

*******How /b, d, g/ differ from /p, t, k/ in Spanish: A dynamic account**

The traditional view of /b d g/ in Spanish is that these segments are underlying stops, contrasting in voicing with /p t k/, that undergo a process of spirantization except phrase initially and after a homorganic nasal or lateral (e.g. Mascaró, 1984). However, a large number of authors argue that these segments are underlying *spirants*, contrasting with /p t k/ in constriction degree, that undergo initial and post-nasal strengthening (e.g. Baković, 1995; Lavoie, 2001). Both of these theories rely on categorical productions of fully occluded versus fully spirantized stops. A large body of evidence shows that this is not the case in real speech: voiced stops in all contexts span a large area between these two extremes (Carrasco & Hualde, 2009; Cole, Hualde & Iskarous, 1999; Eddington, 2009; Ortega-Llebaria, 2004, Hualde et al., 2010). Additionally, voiceless stops can be realized both as fully voiced and spirantized (Lewis, 2001; Machuca, 1997). How, then, are /b d g/ and /p t k/ different? Some authors have proposed that duration (Hualde, 2005) or the feature [\pm tense] (Martínez Celdrán, 2008 and previous) distinguish /b d g/ from /p t k/.

This paper argues for a unified analysis of Spanish stop spirantization and contrast based in Articulatory Phonology (Browman & Goldstein, 1992). The shorter duration of voiced stops (e.g. Lavoie, 2001) may lead to their less constricted production (spirantization) due to increased articulatory undershoot. It is that duration difference, in addition to voicing, that distinguishes /p t k/ from /b d g/. Increased duration phrase initially and due to nasal + stop sequences lead to productions of full stops in those positions without overt allophonic control.

Methods: To test this hypothesis, a pilot study was conducted using 3D electromagnetic articulometry (EMA) with one native speaker of northern peninsular Spanish. The subject produced words in carrier phrases with /p/ and /b/ in /a(##)Ca/ context phrase initially, word initially, and word medially. The duration of the gesture from onset to constriction release was measured, along with the constriction degree (CD, distance between sensors on upper and lower lips).

Result: For total duration, there is a main effect of prosodic boundary ($p < 0.0001$) and a near-significant effect of voicing ($p = 0.08$). T-tests reveal significant differences both word-initially and medially ($p < 0.0001, 0.03$). For CD, there were main effects of both prosodic boundary ($p = 0.0002$) and voicing ($p < 0.0001$). Post hoc test reveals a significant difference between phrase medial /b/, and phrase initial /b/ and /p/ in all prosodic positions ($p < 0.0001$). Linear regressions (Figure 1) show a significant effect of duration on CD for /b/ ($p < 0.005$), though not for /p/, indicating that duration may underlie some reduction in CD. As can be seen from Figure 1, however, /b/ and /p/ with the same duration differ in CD, against our initial hypothesis. An ANOVA test reveals no difference for gestural stiffness, ruling out that parameter as the cause of this difference. However, it is known that stops have a CD target beyond the point of articulator contact (Löfqvist, 2005). Though /b/ and /p/ do differ in CD, it is proposed that /b d g/ have a *less negative* target than /p t k/ but still one that results in full occlusion. An articulatory modeling study conducted using TaDA (Saltzman, Nam, Krivokapić & Goldstein, 2008), confirms that a CD for /p t k/ of -2 mm and for /b d g/ of -0.5 mm gives the correct articulatory and acoustic output both phrase-medially and initially (duration = 80 ms, 200ms respectively) while a CD for /b d g/ of 0 mm results in incomplete closure and audible frication even at long durations (Figure 2).

In summary, these data indicate that a) voiced stops in Spanish are, in fact, stops and not spirants and b) the distinction between voiced and voiceless stops must be at least two-way, with differences in duration and constriction degree in addition to a possible voicing distinction.

Figure 1

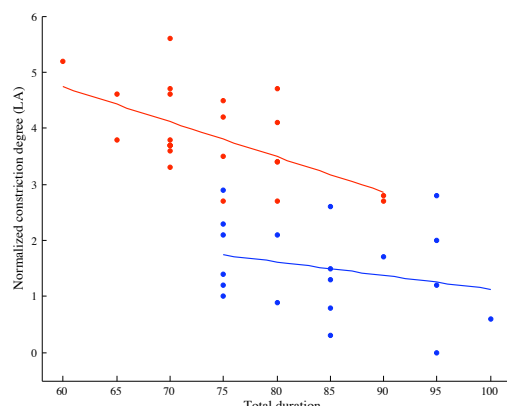
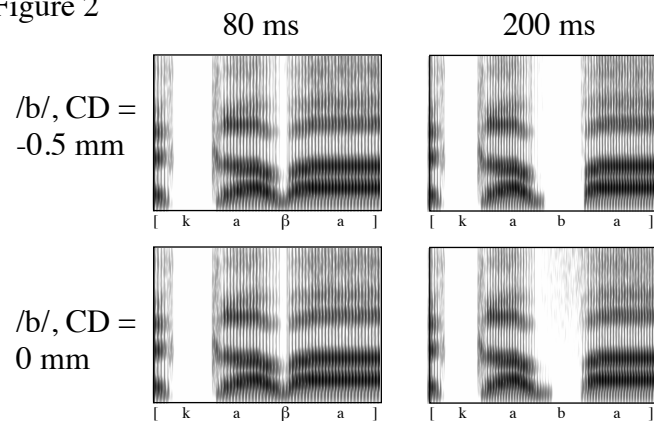


Figure 2



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