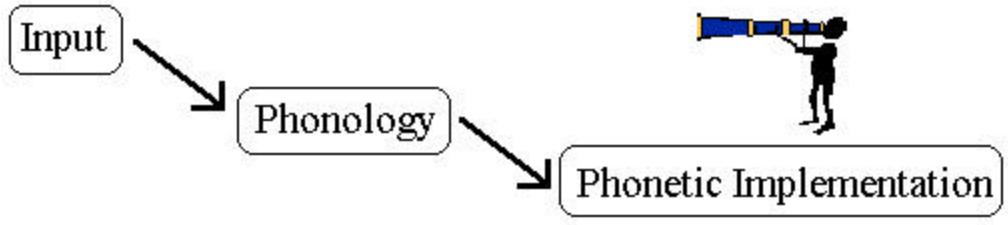


Figure 13: A phonetic implementation system that is sensitive to the input

The benefit of this second position is that is allows a place for the elegant and broad generalisations available to traditional phonological analyses, while the phonetics can still recover, at least at some level, a distinction between underlying forms. The cost is

that we lose the restrictiveness of models such as those of Keating (1990) and Cohn (1993) in that we would have phonetic implementation accessing the underlying distinction between /kapta/ and /kasta/ rather than interpreting the output of the phonological component of the grammar.[7]

Finally, it is important to note that the discussion in this section of the implications of our results for the interface of phonetics and phonology is predicated on the assumption that the underlying forms of our experimental items are /kasta/, /kapta/, /θesta/, and /sekta/. Alternatively, one might claim that the situation does not warrant a synchronic treatment at all. That is, the study could be framed not as one which compares the phonetic implementation of underlying /kasta/ vs. /kapta/, but as one which compares the synchronic realisations in EAS of historical *kasta vs. *kapta-type forms. For example, one might posit URs such as /kaht:a/ for *kasta, in which /h/ is treated as a segment in its own right, versus /ka^{h}t:a/ for *kapta, in which aspiration is treated underlyingly as either part of an aspirated vowel or part of a preaspirated geminate consonant. Other logical possibilities are imaginable. The crucial point, however, is that distinct underlying representations such as these, which do not reference a medial, synchronic /s/ versus /p/ distinction in these forms in EAS, could arguably be invoked in an account of the differences in phonetic implementation that we found in our experimental study. If such a scenario is viable, it becomes unclear whether our results raise the kinds questions that we have posed for traditional views of the synchronic phonetics/phonology interface. The issue, then, is whether our assumption of synchronic underlying forms such as /kasta/ and /kapta/ for EAS is well motivated.[8] We turn our attention to this issue in §4.3.

4.3 On the URs of our experimental items

Standard phonological evidence in support of our URs would be most directly provided by the presence of alternations in the data. The medial clusters in our experimental words, however, do not provide alternating contexts. We argue, nonetheless, that there exists a constellation of facts which, when considered together, support our view. These include the presence of synchronic alternations in singular forms ending in underlying obstruents, the phonological treatment of borrowings in EAS whose phonotactics condition medial aspiration of the type under examination here, variation, both with respect to production and exposure for EAS speakers, and exposure via standardised Spanish orthography to representations that reinforce graphically the underlying representations that we have posited.

We turn first to the issue of alternations. Although there is an absence of word-medial alternations, there are, in fact, root-final cases of alternation which motivate the kind of underlying representations that we assume in the above discussion. Obvious examples can be found in non-plural nouns ending in /s/, such as /θipres/ 'cypress' or /tos/ 'cough', which are predictably realised in EAS with aspiration of the final /s/, i.e. as [θi.'pre^{h}] and [to^{h}], respectively. Crucially, when pluralised, the final, underlying /s/ of each root surfaces–because it is syllabified in the plural form as on onset–yielding the respective plural forms [θi.'pre.s̲e^{h}] and ['to.s̲e^{h}], with aspiration only of the /s/ of the plural morpheme. Note that such alternations are not limited to /s/-final roots. For example, forms such as /edad/ 'age' and /berdad/ 'truth' also undergo predictable coda-aspiration in EAS, surfacing as [e.'da^{h}] and [ber. 'da^{h}]. As with the /s/-final cases above, the final, underlying /d/ in each surfaces under pluralisation, yielding [e.'da.d̲e^{h}] and [ber.'da.d̲e^{h}],

respectively.[9] The same holds for forms containing a final, underlying /θ/, such as /θikatriθ/ 'scar', which alternates between the deletion of the root-final consonant and aspiration of the final vowel ([θi.ka.tri^{h}]) in the singular and the presence of the underlying, root-final obstruent in the plural ([θi.ka.tri.θe^{h}]). Additionally, lexicalised forms borrowed from French such as /majoret/ 'majorette' and /bedet/ 'musical theatre star' behave in the same fashion. In the singular, these are realised in EAS with the aspiration of the final vowel and the loss of the underlying /t/ (i.e. [ma.jo.'re^{h}] and [be.'de^{h}]), while root-final /t/ surfaces as an onset in their plural forms ([ma.jo.'re.te^{h}] and [be.'de.te^{h}].

Of particular relevance here is that all of these alternations motivate the positing of URs with distinct underlying final obstruents, such as /tos/, /berdad/, /θikatriθ/, and /majoret/, given that this approach allows for a maximally general phonological analysis involving the context-sensitive aspiration of all obstruents in coda position in EAS. Crucially, we do not posit these URs for EAS because they correspond to SPS forms. Rather, to posit underlyingly aspirated forms excessively complicates the phonological analysis, as we would be forced to account for why some underlyingly aspirated forms surface in the plural with a root-final /s/, while others surface with root-final /d/ or /θ/ or /t/ and so forth.

Returning then to the viability of URs such as /kasta/ and /kapta/ for the words in our study, we note that while the alternating forms above do not directly motivate the URs we have assumed, they do motivate a synchronic phonological analysis involving the kind of coda-aspiration that we have examined in a word-medial context in this study. That is, in cases such as [to^{h}] and [berda^{h}], there is no case to be made for viewing aspiration merely

as diachronically related to historical *tos and *berdad. Rather, a synchronic analysis is required.

The behaviour of borrowed forms with medial clusters provides additional, strong evidence that a synchronic analysis is likewise motivated for forms exhibiting word-internal coda aspiration. Examples of word-medial aspiration in recent borrowings abound in brand names, non-native computer terminology, and other borrowings. For example, we find aspirated forms such as [e^{h}s.son] 'Epson' with a medial /ps/ in the source form, [pe^{h}s.si] 'Pepsi' /ps/, [la^{h}t.to^{h}] 'laptop' /pt/, [bi^{h}m.ma^{h}] 'bitmap' /tm/, and [dʒe^{h}l.la^{h}] 'jet lag' /tl/. Note that all of the source forms contain medial clusters that cannot be syllabified as complex onsets. As expected, the first member of the cluster is deleted; the vowel aspirates; and the second member of the cluster lengthens, just as in experimental /kasta/-/kapta/ type forms. Importantly, aspiration in these borrowed forms is not amenable to the kind of historical approach suggested above. Rather, they illustrate the productive, synchronic nature of the phenomenon. In short, word-final contexts exhibit alternations that motivate the kind of URs that we have posited for /kasta/ and /kapta/-type forms. And borrowings attest to the synchronic productivity of aspiration in word-internal contexts. On traditional phonological grounds, these factors lead us to view our position on the URs for the experimental forms as well-motivated in the synchronic grammar.

Finally, we turn to the issue of the bidialectalism of our speakers and its relevance to the URs we have posited. Admittedly, this is a complex issue. While it would be an oversimplification to assume that familiarity with SPS suffices to motivate URs such as /kasta/ for Eastern Andalusian, it would be similarly oversimplistic to view SPS forms as

completely unrelated to the synchronic URs of EAS speakers. Speakers in Granada are exposed to dialectal variation including numerous SPS forms both in daily life and in media such as television, film, and radio. In turn, a Granada speaker can produce (even in a single conversation) both non-aspirated forms such as [kasta] and aspirated forms such as [ka^{h}tta], although the latter predominates. Therefore, these speakers are metalinguistically aware of the doublet forms, which provide de facto sets of alternations, in the which alternating pairs such as [kasta] ~ [ka^{h}tta] are not conditioned morpho-phonologically but rather by sociolinguistic factors.

Moreover, it is relevant to point out that Spain has a high rate of literacy (97%)[10] in a standardised orthography that directly reinforces the medial consonant distinctions that we have posited in our URs: /kasta/(spelled 'casta'), /kapta/ (spelled 'capta'), /θesta/ (spelled 'cesta'), and /sekta/ (spelled 'secta'). Though traditional work in generative phonology discounts orthographic knowledge in the construction of phonological grammars, in our view such an approach is not altogether warranted. As in the discussion of bidialectalism above, we do not claim that literacy alone in the written standard motivates the URs we have posited. Rather, we argue that widespread literacy in a standard orthography, which reinforces the representations that we have defended above on synchronic phonological grounds, provides further support for our position. This notion is supported by psycholinguistic research, which long ago showed that literacy training crucially affects subjects' abilities to perform adequately in phoneme perception tasks (Morais, Cary, Alegria, and Bertelson 1979). For example, Morais, Bertelson, Cary, and Alegria (1988) demonstrate that illiterate Portuguese-speaking adults were unable to cope with phonetic segments in both detection and progressive free segmentation tasks.

Such results indicate an essential link between phoneme awareness and literacy. In the same way, we argue that the literacy of all of our subjects (and of the overwhelming majority of Andalusians) must be recognised as fostering a metalinguistic awareness of the underlying, word-medial phonemic contrasts in forms such as /kasta/ versus /kapta/ or /sekta/ versus /θesta/.

In sum, we have adduced evidence from a range of areas which support the underlying representations that we have posited for our experimental forms. These include synchronic alternations in root-final position, the aspirating behaviour of borrowings with medial clusters such as those under study here. Both of these phenomena show coda aspiration to be a productive part of the synchronic phonology of EAS. Additionally, we have argued that the bidialectalism of our subjects, and the metalinguistic awareness of the phonemic content of lexical items fostered by literacy in the written standard provide external evidence in support of the synchronic underlying representations that we have posited in the above discussion.

5. Conclusions

We have presented evidence in this paper that aspiration of coda obstruents in EAS yields fine-grained phonetic differences that depend on the quality of the underlying obstruent. Specifically, we have examined differences in phonetic implementation in the minimal pair of words /kasta/ versus /kapta/ and in the near minimal pair /θesta/ versus /sekta/. We have shown that although all undergo "coda aspiration", which would appear to phonologically neutralise the contrast between the first consonant of the medial cluster in each pair, neutralisation is not complete. Specifically, forms with underlying /s/ are consistently produced with a longer duration of aspiration than forms with an aspirated

voiceless stop. At the same time, forms with an underlying voiceless stop, such as /kapta/, consistently undergo more consonant gemination, possibly because of a combination of a wider glottal width target for /s/ on the one hand and a type of compensation to fill a set temporal window for the combined duration of aspiration and gemination on the other.

Our results inform two larger areas of discussion. First, they call attention to the limitations inherent in an approach to phonology which relies exclusively on impressionistically transcribed data. Second, our findings lead us to reflect on the nature of the phonetics/phonology interface. In particular, we suggest that an adequate understanding of the data requires an enriched model of phonetic implementation that can do more than simply interpret the output of a categorical phonology. We propose two possibilities for accounting for the kind of phonetic knowledge under discussion here. One involves wholesale incorporation of finely grained phonetic features into the phonology, while the other allows for a more traditional phonetics/phonology interface, modulo the proviso that phonetic implementation can also be informed by underlying feature specification.

Finally, it is noteworthy that these data can be related to the literature on near mergers. Though we have shown that the process is a synchronic, productive phenomenon in EAS phonology, the subtle nature of the differences in phonetic implementation that we find may be indicative of the nature of the phonetic differences in cases of so-called near mergers that have been discussed in a diachronic context in sociolinguistic work (see, for example, Labov et al. 1972, Milroy and Harris 1980, DiPaolo and Faber 1990, Labov 1994, and others)–situations in which contrasts that

appear to have been neutralised later re-emerge (sometimes after several generations) along the lines of the original contrast. It has been argued that, as with the pairs such as /kasta/ and /kapta/ studied here, subtle phonetic differences are actually preserved through time by a speech community, thus allowing speakers to ‘unmerge’ the putatively neutralised forms. We suggest that /kasta/ and /kapta/ make an outstanding candidate pair for understanding such near mergers—while they may be for all intents and purposes neutralised phonologically for the current generation of speakers, as long as speakers continue to preserve any sort of consistent phonetic difference or differences, the words have the potential to split again along the lines of their underlying distinctions.

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Notes

[*] Acknowledgements...

[1] Word-final s-aspiration in EAS is also associated with the laxing of the final vowel and a right-to-left process of vowel harmony (see, for example, Navarro Tomás 1939, Zubizarreta 1979, Lieber 1987, Sanders 1994). As vowel harmony is triggered by word-final and not word-internal s-aspiration, however, this phenomenon will not be addressed in this paper.

[2] Although we refer to these studies as experiments "one" and "two," all data was collected in a single experimental setting. The two analyses were carried out separately as different experiments.

[3] While we might think that a higher education level might lead subjects to speak in a more standard fashion, all of the subjects here strongly self-identified as Andalusian, and none expressed any inclination to reject EAS in favour of SPS.

[4] In addition to not being particularly relevant to the question in experiment two, we are wary of comparing the vowel durations across the /θesta/ and /sekta/ contexts, given that they are not in fact a true minimal pair and the quality of the initial consonant may interfere with the measurement of the following vowel.

[5] The subtlety of the differences does call into question the perceptual salience of the contrast between aspirated /kasta/ versus /kapta/. Although a perception study is needed before drawing any firm conclusions, we see no obvious indications that speakers are

aware of the contrast between aspirated tokens of these two words. If the distinction is not in fact perceptible, we would be confronted with what Dinnsen (1985) refers to as 'Type B' neutralisation, a situation in which speakers are producing differences that they are not actually able to perceive. It is important to remember, however, that only three variables were measured in this experiment—vowel duration, aspiration duration, and consonant closure duration. There are other variables, such as VOT and breathy phonation on the voiced portion of the vowel, that might also cue perceptual differences between the two words.

[6] As Elizabeth Cowper (p.c.) has noted to us, our logic leads us to predict that coda /k/ and coda /p/ should in fact undergo phonetic neutralisation in forms such as /akto/ 'act, action' and /apto/ 'apt,' given that neither contains an /s/ in the critical position.

[7] The view sketched under this scenario would also be compatible with the approach of Zsiga (1997), which assumes a traditional, categorical phonology and a subsequent model of phonetic implementation that employs the gestural scoring of Articulatory Phonology. Again, however, the interpretive, phonetic component of the grammar would have to be enriched in that it would have access to underlying information as well as access to the output of the categorical phonology.

[8] We are grateful to an anonymous reviewer for discussion of this issue.

[9] For simplicity we abstract away here from the well-known intervocalic lenition of /d/ in our phonetic transcription of forms such as [e.'da.d̲e^{h}], in which both /d/ phonemes would be produced as voiced interdental fricatives.

[10] This figure is taken from the CIA's world fact book:

http://www.cia.gov/cia/publications/factbook/geos/sp.html