1. **INTRODUCTION.** Let me begin with an overview of the present study. This study is about the acoustic differences between Spanish and English coronal stops as produced by monolingual and bilingual speakers. Spanish and English both have /d/ and /t/; that is, [coronal] consonants. These consonants are not identical. Spanish /d/ and /t/ have been described as dental while English /d/ and /t/ have been described as alveolar. The present study is concerned with the following three aspects: (i) a description of the acoustics of Spanish and English /d/ and /t/ at their release, (ii) a comparison of the speech of monolinguals and bilinguals, and (iii) a comparison of the Spanish and English productions of bilingual speakers.
2. Spanish and English have an identical system of voiced and voiceless stops. Thus, both languages contrast voiced and voiceless stops. The way they do that, however, differs: Spanish /d/ is prevoiced (i.e., has a negative VOT) while /t/ is voiceless (i.e., has a short-lag VOT); English /d/ is voiceless (i.e., has a short-lag VOT) while /t/ is aspirated (i.e., has a long-lag VOT).
3. But this is not the only way in which the voiceless stops differ as a function of language. As mentioned above, the phonetic descriptions of Spanish [coronal] stops show them to be 'dental' while the descriptions of English [coronal] stops show them to be alveolar. This has been described through impressionistic observations and through some articulatory data. We, however, do not have any acoustic data to capture these observations. While English [coronal] stops have been investigated before, to our knowledge there is no comparable data for Spanish.
4. Some studies have intended to describe the acoustics of dental vs. alveolar stops in various languages. Jongman et al. investigate the case of Malayalam, which contrasts dental and alveolar stops. This study also compares the dental stops of Dutch with the alveolar stops of English. Stoel-Gamon et al. compare the dental stops of Swedish with those of English (and they test more acoustic correlates of place of articulation than prior studies). To date, the most comprehensive studies are those of Sundara, who compared the dental stops of French with those of English in two groups of monolingual speakers of these languages and then compared them in the productions of a group of simultaneous French-English bilinguals.
5. The acoustic descriptions to date show that, at the release burst, alveolar stops are louder (i.e., they have a higher amplitude or intensity relative to the following vowel) than dental stops. The spectral envelope of the burst also differs as a function of place of articulation: the center of gravity of the spectrum (or the mean energy) is higher for alveolars than for dentals, the standard deviation of the spectrum is more compact for alveolars than for dentals and the kurtosis of the spectrum is more peaked for alveolars than for dentals.
6. Now, these correlates are not really robust. Malayalam, the only studied language that contrasts alveolars and dentals, uses at least one of these correlates rather strictly, relative intensity. This means that, in this case, there is little overlap between the two distributions and the correlates are robust in signaling place of articulation. But most languages have *either* dentals *or* alveolars, not both. In these languages, the acoustic correlates are predictably more flexible or variable; they lead to more overlap between the acoustics of dentals vs. alveolars. So, the question arises as to what happens in bilingualism? It could be said that a bilingual who speaks a language that has alveolars and one that has dentals has *both* features in her phonological system, like a Malayalam speaker; however, these features are never in systemic opposition...
7. The case of bilinguals is, therefore, special. In bilingualism, links are formed between sound categories in the two languages, so that there are some sound-to-sound correspondences or cross-language cognates. This is usually reflected through interlingual assimilations of sounds, which are in turn reflected through a compromise between the phonetic characteristics of the sounds of the two languages. In a classic study, Caramazza et al. showed that a group of

French-English bilinguals from Montreal, Quebec used different VOT values for their English and French voiceless stops, thus showing that they have representations for both sounds. The phonetic values, however, were compromised between the two languages, meaning that they were intermediate between those pertaining to monolingual speakers of each of the two languages. Now, returning to the case that concerns us here, since the articulatory difference between dental and alveolars is small and the acoustics of these sounds seem to be somewhat unstable it is reasonable to hypothesize that bilinguals might compromise the place of articulation of their [coronal] consonants and even conflate them to one place.

8. This is the question Sundara addressed. For a group of French-English bilinguals from Montreal, however, she showed that the bilinguals had separate representations for their dental (French) and alveolar (English) coronal stops. While the acoustics of these stops differed for the two languages, Sundara also found that these characteristics were compromised: the bilinguals differed from the monolinguals and the distinction between the two places was captured only by some acoustic correlates (and not others) in a non-systematic manner.
9. Could this be a characteristic of the French-English population in Quebec or is this a general pattern of bilingualism? This is an important question because some early and simultaneous bilingual populations have been found not to differ from monolingual speakers of each of their languages. Some scholars posit that bilinguals might have separate (though perhaps not fully independent) phonetic systems for their two languages. Unlike Caramazza et al., Magloire and Green, for instance, showed, for the Spanish-English bilingual population of Southern Arizona, that these bilinguals *did not* use compromised VOT values in either of their two languages—they behaved just like monolinguals. We build on Magloire and Green's finding for the Southern Arizona Spanish-English bilingual population and ask whether they can help us investigate the acoustic characteristics of coronal stops in a within-subjects design, just as Malayalam allows.
10. **METHOD.** For our study, we recruited 32 participants, all of them females. There were 8 Spanish speakers from Majorca, Spain; 8 English speakers from Tucson, Arizona; and 16 early, proficient Spanish-English bilinguals from Tucson, Arizona. They were all young adults. The attributes of the bilinguals were examined with the help of the bilingual language profile questionnaire of Birdsong and colleagues.
11. This questionnaire has four components; it asks about history, use, competency and attitudes towards the two languages. The responses are numeric and thus allow for the calculation of an index of dominance assigned to each bilingual individual. In this index, zero represents balanced bilingualism while the negative and positive extremes represent monolingualism. Our bilinguals had indices near zero, representing high proficiency in (and much experience with) the two languages. We divided the bilinguals in two groups according to whether they had slightly negative numbers (and thus were dominant in English) or slightly positive numbers (and thus were dominant in Spanish).
12. The materials consisted of target words with /d/ and /t/ in utterance-initial position, and thus also word-initial position. The words were followed by a carriers phrase. Lexical stress was manipulated and balanced—but it is not examined here. The vowel following the stop was controlled so that we used only /a/ in Spanish and /ae/ in English. These vowels, although acoustically different nonetheless, are less different in the dialect of English spoken in Arizona than one might anticipate by looking at descriptions of English phonetics based on other dialects.
13. In order to collect speech samples we used the delayed shadowing technique. We asked our 32 speakers to listen to and then repeat the list of materials as they had been pre-recorded by six

male talkers, 3 Spanish talkers and 3 English talkers. Each speaker listened to and then repeated the same list of materials, but always in a different random order. The monolinguals provided data only in their language while the bilinguals were recorded in both of their languages. It is important to highlight that the bilinguals produced Spanish and English samples in the same session, in the same block—the materials were interspersed in random order.

14. The dataset comprises a total of 3456 observations. We had to exclude 76 tokens due to various errors. We end up with 3380 data tokens with the following design: 24 words * 3 iterations * 2 languages.
15. The analyses was based on two basic acoustic features: Voice Onset Times and the characteristics of the spectrum extracted at the release of the articulators. The voice onset times were measured following standard procedure (in ms). The power spectrum was extracted from a Gaussian window left-aligned with the onset of the burst. This window varied as follows: if VOT was positive but less than 20 ms, the length of the window was determined by the length of the VOT measure. In all other cases, the window was 20 milliseconds.
16. From these we extract the following metrics: VOT, obviously; the fours spectral moments of the power spectrum of the burst (center of gravity, standard deviation, skewness and kurtosis) and a measure of relative intensity, which was calculated by subtracting the intensity at the midpoint of the vowel from that of the burst.
17. Here, we talk about VOT, Center of Gravity and Relative Intensity.
18. We have analyzed the data using various statistical methods. Here, we report on the results of basic factorial analyses of variance (ANOVA). The responses are VOT, Center of Gravity and Relative Intensity. The factors are language, voicing and speaker group.
19. Our dataset allows us to ask the following questions. We address them by subsetting our dataset. (1) How do English and Spanish /d/ and /t/ differ from each other? This is addressed by comparing the monolingual productions, (2) How do Spanish-speaking monolinguals and bilinguals differ? This is addressed by examining the Spanish productions across groups, (3) How do English-speaking monolinguals and bilinguals differ? This is addressed by examining the English productions across groups. (4) Finally, How do the languages of a bilingual differ from each other? This is examined by comparing the Spanish with the English productions of the bilinguals only.
20. STUDY 1. We now move on to the first research question: This figure plots VOT as a function of language group and voicing (/d/ vs. /t/). The y-axis represents VOT in ms. The left panel corresponds to Spanish; the right panel, to English. Within each panel, the value on your left corresponds to /d/; the one on your right, to /t/. The horizontal line in the middle of each panel stands for VOT = 0. The data shows that Spanish and English differ in how they use VOT in these consonants. Spanish /d/ is prevoiced (it has a negative VOT), Spanish /t/ is voiceless (it has a positive, short-lag VOT), English /d/ is also voiceless (it has a positive, short-lag VOT) and, finally, English /t/ is aspirated (it has a positive, long-lag VOT).
21. This figure plots the Center of Gravity data. Once again, the panel on your left corresponds to Spanish; the one on your right, to English. Within each panel, the values for /d/ are plotted, then those for /t/. The y-axis is Center of Gravity (in Hz) and it goes from 0, at the bottom, to 5000, at the top. The plot shows that Spanish /d/ and /t/ do not differ from each other and they have low-frequency resonances (< 1000 Hz). English /d/ has mid-frequency resonances (~ 2000 Hz). Finally, English /d/ has high-frequency resonances (~ 4000 Hz). Thus, the analysis shows that Spanish and English coronal stops clearly differ in terms of the spectral envelope of their burst.
22. The last plot is to be read in a similar way. The two panels represent the two languages, and each panel has a value for /d/ (on the left) and one for /t/ (on the right). Here, the y-axis plots

our measure of relative intensity and the horizontal line in the middle of the panels stands for zero. The Spanish values are negative, which means that the following vowel was much louder than the burst of the coronal stop. For English, on the other hand, the burst was as loud (if not louder) as the following vowel. It's important to highlight that Spanish coronal stops seem to differ robustly from Spanish ones.

23. STUDY 2. Now, we move on to study 2. In this study we compare the acoustic characteristics of Spanish /d/ and /t/ stops across groups of Spanish speakers: Spanish-speaking monolinguals, Spanish-dominant bilinguals and English-dominant bilinguals.
24. The panels are to be read as follows. The left panel plots the monolingual Spanish data; the one in the middle, the Spanish-dominant bilingual data; and the one on the right, the English-dominant bilingual data. Within each panel, the value on the left corresponds to /d/ and, that on the right, to /t/. VOT is plotted on the y-axis, with 0 in the middle of the y-axis. The comparison showed that Spanish monolinguals and bilinguals did not differ in how they use VOT to contrast /d/ and /t/. Across groups, the values are similar.
25. Regarding the Center of Gravity metric, the comparison detected a small, but significant, difference between the monolinguals and each of the two bilingual groups. Although all of the values are well below 1000 Hz (and thus relatively very low), the bilinguals' values are slightly higher than the monolinguals' ones. /d/ and /t/ do not differ for any group of speakers.
26. Finally, our analysis of the Relative Intensity metric was not able to reveal any differences across groups. For both monolinguals and bilinguals, Relative Intensity values were negative, which means that the burst was much softer than the midpoint of the following vowel. None of the groups used different values for /d/ and /t/.
27. In sum, the bilingual speakers do not seem to differ from the monolinguals. The only detected difference is one in Center of Gravity, but the effect is very small and, in any case, all values are below 1000 Hz, which is characteristic of dental stops—i.e., the bilinguals are not producing alveolars in their Spanish.
28. STUDY 3. We proceed to study 3. In this study we compare the acoustic characteristics of English /d/ and /t/ stops across groups of English speakers: English-speaking monolinguals, Spanish-dominant bilinguals and English-dominant bilinguals.
29. As before, the panels are to be read as follows: The left panel plots the monolingual English data; the one in the middle, the Spanish-dominant bilingual data; and the one on the right, the English-dominant bilingual data. Within each panel, the value on the left corresponds to /d/ and, that on the right, to /t/. VOT is plotted on the y-axis, with 0 in the middle of the y-axis. The comparison showed that English monolinguals and bilinguals did not differ in how they use VOT to contrast /d/ and /t/. Across groups, the values are similar. There is a tendency for values to be closer to zero for /d/ in bilingual speech. This reflects the fact that the bilinguals were more likely to use prevoicing; they did so in some of their tokens. The effect does not show up in these statistics, but it does in more sensitive ones.
30. The Center of Gravity measures also revealed obvious similarities across groups—there were no statistical differences across groups. /d/ differs from /t/ for all speakers. While /d/ has a center of gravity around 2000 Hz, /t/ has one around 4000 Hz or above. There is a tendency for English-dominant bilinguals to have even higher values for their English /t/. The pattern, however, is comparable across groups.
31. The last metric is that of Relative Intensity. Once again, the pattern is similar across groups, though not identical. /d/ has a softer burst than /t/ for all subjects. The burst of /t/ is louder than the midpoint of the vowel. Even for /d/, however, the values are not very far from zero, although they are lower for the bilinguals than for the monolinguals. The statistics do not reveal

any interactions between voicing and speaker group.

32. To summarize, there were no reliable differences across groups of English speakers. There are some tendencies here or there, but they do not seem to be reliable with the statistical tests we are using.
33. STUDY 4. Our last research question is addressed in study 4. In this study we compare the acoustic characteristics of English /d/ and /t/ with those of Spanish /d/ and /t/ in a within-subjects design. That is, we compare the Spanish and English productions of the bilinguals. Since we did not observe any differences between English- and Spanish-dominant bilinguals in their phonetics, we pool the data from both groups into one single dataset. Our dataset, therefore, now has observations from 16 subjects.
34. First, we examined VOT. In this figure, VOT is plotted on the y-axis, with zero in the middle of the plots. The left panel plots the Spanish data; the right panel, the English data. Within each panel, /d/ is plotted on the left and /t/, on the right. The data shows that the bilinguals use VOT differently for their two languages and they use it as expected to distinguish /d/ from /t/ in each language, as Magloire and Green had already shown for this population. In particular, Spanish /d/ is prevoiced, English /t/ is aspirated. Both Spanish /t/ and English /d/ are voiceless and have a short-lag VOT.
35. The Center of Gravity metric shows a stark difference between Spanish and English consonants. The Spanish values, on your left, show that /d/ and /t/ do not differ in this language with regards to the center of gravity of the spectrum of the burst. The values are below 1000 Hz for both consonants. The English values are much higher, with /d/ displaying values close to 2000 Hz and /t/ displaying values above 4000 Hz.
36. Finally, the Relative Intensity metric is also able to capture a crisp difference between the Spanish and English productions of our 16 bilinguals. Spanish /d/ and /t/ do not differ from each other—both consonants have soft bursts, relative to the midpoint of the following vowel. The English coronal consonants, on the other hand, display louder bursts. For /d/ the values are close to zero, but still negative. For /t/, the values are positive. This means that /t/ has a loud burst, relative to that of /d/ as well as to those of Spanish /d/ and /t/.
37. In sum, our analyses show that Spanish and English /d/ and /t/ differ in a discreet manner. VOT is used to contrast the voiced and the voiceless stops in ways specific to each language, as expected. Center of Gravity also reveals a stark difference between the coronal consonants of the two languages, as does Relative Intensity. This suggests that our 16 bilinguals, as a group, have representations for dental consonants, which they use in their Spanish, as well as for alveolar consonants, which they use in their English. They seem to have developed separate phonetic (sub)systems to be used in each of their two languages.
38. Let me conclude the Results section by showing a figure that plots all of our metrics in all of our groups and languages together, in one slide. This figure, which I can show later in more detail, if you wish, plots the English data on the first row of panels, and the Spanish data on the second. The first column plots the monolingual data, with the English monolinguals on top and the Spanish monolinguals at the bottom. The second column corresponds to the English-dominant bilinguals, with English and top and Spanish at the bottom. The third column plots the Spanish-dominant data, with English on top and Spanish at the bottom. Each panel shows VOT on the x-axis, Relative Intensity on the y-axis, and Center of Gravity as a function of the size of the dots. The blue dots correspond to /t/; the pink dots, to /d/. The plots show that, in addition to the well-known VOT differences, Spanish and English /d/ and /t/ differ as follows: Relative Intensity is higher in English than in Spanish (the dots are higher on the y-axis in English than they are in Spanish); Center of Gravity is generally higher in English than in Spanish (the dots

are much larger in English, across the board, than in Spanish). This holds even when we compare the two languages of a bilingual.

39. Let us now proceed to the discussion and the conclusion sections.
40. In this presentation we have reported our finding that Spanish and English coronal stops differ in (1) their use of VOT to implement the fortis-lenis contrast, (2) their resonant frequencies at their release and (3) the relative amplitude of their burst. In particular, Spanish coronal stops have softer bursts and lower resonance frequencies at their release than English coronal stops.
41. We have found that this is true when we compare speakers of both languages in a between subjects design as well as when we compare bilingual speakers of these languages in a within-subjects design. Our findings suggest the conclusion that our bilinguals have separate phonetic (sub)systems for stops in their two languages.
42. Our findings are in line with those of prior acoustic studies by Jongman et al., Stoel-Gamon et al., and Sundara. In particular, the acoustic characteristics of Spanish /d t/ follow the pattern of those of French, Dutch and Swedish, which have also been described as dental, unlike those of English. (Or perhaps we should call them laminal rather than dental.)
43. Now, the question is why do they have these acoustic characteristics? What do these tell us about their articulation? Regarding the burst amplitude differences, perhaps lamino-dental constrictions, which have more contact surface than apico-alveolar ones, are released more slowly, leading to softer bursts. Or perhaps the path of the airstream after the constriction hits more of an obstacle at the upper teeth, which increases the amplitude of the turbulence, in the alveolars than in the dentals.
44. Regarding their resonance-frequency differences, the problem is as follows: If dental contact is more fronted than alveolar contact, we would expect higher resonance frequencies for the dentals than for the alveolars because the size of the front cavity (in front of the constriction) would be smaller for the dentals for the alveolar. But this is not what we find. We find quite the opposite, consistently across studies. Therefore, one of our conclusions is that the characterization of Spanish coronals is misleading. Although there may be contact at the teeth, in the dentals the constriction must occur further behind (in the alveolar ridge), probably even in a more posterior position than that in the alveolar stops. This constriction would be at the alveolar ridge and it would use the tongue blade or even the predorsum.
45. To conclude, this study compared the acoustics of Spanish and English coronal stops, which were found to differ in various ways, confirming the intuition that their articulations differ. We also found that early, proficient Spanish-English bilinguals keep separate (sub)systems for their coronal stops. So, perhaps, sometimes a bilingual is two monolinguals in one person.
46. Thank you.