The effect of duration and degree of constriction on the perception of Spanish phonemic voiced and voiceless stops

Spanish has two series of phonemic stops that are often described as being contrastive based on voicing differences: /ptk/ on one hand, which are usually described as voiceless stops; and /bdg/ on the other, which are usually described as voiced stops. Nevertheless, recent research shows that Spanish /ptk/ are often lenited and phonetically voiced (e.g., Hualde et al., 2011). These findings have significant phonological implications because /ptk/ lenition may lead to phonetic overlap with /bdg/. Nevertheless, some authors (e.g., Hualde et al., 2011) have found that, even when /ptk/ are phonetically voiced, they are significantly different from /bdg/ in speech production because the former are longer and more constricted than the latter. These findings raise the question of whether Spanish listeners rely on duration and intensity differences to perceptually categorize phonetically voiced stimuli as /ptk/ or /bdg/. The goal of the current investigation is precisely to answer this question.

To this end, this paper presents the results of a perceptual identification task that examined the extent to which Spanish listeners rely on degree of constriction and duration to perceptually categorize stimuli as either /ptk/ or /bdg/ when the stimuli were phonetically voiced. In order to create the stimuli of the perceptual identification task, a native speaker of Spanish recorded a series of six minimal pairs involving the /ptk/ ~ /bdg/ contrast in intervocalic position. These minimal pairs and their phonetic transcriptions are presented in Table 1.

Table 1. Minimal pairs recorded to create the stimuli of the perception task

La bala	[la.ˈβ̞a.la]	'the bullet'	*La pala*	[la.ˈpa.la]	'the shovel'
Mi día	[mi.ˈð̞i.a]	'my day'	*Mi tía*	[mi.ˈti.a]	'my aunt'
La goma	[la.ˈɣo.ma]	'the eraser'	*La coma*	[la.ˈko.ma]	'the comma'
La roba	[la.ˈro.β̞a]	's/he steals it'	*La ropa*	[la.ˈro.pa]	'the clothes'
El dado	[el.ˈda.ð̞o]	'the die'	*El dato*	[el.ˈda.to]	'the datum'
La vaga	[la.ˈβ̞a.ɣa]	'the lazy one'	*La vaca*	[la.ˈβ̞a.ka]	'the cow'

In order to create a range of degrees of constriction and duration of /bdg/, two acoustic properties of the /bdg/ tokens were digitally manipulated: their overall segmental duration was increased by 50% and their overall intensity was reduced twice (once by 15 dB and once 30 dB in order to create occlusive and very occlusive instances of /bdg/ respectively). These manipulations yielded a total of six different types of /bdg/ stimuli that are summarized in Table 2.

Table 2. Stimuli that resulted from each original recording

Type of stimulus	**Intensity**	**Duration**
Original /bdg/	n.m.[a]	n.m.[a]
Long /bdg/	n.m.[a]	Increased by 50%
Occlusive /bdg/	Reduced by 15 dB	n.m.[a]
Long & occlusive /bdg/	Reduced by 15 dB	Increased by 50%
Very occlusive /bdg/	Reduced by 30 dB	n.m.[a]
Long & very occlusive /bdg/	Reduced by 30 dB	Increased by 50%

[a]n.m. = not manipulated

These manipulations yielded a total of 36 different stimuli (6 original words with /bdg/ × 6 types of stimuli). In addition, 20 distractors containing a variety of segments different from /ptk/ and /bdg/ were also included in the task, making a total of 56 stimuli for the perceptual identification task. A total of 97 participants from Spain completed the perceptual identification task in which they were asked to select from two possible options the word they heard after listening to each stimulus (e.g., *la pala* 'the shovel' or *la bala* 'the bullet'). They were also asked to rate the pronunciation of each stimulus using a 4-point Likert scale (very good, good, bad, very bad).

Two analyses were carried out. The first one aimed to investigate the effect of type of stimulus (see Table 2 above) on the perception of /ptk/ or /bdg/. To do so, a mixed-effects binomial logistic regression was run with participants' responses as the dependent variable (i.e., whether they perceived a word with /ptk/ or a word with /bdg/), type of stimulus as the independent variable, and both word and participant as random effects.

The second analysis aimed to examine how the different types of stimuli were perceived by the listeners. In order to do so, the data was split into two data subsets. One was a subset that contained only the data that had been perceived /ptk/ by listeners. The other one was a subset that contained only the data that had been perceived as /bdg/ by listeners. The data from each of these subsets were fitted to two separate mixed-effects ordinal regressions with participants' responses as the dependent variable (very good > good > bad > very bad), type of stimulus as the independent variable, and both word and participant as random effects.

The results of the analyses revealed a significant effect of type of stimulus on the perception of /ptk/ and /bdg/. Specifically, the odds of perceiving /ptk/ increased significantly when the stimulus was both longer and more constricted than the original production. Additionally, the results also suggest a significant effect of type of stimulus on how listeners rated the stimuli perceived as /bdg/. Specifically, longer and more constricted stimuli were perceived as worse instances of /bdg/ than those that were shorter and less constricted. No significant effect was found of type of stimulus on listeners' ratings of perceived /ptk/. These findings have important phonological implications because, while the contrast between /ptk/ and /bdg/ is often described based on a voicing distinction, these results suggest that voicing alone cannot account for this contrast since all the stimuli analyzed were phonetically voiced, but not all of them were perceived as voiced phonemes. This is consistent with previous claims according to which the /ptk/ ~ /bdg/ contrast in Spanish is not really based on voicing alone but on tension (e.g., Martínez-Celdrán, 2009). The results presented here indicate that when stimuli are tenser (i.e., longer and more constricted), listeners can perceive them as /ptk/ even when they are phonetically voiced. In this sense, this study provides a significant contribution by expanding our understanding of the phonological system of Spanish with empirical perceptual data that sheds light on the factors to which Spanish listeners attend in order to categorize these two groups of stops.

References

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