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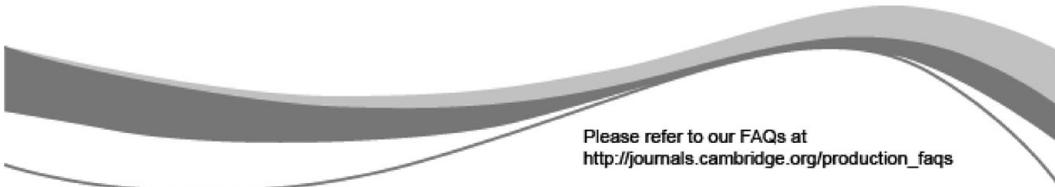
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Temporal acoustic correlates of the voicing contrast in European Portuguese stops

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This study focuses on the temporal analysis of stops /p b t d k g/ and devoicing analysis of voiced stops /b d g/ produced in different word positions by six native speakers of European Portuguese. The study explores acoustic properties related to voicing. The following acoustic properties were measured: voice onset time (VOT), stop duration, closure duration, release duration, voicing into closure duration, duration of the preceding vowel and duration of the following vowel. Results suggested that when [b d g] were devoiced, the acoustic properties stop duration, closure duration, duration of the following vowel, duration of the preceding vowel and duration of voicing into closure were relevant for the voicing distinction. Implications for research and practice in speech and language therapy are discussed. Further investigation is needed to find how the productions analysed in the present study were perceived by listeners, specifically productions of devoiced stops.

1 Introduction

There have been many studies of stop voicing distinctions (Caramazza & Yeni-Komshian 1974, Klatt 1975, Luce & Charles-Luce 1985, Cho & Ladefoged 1999, Brunner, Fuchs, Perrier & Kim 2003, van Alphen & Smits 2004), showing that the properties that are relevant vary across languages. However, there are few studies of European Portuguese (EP), none of which analyse the different stops in word-final position (Andrade 1980, Viana 1984, Veloso 1995, Castro & Barbosa 1996). This is a study of the voicing distinction and other production characteristics in EP using new detailed temporal descriptions and devoicing criteria.

33 Lisker & Abramson (1964) found in a cross-linguistic study of word-initial position
 34 three categories of voice onset time (VOT): voicing lead (voiced), short lag (voiceless
 35 unaspirated) and long lag (voiceless aspirated). Keating, Linker & Huffman (1983) examined
 36 51 languages and showed that the voiceless unaspirated category is the most common category.
 37 Almost all the studied languages used this category. The voiced and voiceless aspirated
 38 categories appeared equally frequently as the voicing category contrasting with the voiceless
 39 unaspirated category. Keating et al. (1983) also observed that the use of these different VOT
 40 categories varied as a function of word position in many languages.

41 Andrade (1980) compared the VOT of homorganic stops, in initial position before a vowel,
 42 in words produced by a speaker of EP. Results showed that some voiced stops had a period
 43 of prevoicing (between 120 and 130 ms) followed by a devoiced period (between 10 and
 44 20 ms). Results also showed that the VOT was larger for velars than for labials and dentals,
 45 as in English (Klatt 1975, Cho & Ladefoged 1999). Viana (1984) concluded that [b d g] were
 46 sometimes devoiced in EP. Viana (1984) and Veloso (1995) observed that stop duration and
 47 duration of the following vowel were acoustic properties that cued voicing in EP.

48 Voicing of stops produced by speakers of various other languages have long been studied.
 49 Caramazza & Yeni-Komshian (1974) concluded that in Canadian French more than 58% of
 50 the voiced tokens were produced without prevoicing. Luce & Charles-Luce (1985) suggested
 51 that vowel duration was the most reliable correlate of voicing for stops in word-final position.
 52 The mean vowel duration was longer for words ending in voiced stops (177 ms) than those
 53 ending in voiceless stops (122 ms). Brunner et al. (2003) suggested other acoustic properties
 54 related to the voicing distinction for Korean velar stops in medial position, namely closure
 55 duration, duration of the following vowel, duration of the preceding vowel and voicing into
 56 closure duration. Van Alphen & Smits (2004) showed that stops were often devoiced in Dutch
 57 and that there were multiple acoustic properties related to the voicing distinction, e.g. the
 58 duration of prevoicing for both labial and alveolar stops, F0 movement for labials and the
 59 spectral centre of gravity of the burst for alveolars.

60 Vowel devoicing and deletion in EP, as well as the effect of deletion in the neighbouring
 61 segments, have been also studied for more than a century (Andrade 1994). Andrade (1993,
 62 1995) presented acoustic and perceptual studies of CC stop clusters with equal and different
 63 places of articulation, as well as with and without an underlying vowel. Those studies provide
 64 important information on the effects of vowel devoicing and deletion on the temporal and
 65 spectral characteristics of the consonants. Moreover, in a sequence of two words, when the
 66 last syllable of the first word is identical or very similar to the first syllable of the second
 67 word, the final vowel of the former may be deleted and the two consonants may become a
 68 geminate or reduce to just one consonant. This phenomenon, known as syllable degemination
 69 (or haplology), was originally studied by Sá Nogueira (1938, 1941) and more recently re-
 70 analysed by Frota (2000) in the Prosodic Phonology framework. Frota (2000) showed, based
 71 on the analysis of spectrograms and auditory tests, that a C1V1C2V2¹ sequence reduces to
 72 C2V2 at prosodic word boundaries within a phonological phrase, to C1C2V2 at a phonological
 73 phrase boundary and remains as such at intonational phrase boundaries, where reduction is
 74 most disfavoured/blocked.

75 The principal aim of this study is to contribute to the knowledge of the acoustic properties
 76 related to the voicing distinction of stop consonants /p b t d k g/. So far, there have been no
 77 journal studies published about the production of EP stops, so there is a lack of reference
 78 data for normal cross-language studies, and no baseline data that can be used by Portuguese
 79 speech and language therapists in their clinical practice (e.g. VOT values could be used in the

¹ C1 = C2

80 differential diagnosis of different types of dysarthria, as reported for other languages) (Morris
81 1989, Ackermann & Hertrich 1997).²

82 In this study, the stops were produced in all word positions (initial, medial and final), as
83 there is no research that has analysed EP stops in word-final position. An exhaustive temporal
84 analysis was conducted (an EGG signal was used to determine voicing onset/offset) to obtain
85 different acoustic properties (VOT, stop duration, closure duration, release duration, voicing
86 into closure duration, duration of the preceding vowel and duration of the following vowel) in
87 all word positions. Also, criteria that have been previously used for devoicing analysis of fricatives
88 (Jesus & Shadle 2002, 2003; Jesus & Jackson 2008) were adapted to the study of stops.

89 2 Method

90 2.1 Recording and annotation

91 A corpus of 54 European Portuguese real words containing six stops, /p b t d k g/, was
92 recorded using a Philips SBC ME 400 unidirectional condenser microphone located 20 cm
93 in front of the subject's mouth. An electroglottograph (EGG) signal was also collected using
94 an EGG processor (model EG-PC3 produced by Tiger DRS, Inc., USA). The acoustic and
95 EGG signals were pre-amplified (Rane MS 1-b) and recorded with a Sony PCM-R300 DAT
96 recorder, each with 16 bits and a sampling frequency of 48 kHz.

97 The corpus contained an equal number of words (eighteen) with stops in three positions:
98 initial position, followed by the vowels /a/, /i/ and /u/; medial position, preceded by the vowels
99 /a/, /i/ and /u/ and followed by the vowel /ɐ/; and final position, preceded by the vowels /ɔ/
100 and /a/. The words were produced within the frame sentence *Diga ___ por favor*.³ The words
101 in the corpus are listed in the Appendix. The subjects were six native speakers of EP: three
102 men – LJ (second author), HR and PA (aged 25–34 years) – and three women – ML (first
103 author), IM and SC (aged 24–42) – all without any speech, language or hearing problems.
104 LJ, HR, ML and IM lived in Aveiro, and PA and SC lived in Porto. In these regions, due to
105 dialect characteristics, voiced stop consonants are often produced as non-strident continuants
106 (fricated stops; Viana 1984, Cruz-Ferreira 1999). We used six stops in three word positions,
107 produced by six speakers in a frame sentence.

108 The corpus was manually segmented with *Adobe Audition* 3.0. The words were then
109 analysed using the *Speech Filing System (SFS)* version 4.7/Windows (Huckvale et al. 1987).
110 The acoustic events that were annotated are listed here (see Figures 1 and 2).

- 111 1. The beginning of a preceding vowel (IV1) was defined using the following criterion: the
112 instant in time at which the second formant intensity becomes characteristic for a vowel
113 in the spectrogram (Brunner et al. 2003).⁴ Figure 1 shows an example where this criterion
114 was used (tokens where the EGG signal was clearly periodic before F2 onset). When the
115 EGG signal was not periodic before F2 onset, IV1 was marked where the periodic signal
116 begins both in the acoustic and EGG signals.
- 117 2. The end of a preceding vowel and beginning of closure (IO) was marked where the second
118 formant was no longer visible in the spectrogram (Brunner et al. 2003). It was always

Q1 ² The only related study published in a journal is that of Barroco, Domingues, Pires, Lousada & Jesus (2007). It analyses stops in two Portuguese children, one with speech disorders and one with normal speech.

³ Sentences were produced with a pause between the end of the target word and the voiceless bilabial stop consonant that followed, so the carrier sentence did not have a direct impact on the duration measurements of the target stop consonants occurring in word-final position.

⁴ The words were analysed using wideband spectrograms. The bandwidth for the wideband display was fixed at 300Hz.

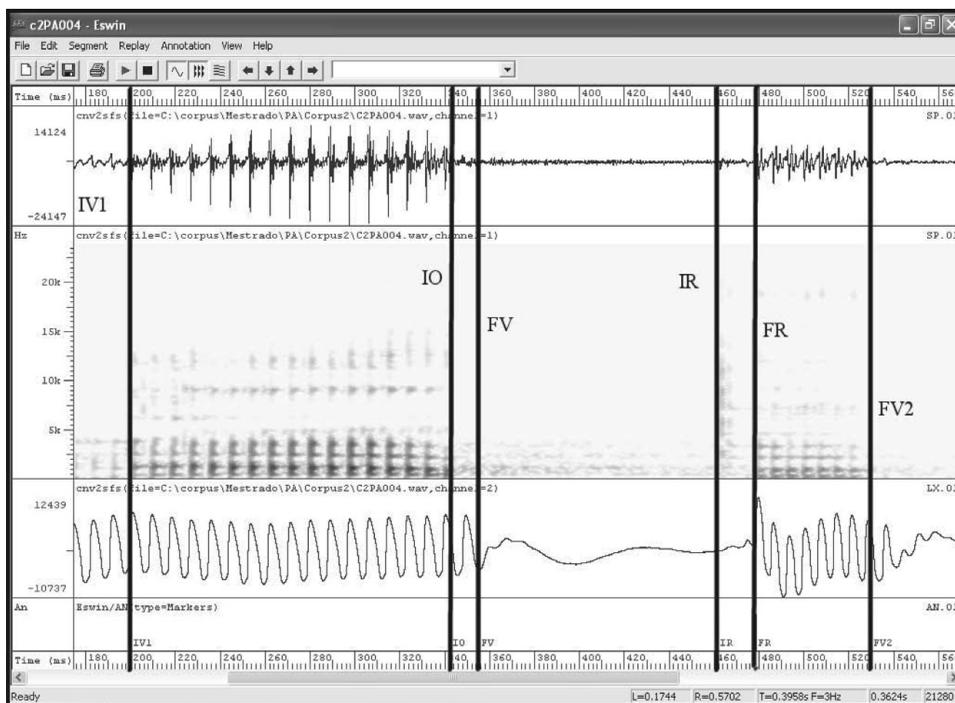


Figure 1 Waveform and its spectrogram, and EGG signal of the VCV sequence in the word ['napɐ] 'sheepskin' produced by speaker PA.

- 119 possible to determine IO because the words were produced within a frame sentence, so
 120 even word-initial stops were preceded by a word that ended with a vowel.
 121 3. The beginning of prevoicing (IPV) was defined as the instant in time at which evidence
 122 of vocal fold vibration could be observed in the acoustic and EGG signals (van Alphen
 123 & Smits 2004).
 124 4. The voice offset (FV) was marked at the point where the periodic signal ends (the vocal
 125 folds ceased to vibrate) in the acoustic and EGG signals, as can be seen in Figure 1.
 126 5. The end of prevoicing (FPV) was defined as the instant in time where the burst started.
 127 6. The end of closure and the beginning of the release (IR) was defined by a sudden peak
 128 in the waveform and as a vertical bar in the spectrogram. When there were multiple bursts,
 129 the one with the highest intensity was chosen, as the one with the highest intensity is
 130 believed to correspond to the actual opening (Fuchs 2005).
 131 7. The end of release and beginning of the following vowel (FR) was marked where the
 132 second formant amplitude begins in the spectrogram (Brunner et al. 2003) or where the
 133 periodic signal begins both in the acoustic and in the EGG signals.
 134 8. The end of the following vowel (FV2) was set where the second formant was no longer
 135 visible in the spectrogram (Brunner et al. 2003).

136 In the annotation files, we also registered the position in the word (initial, medial and final)
 137 and the type of voicing according to new criteria based on those previously proposed for
 138 fricatives by Jesus & Shadle (2002):

- 139 • When voicing was present less than a third of the closure interval, the stop was classified
 140 as devoiced.

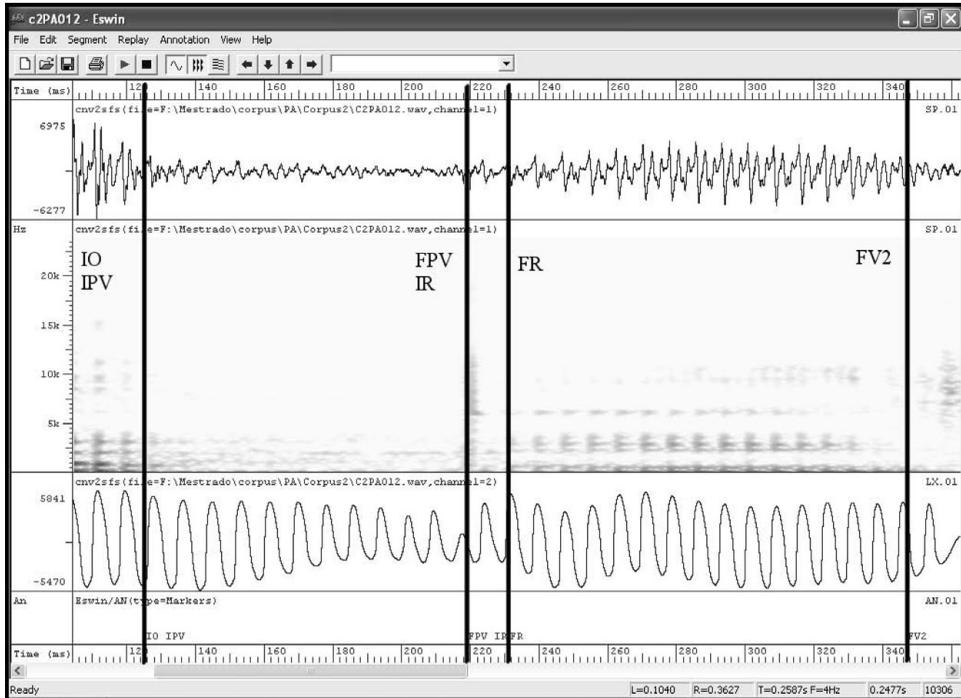


Figure 2 Waveform and its spectrogram, and EGG signal of the first CV sequence in the word ['bufu] 'owl' produced by speaker PA.

- 141 ● When voicing lasted from between a third and a half of the closure duration, the stop was
 142 classified as partially devoiced.
 143 ● When the duration of voicing was greater than a half of the closure duration, the stop was
 144 classified as voiced.⁵

145 2.2 Temporal analysis

146 The following temporal measurements were extracted from the annotation files of the corpus
 147 for all speakers:

- 148 1. Duration of preceding vowel: IO-IV1.
- 149 2. Voicing into closure duration: FV-IO (for stops in medial and in final positions).
- 150 3. Closure duration: IR-IO.
- 151 4. Voice onset time (VOT): FR-IR (for voiceless, devoiced and partially devoiced stops) or
 152 IPV-IR (for voiced stops).
- 153 5. Release duration: FR-IR (positive VOT).
- 154 6. Duration of following vowel: FV2-FR.
- 155 7. Stop duration: FR-IO.

156 This list of temporal measures presents some redundancies (e.g. stop duration could be
 157 calculated through the duration of all components of the stop), but it allowed us to design an
 158 algorithm to automatically extract the durations, using *Matlab* scripts.

⁵ These criteria are also used in Pinho, Jesus & Barney (2010).

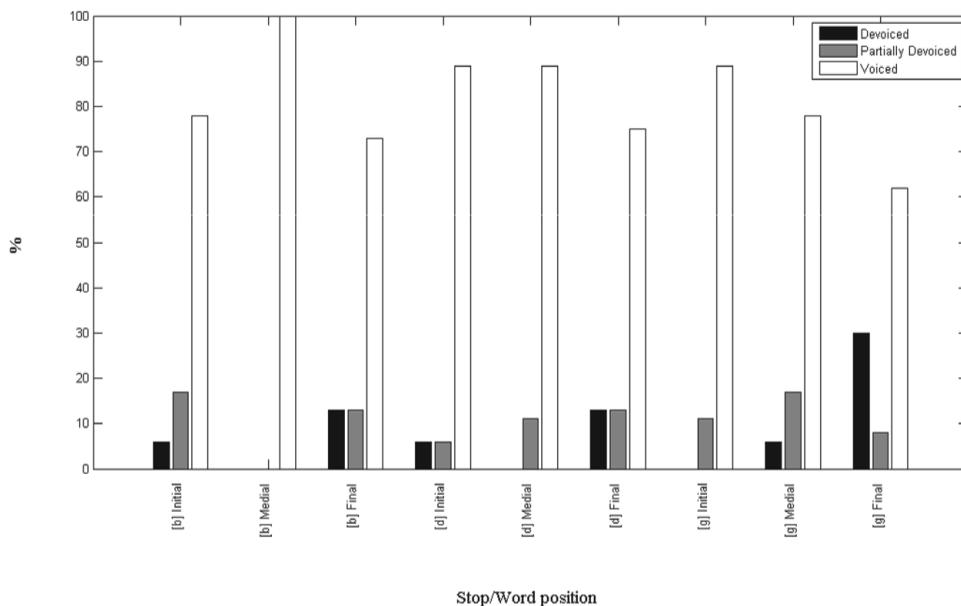


Figure 3 Devoicing of [b d g] for all speakers in different word positions.

159 2.3 Statistical tests

160 The software package SPSS 10.0 for Windows was used to run the statistical tests for stop
 161 durations. We first determined if the distribution was normal, based on the observation
 162 of histograms, analysis of QQ-plots of normal distribution and the results of both the
 163 Kolmogorov-Smirnov test with Lilliefors correction and Shapiro-Wilk test in initial, medial
 164 and final positions. The results refute the normality of the data for medial ($p < .05$) and final
 165 position ($p < .05$) so we used the Mann-Whitney U test to compare the groups (duration of
 166 voiceless stops vs. duration of voiced stops). This non-parametric test allows us to compare
 167 the means of two groups when the data are not normal.⁶

168 3 Results

169 3.1 Devoicing analysis

170 Results of devoicing as a function of place of articulation showed that in initial position,
 171 the percentage of devoiced stops was exactly the same for [b] and [d] and was zero for [g].
 172 However, [g] was partially devoiced in some cases. The percentage of devoicing increased
 173 as the place of articulation moved posteriorly in medial position (see Figure 3). In word-final
 174 position, the percentage of devoiced stops was greater for [g] than for [b] and [d].

⁶ The use of non-parametric statistical tests does not imply that sample means and standard deviations are meaningless. In addition, we provide the sample median as a complement to the traditional mean and standard deviation statistics. Since the size of the considered sample lies between 38 and 54, we believe that the goodness-of-fit test considered (Kolmogorov-Smirnov with Lilliefors correction and Shapiro-Wilk) is meaningful.

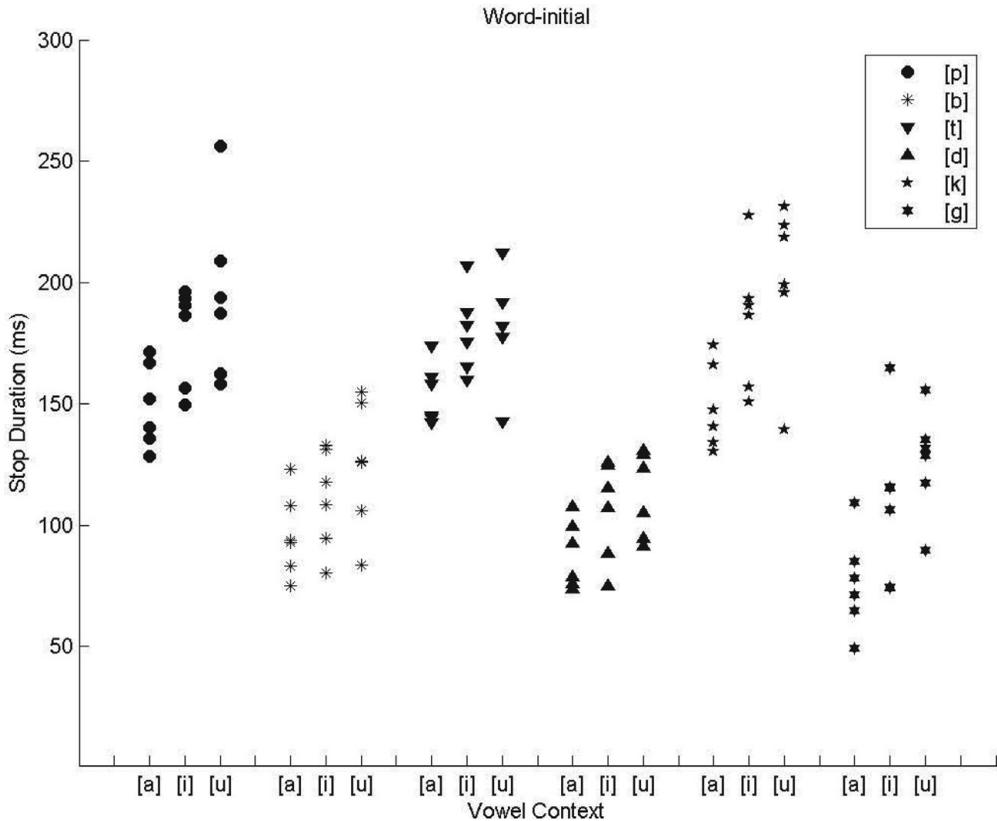


Figure 4 Stop duration of [p t k b d g] in initial position.

175 3.2 Temporal analysis

176 The results of stop duration, closure duration, release duration, duration of the preceding vowel
 177 and duration of the following vowel, voicing into closure duration, and VOT are presented
 178 separately in the following sections.

179 3.2.1 Stop duration

180 The mean duration (averaged over the six speakers) of stops in initial position was: 174 ms for
 181 [p], 173 ms for [t], 178 ms for [k], 111 ms for [b], 102 ms for [d] and 104 ms for [g]. Mean stop
 182 duration was longer for voiceless (mean = 175 ms, N = 54) than for voiced stops (mean =
 183 106 ms, N = 54), as shown in Figure 4. For stops in medial position, the values were: 129
 184 ms for [p], 135 ms for [t], 140 ms for [k], 74 ms for [b], 85 ms for [d] and 76 ms for [g].
 185 Mean stop duration was longer for voiceless (mean = 134 ms, N = 54) than for voiced stops
 186 (mean = 78 ms, N = 53). In final position, the values were: 164 ms for [p], 176 ms for [t],
 187 173 ms for [k], 131 ms for [b], 117 ms for [d] and 132 ms for [g]. Mean stop duration was
 188 also longer for voiceless (mean = 172 ms, N = 44) than for voiced stops (mean = 126 ms,
 189 N = 38). These differences were statistically significant ($p < .001$) using the Mann-Whitney
 190 U test. The analysis of the p-value of this test led us to conclude that there were significant
 191 differences between the duration of voiced stops and the duration of voiceless stops in initial,
 192 medial and final positions. The statistical tests were not applied for the other parameters
 193 because the database did not always provide more than 30 tokens in each group. This fact
 194 occurs for different reasons, e.g. the closure duration in some cases was not determined

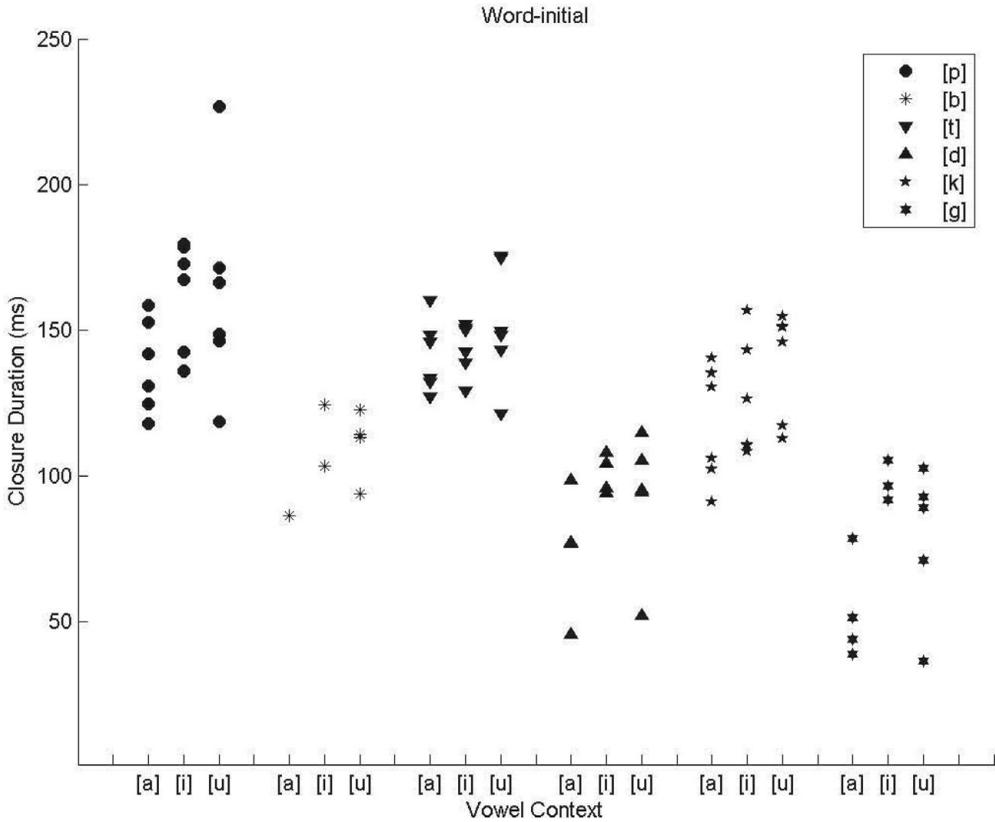


Figure 5 Closure duration of [p t k b d g] in initial position.

195 (it was impossible to determine the end of closure because many speakers produced the
 196 voiced stops without a release, particularly in medial and in final positions).

197 **3.2.2 Closure duration**

198 Mean closure duration of stops in initial position was: 155 ms for [p], 146 ms for [t], 128 ms
 199 for [k], 108 ms for [b], 90 ms for [d] and 75 ms for [g]. Mean closure duration was longer for
 200 voiceless (mean = 143 ms, N = 54) than for voiced stops (mean = 88 ms, N = 20), as can
 201 be seen in Figure 5. In medial position, the values of closure duration were: 110 ms for [p],
 202 114 ms for [t], 104 ms for [k], 102 ms for [b], 57 ms for [d] and 79 ms for [g]. Mean closure
 203 duration was longer for voiceless (mean = 109 ms, N = 54) than for voiced stops (mean =
 204 65 ms, N = 16). The values obtained for stops in final position were: 123 ms for [p], 131 ms
 205 for [t], 132 ms for [k], 90 ms for [b], 77 ms for [d] and 86 ms for [g]. Mean closure duration
 206 was longer for voiceless (mean = 129 ms, N = 44) than for voiced stops (mean = 82 ms,
 207 N = 21).

208 **3.2.3 Release duration**

209 The release duration was longer for voiceless (mean = 33 ms, N = 54) than for voiced stops
 210 (mean = 26 ms, N = 33) in initial position. In medial position the release duration was longer
 211 for voiced (mean = 32 ms, N = 17) than for voiceless stops (mean = 25 ms, N = 54). In
 212 final position the release duration was also longer for voiced (mean = 60 ms, N = 18) than
 213 for voiceless stops (mean = 43 ms, N = 44).

Table 1 Mean duration of the following vowel in the context of stops [p t k b d g] in initial position.

[a]	Mean (ms)	[i]	Mean (ms)	[u]	Mean (ms)
[pa]	121	[pi]	82	[pu]	83
[ta]	119	[ti]	63	[tu]	88
[ka]	105	[ki]	65	[ku]	90
[ba]	143	[bi]	82	[bu]	103
[da]	134	[di]	91	[du]	100
[ga]	134	[gi]	97	[gu]	115

Table 2 Mean duration of the preceding vowel in the context of stops [p t k b d g] in medial position.

[a]	Mean (ms)	[i]	Mean (ms)	[u]	Mean (ms)
[ap]	127	[ip]	87	[up]	81
[at]	128	[it]	84	[ut]	86
[ak]	125	[ik]	75	[uk]	88
[ab]	153	[ib]	88	[ub]	95
[ad]	159	[id]	106	[ud]	113
[ag]	156	[ig]	114	[ug]	119

214 3.2.4 Duration of vowels

215 The duration of the following vowel was longer in voiced–stop contexts (N = 54) than in
 216 voiceless–stop contexts (N = 54), when stops occurred in initial position, except for [pi] and
 217 [bi] (see Table 1) and in medial position. The duration of the preceding vowel was longer in
 218 voiced–stop contexts (N = 54 in both groups), when stops occurred in medial (see Table 2)
 219 and final positions.

220 3.2.5 Voicing into closure duration

221 The voicing into closure duration was longer for voiced (N = 10 in word-medial position and
 222 N = 23 in word-final position) than for voiceless stops (N = 54 in word-medial position and
 223 N = 52 in word-final position) in medial and word-final positions (see Figure 6). The voicing
 224 into closure duration in voiceless stops corresponds to the interval of time during which the
 225 vocal folds continue to vibrate so it is expected to be shorter for these stops.

226 3.2.6 VOT

227 In initial and medial position, voiceless stops had a positive VOT, and voiced stops had a
 228 negative VOT (fully voiced stops) or a positive VOT. The duration of positive VOT (averaged
 229 over all speakers, N = 18) in initial position was: 20 ms for [p], 28 ms for [t], 51 ms for [k],
 230 28 ms for [b], 16 ms for [d] and 17 ms for [g]. Mean VOT duration for voiceless stops was
 231 33 ms and mean VOT duration for voiced stops was 20 ms. The average values of negative
 232 VOT were: –114 ms for [b], –89 ms for [d] and –73 ms for [g] (mean [b d g] = –88 ms).

233 In medial position, the duration of positive VOT (averaged over all speakers, N = 18)
 234 was: 19 ms for [p], 22 ms for [t], 35 ms for [k], 33 ms for [d] and 38 ms for [g]. The mean
 235 value for [b] was not reported here because many speakers produced the stop without a burst
 236 (it was not possible to determine release onset). Mean VOT duration for voiceless stops was
 237 25 ms, and mean VOT duration for voiced stops was 36 ms. The values of negative VOT
 238 were: –102 ms for [b] and –52 ms for [d] (mean [b d] = –59 ms).

239 Overall, VOT was on average shorter for [p] than for [t], and shorter for [t] than for [k] in
 240 initial and medial positions. In addition, VOT was on average longer before high vowels than
 241 before low vowels, which suggests that the VOT changed as a function of the characteristics
 242 of the following vowel (see Table 3).

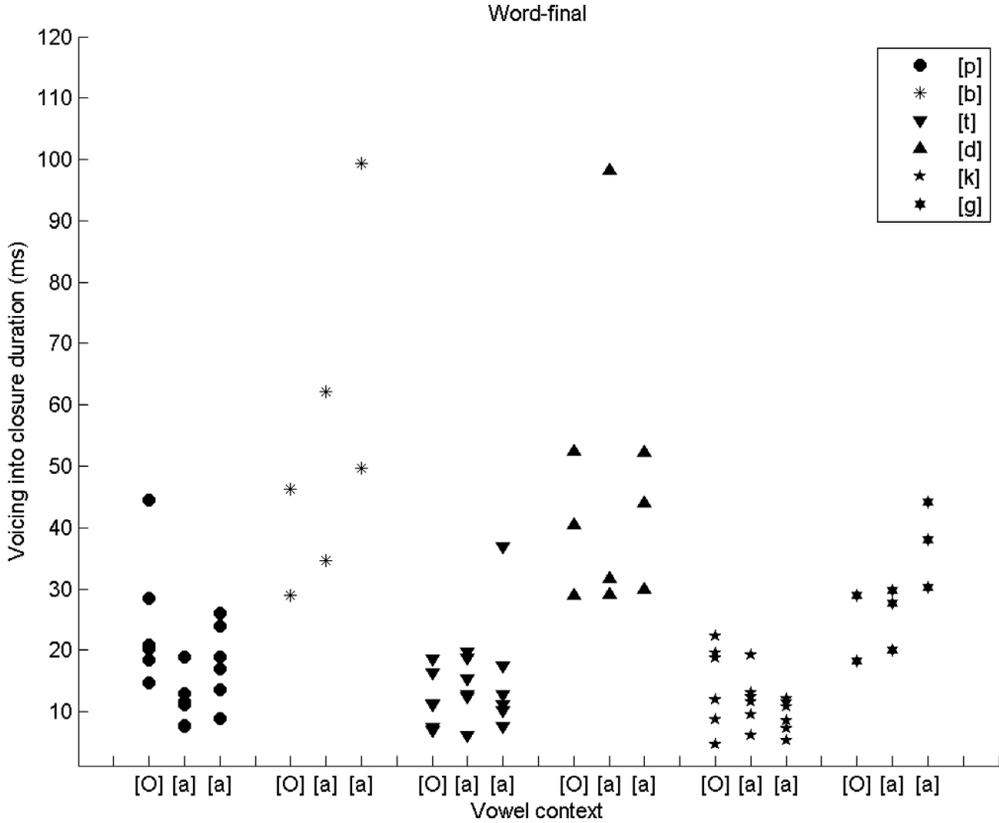


Figure 6 Voicing into closure duration of [p t k b d g] in final position.

Table 3 VOT in initial position as a function of the following vowel. Vowels are grouped in terms of their height.

Context	N	Mean (ms)	Standard deviation (ms)	Median (ms)
[pa]	6	12	2	11
[pi pu]	12	24	11	22
[ta]	6	13	1	13
[ti tu]	12	35	11	36
[ka]	6	31	8	32
[ki ku]	12	60	17	64

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4 Discussion

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This study examined the acoustic properties correlated with the voicing distinction, based on a corpus that included stops in different word positions, as a contribution to the acoustic description of EP stops.

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The analysis of devoicing showed that stops [b d g] were sometimes partially devoiced or devoiced as reported previously for Canadian French (Caramazza & Yeni-Komshian 1974), EP (Andrade 1980, Viana 1984) and Dutch (van Alphen & Smits 2004). Vibration of the vocal folds can only occur when two physiological and aerodynamic conditions are met. First, the vocal folds must be adducted and tensed. Second, a sufficient transglottal pressure gradient is needed to cause enough positive airflow through the glottis to maintain vibration (van den

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253 Berg 1958). There is a recognised difficulty in supporting vibration during stop production
 254 because the air flowing through the glottis accumulates in the oral cavity, causing oral pressure
 255 to approach subglottal pressure (Ohala 1983).

256 The results also showed that the percentage of devoicing increased as the place of
 257 articulation moved posteriorly except for stops in initial position. There is evidence that
 258 devoicing varies as function of place of articulation. Ohala (1983) has suggested that voiced
 259 velar stops are more easily devoiced than voiced stops produced at other places of articulation.
 260 This is due to aerodynamic reasons and to the net compliance of the surfaces on which oral air
 261 pressure impinges during the production of stops. In velar stops, only the pharyngeal walls and
 262 part of the soft palate can yield to the air pressure. In dentals, these surfaces plus the greater
 263 part of the tongue surfaces and all of the soft palate are involved. In labials, these surfaces
 264 plus all of the tongue surface and some parts of the cheeks participate (Rothenberg 1968).

265 In initial position, the mean stop duration was longer for voiceless (175 ms) than for
 266 voiced stops (106 ms). These results agree with those of Viana (1984) and Veloso (1995).
 267 In medial position, the stop duration was longer for voiceless (134 ms) than for voiced stops
 268 (78 ms). In final position, this measure was also longer for voiceless (172 ms) than for voiced
 269 stops (126 ms). The duration of the preceding vowel was longer in voiced stop contexts,
 270 when stops occurred in medial position, as shown previously by Brunner et al. (2003). The
 271 duration of the preceding vowel before voiced stops has been shown to be longer than before
 272 voiceless stops in English (Peterson & Lehiste 1960, Luce & Charles-Luce 1985). The mean
 273 closure duration in initial position was longer for voiceless (143 ms) than for voiced stops
 274 (88 ms) confirming the results reported by Viana (1984). In medial position, voiceless stops
 275 had longer closure durations (109 ms) than voiced stops (65 ms), as previously reported for
 276 Korean (Brunner et al. 2003). The closure duration was also longer for voiceless (129 ms)
 277 than for voiced stops (82 ms) in final position.

278 Longer vowel durations were accompanied by shorter closure durations for /b d g/
 279 while shorter vowel durations were associated with longer closure durations for /p t k/.
 280 Kluender, Diehl & Wright (1988) have suggested an auditory explanation for these results.
 281 They have proposed that covariation of voicing correlates is planned to increase perceptual
 282 distinctiveness. Consequently, vowel duration differences serve to augment the distinctiveness
 283 of the closure duration cue to the voicing distinction. Long vowel durations preceding short
 284 closures result in the perception of even shorter closures, whereas short vowels preceding
 285 long closure intervals are perceived as longer closures. This auditory hypothesis suggested
 286 that speakers can exert control over the cues that have mutually reinforcing auditory effects
 287 to signal phonetic contrasts.

288 The release duration was longer for voiceless (33 ms) than for voiced stops (26 ms) in
 289 initial position, as in other studies of EP (Viana 1984) and in a study of Dutch (van Alphen &
 290 Smits 2004). In medial position, the release duration was longer for voiced (32 ms) than for
 291 voiceless stops (25 ms), which is not expected, although the number of occurrences of voiced
 292 stops was much lower than that of voiceless stops, to generalise these results. In final position,
 293 the release duration was also longer for voiced (60 ms) than for voiceless stops (43 ms).

294 The duration of the following vowel was longer in voiced stop contexts than in voiceless
 295 stop contexts, when stops occurred in initial and medial positions, confirming results from
 296 previous studies of EP (Viana 1984) and Korean (Brunner et al. 2003). The voicing into
 297 closure duration was longer for voiced than for voiceless stops in word-medial and word-final
 298 positions, as we expected. The results of voicing into closure duration for stops in medial
 299 position were similar to those presented by Brunner et al. (2003).

300 These results suggested that when [b d g] were devoiced, the acoustic properties stop
 301 duration, closure duration, duration of the following vowel, duration of the preceding vowel
 302 and duration of voicing into closure were relevant for the voicing distinction, and not only the
 303 two properties (stop duration and duration of the following vowel) that have been previously
 304 proposed for EP (Viana 1984, Veloso 1995). Perceptual tests are needed to complement our
 305 data to reveal how the productions of the present study were perceived by listeners, e.g. in
 306 devoiced stops.

307 Results also showed that many voiced stops were produced without a release particularly
 308 in medial and in final positions. This can be due to the fact that voiced stops may be produced as
 309 non-strident continuants (fricated stops), which often occurs in some speakers' regions. These
 310 fricated stops may be characterised by weak friction noise or by a transitional approximant-like
 311 formant structure, depending on the surrounding segmental and prosodic context. Frication of
 312 stops is most favoured in word-medial position (Viana 1984, Cruz-Ferreira 1999). Concerning
 313 final position, release can also be missing because a stop followed by another stop ([p] of *por*
 314 *favor* in the second part of the frame sentence) may be unreleased (Andrade 1994).

315 Results confirmed that place of articulation and VOT were related (VOT was longer
 316 for [k] than for [t] and [p]), as previously reported by Klatt (1975), Andrade (1980), Viana
 317 (1984) and Cho & Ladefoged (1999). In velar stops, the volume of the cavity behind the
 318 point of constriction is relatively smaller than in bilabial and dental stops, and this causes a
 319 greater pressure, which will take longer to fall, allowing adequate transglottal pressure for
 320 the beginning of vocal fold vibration (Cho & Ladefoged 1999: 209). This could explain why
 321 the VOT was longer for [k] than for [t] and [p]. The volume of the cavity in front of the point
 322 of constriction is greater in velar stops than in bilabial and dental stops, and this causes a
 323 greater obstruction to the release of the pressure behind the velar stop; thus this pressure will
 324 take longer to fall, provoking a delay in the production of adequate transglottal pressure (Cho
 325 & Ladefoged 1999: 209), also resulting in a longer VOT for [k] than for [t] and [p]. A faster
 326 articulatory velocity in bilabials (movement of the lips) than in velars (movement of tongue
 327 dorsum) allows a more rapid decrease in the pressure behind the closure and consequently a
 328 shorter time before an appropriate transglottal pressure (Cho & Ladefoged 1999: 210), which
 329 results in a shorter VOT for [p] than for [k]. Results also indicate that the VOT changed as a
 330 function of the characteristics of the following vowel, as previously observed by Klatt (1975)
 331 and Viana (1984).

332 Results show that the stops /b d g/ in EP are generally fully voiced (see Figure 3). Voiceless
 333 stops /p t k/ are unaspirated, as in French, Spanish, Italian and many other Romance languages
 334 (Ladefoged 2006: 148), making the stop /p/ of these languages similar to English initial /b/.
 335 The VOT data presented in this study complement previous studies (Lisker & Abramson
 336 1964, Keating et al. 1983) that compare VOT in different languages.

337 5 Conclusions

338 Until now, studies of Portuguese stops have been few and limited. The analysis of EP stops
 339 in different word positions contributes to the acoustic phonetic description of EP stops. The
 340 devoicing analysis and the detailed temporal description used in this work are also new for
 341 EP stops. The data obtained in the present study could now be used by Portuguese speech and
 342 language therapists, namely VOT values could be used in the differential diagnosis of types
 343 of dysarthria, as previously reported in other studies (Morris 1989, Ackermann & Hertrich
 344 1997), and devoicing values could also be used as reference data to compare with dysarthric
 345 patients who usually devoice consonants, particularly in word-final position (Scott & Ringel
 346 1971, Platt, Andrews & Howie 1980).

347 The criteria adapted from Jesus & Shadle (2002) are a new, useful and practical method
 348 to analyse devoicing in stops. These criteria have been applied to the analysis of stops for the
 349 first time in the current study and have been applied in other studies (Barroco et al. 2007,
 350 Pinho, Jesus & Barney 2010) for normal and disordered speech. The exhaustive temporal
 351 description presented in this study allows analysis of different acoustic events that are relevant
 352 to the voicing distinction in stops when these consonants are devoiced.

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 357 author's M.Sc. in Speech and Hearing Sciences at the Universidade de Aveiro, Portugal.

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Appendix. Corpus used for the experiments

The transcriptions using the International Phonetic Alphabet (IPA) were adapted from the illustration proposed by Cruz-Ferreira (1999) for European Portuguese.

Table A1 Words of corpus with stops /p b/ in initial, medial and final position.

Stop	Position	Word	IPA
/p/	Initial	pato	[ˈpatu]
		pico	[ˈpiku]
		pufu	[ˈpufu]
	Medial	napa	[ˈnapɐ]
		ripa	[ˈripe]
		lupa	[ˈlupe]
		top	[ˈtɔp]
	Final	pape	[ˈpap]
		tape	[ˈtap]
		bato	[ˈbatu]
/b/	Initial	bico	[ˈbiku]
		bufo	[ˈbufu]
		naba	[ˈnabɐ]
	Medial	chiba	[ˈʃibe]
		juba	[ˈʒube]
		sobe	[ˈsɔb]
	Final	sabe	[ˈsab]
		cabe	[ˈkab]

Table A2 Words of corpus with stops /t d/ in initial, medial and final position.

Stop	Position	Word	IPA
/t/	Initial	tacto	[ˈtatu]
		tica	[ˈtike]
		tuna	[ˈtunɐ]
	Medial	nata	[ˈnatɐ]
		Rita	[ˈrite]
		luta	[ˈlute]
		pote	[ˈpɔt]
	Final	bate	[ˈbat]
		date	[ˈdat]
		dato	[ˈdatu]
/d/	Initial	dica	[ˈdike]
		duna	[ˈdunɐ]
		nada	[ˈnade]
	Medial	vida	[ˈvide]
		buda	[ˈbude]
		pode	[ˈpɔd]
	Final	nade	[ˈnad]
		jade	[ˈʒad]

Table A3 Words of corpus with stops /k g/ in initial, medial and final position.

Stop	Position	Word	IPA
/k/	Initial	cacto	[ˈkatu]
		quita	[ˈkite]
		cume	[ˈkum]
	Medial	vaca	[ˈvakɐ]
		pica	[ˈpikɐ]
		nuca	[ˈnuke]
		Roque	[ˈrɔk]
	Final	saque	[ˈsak]
		taque	[ˈtak]
gato		[ˈgatu]	
/g/	Initial	guita	[ˈgite]
		gume	[ˈgum]
		vaga	[ˈvagɐ]
	Medial	viga	[ˈvigɐ]
		guga	[ˈgugɐ]
		rogue	[ˈrɔg]
	Final	pague	[ˈpag]
		vague	[ˈvag]

361 References

- 362 Ackermann, Hermann & Ingo Hertrich. 1997. Voice onset time in ataxic dysarthria. *Brain and Language*
363 56(3), 321–333.
- 364 Andrade, Amália. 1980. *Estudos experimentais aerodinâmicos, acústicos e palatográficos do vozeamento*
365 *nas consoantes*. Lisboa, Portugal: Centro de Linguística da Universidade de Lisboa.
- 366 Andrade, Amália. 1993. Estudo experimental de sequências de oclusivas em Português Europeu. *IX*
367 *Encontro Nacional da Associação Portuguesa de Linguística*, Coimbra, Portugal, 1–15.
- 368 Andrade, Amália. 1994. Reflexões sobre o ‘e-mudo’ em Português Europeu. *Congresso Internacional*
369 *Sobre o Português*, Lisboa, Portugal, vol. 2, 303–344.
- 370 Andrade, Amália. 1995. Percepção de C ou CC oclusivas por ouvintes nativos do Português. *XI Encontro*
371 *Nacional da Associação Portuguesa de Linguística*, Lisboa, Portugal, vol. 3, 153–186.
- 372 Barroco, Mário, Marta Domingues, Maria F. Pires, Marisa Lousada & Luis M. T. Jesus. 2007.
373 Análise temporal das oclusivas orais do Português Europeu: Um estudo de caso de normalidade e
374 perturbação fonológica (Temporal analysis of European Portuguese stops: a case study of normality
375 and phonologically disturbance). *Revista CEFAC* 9(2), 154–163.
- 376 Brunner, Jana, Susanne Fuchs, Pascal Perrier & Hyeon-Zoo Kim. 2003. Mechanisms of contrasting Korean
377 velar stops: A catalogue of acoustic and articulatory parameters. *ZAS – Papers in Linguistics* 32,
378 15–30.
- 379 Caramazza, Alfonso & Grace Yeni-Komshian. 1974. Voice onset time in two French dialects. *Journal of*
380 *Phonetics* 2, 239–245.
- 381 Castro, São L. F. & Manuel F. S. Barbosa. 1996. Estudo percepto-acústico do contraste de vozeamento em
382 oclusivas portuguesas: Primeiros resultados. *Psychologica* 15, 159–164.
- 383 Cho, Taehong & Peter Ladefoged. 1999. Variation and universals in VOT: Evidence from 18 languages.
384 *Journal of Phonetics* 27, 207–229.
- 385 Cruz-Ferreira, Madalena. 1999. Portuguese (European). In IPA (eds.), *Handbook of the International*
386 *Phonetic Association: A guide to the use of the International Phonetic Alphabet*, 126–130. Cambridge:
387 Cambridge University Press.
- 388 Frota, Sónia. 2000. *Prosody and focus in European Portuguese: Phonological phrasing and intonation*.
389 New York: Garland.

- 390 Fuchs, Susanne. 2005. *Articulatory correlates of the voicing contrast in alveolar obstruent production in*
 391 *German*. Ph.D. dissertation, Queen Margaret University College.
- 392 Huckvale, Mark, David Michael Brookes, Leigh Dworkin, Michael Johnson, David Pearce & Louise
 393 Whitaker. 1987. The SPAR Speech Filing System. *European Conference on Speech Technology*,
 394 Edinburgh, 305–308.
- 395 Jesus, Luis M. T. & Philip J. B. Jackson. 2008. Frication and voicing classification. In António Teixeira,
 396 Vera Lima, Luís Oliveira & Paulo Quaresma (eds.), *Computational processing of the Portuguese*
 397 *language*, 11–20. Berlin: Springer.
- 398 Jesus, Luis M. T. & Christine H. Shadle. 2002. A parametric study of the spectral characteristics of
 399 European Portuguese fricatives. *Journal of Phonetics* 30(3), 437–464.
- 400 Jesus, Luis M. T. & Christine H. Shadle. 2003. Devoicing measures of European Portuguese fricatives.
 401 In Nuno J. Mamede, Jorge Baptista, Isabel Trancoso & Maria G. V. Nunes (eds.), *Computational*
 402 *processing of the Portuguese language*, 1–8. Berlin: Springer.
- 403 Keating, Patricia A., Wendy Linker & Marie Huffman. 1983. Patterns in allophone distribution for voiced
 404 and voiceless stops. *Journal of Phonetics* 11, 277–290.
- 405 Klatt, Dennis H. 1975. Voice onset time, frication, and aspiration in word-initial consonant clusters. *Journal*
 406 *of Speech and Hearing Research* 18(4), 686–706.
- 407 Klunder, Keith R., Randy L. Diehl & Beverly A. Wright. 1988. Vowel length differences before voiced
 408 and voiceless consonants: an auditory explanation. *Journal of Phonetics* 16, 153–159.
- 409 Ladefoged, Peter. 2006. *A course in phonetics*, 5th edn. Boston: Thomson Wadsworth.
- 410 Lisker, Leigh & Arthur S. Abramson. 1964. A cross-language study of voicing in initial stops: acoustical
 411 measurements. *Word* 20, 384–422.
- 412 Luce, P. & J. Charles-Luce. 1985. Contextual effects on vowel duration, closure duration, and the consonant/
 413 vowel ratio in speech production. *Journal of the Acoustical Society of America* 78(6), 1949–1957.
- 414 Morris, Richard J. 1989. VOT and dysarthria: a descriptive study. *Journal of Communication Disorders*
 415 22(1), 23–33.
- 416 Ohala, John J. 1983. The origin of sound patterns in vocal tract constraints. In P. MacNeilage (eds.), *The*
 417 *production of speech*, 189–216. New York: Springer.
- 418 Peterson, Gordon & Ilse Lehiste. 1960. Duration of syllable nuclei in English. *Journal of the Acoustical*
 419 *Society of America* 32(6), 693–703.
- 420 Pinho, Cátia, Luis M. T. Jesus & Anna Barney. 2010. Aerodynamics of voiced stop production. In
 421 *International Conference on Voice Physiology and Biomechanics*, Madison, WI.
- 422 Platt, L. J., Gavin Andrews & Pauline M. Howie. 1980. Dysarthria of adult cerebral palsy II. Phonemic
 423 analysis of articulation errors. *Journal of Speech and Hearing Research* 23, 41–55.
- 424 Rothenberg, Martin. 1968. *The breath-stream dynamics of simple-released-plosive production*
 425 (Bibliotheca Phonetica 6). Basel: Karger.
- 426 Sá Nogueira, Rodrigo. 1938. *Elementos para um tratado de fonética Portuguesa*. Lisboa: Centro de Estudos
 427 Filológicos.
- 428 Sá Nogueira, Rodrigo. 1941. *Tentativa de explicação dos fenómenos fonéticos do Português*. Lisboa:
 429 Livraria Clássica Editora.
- 430 Scott, Cheryl M. & Robert L. Ringel. 1971. The effects of motor and sensory disruptions on speech: A
 431 description of articulation. *Journal of Speech and Hearing Research* 14, 819–828.
- 432 van Alphen, Petra M. & Roel Smits. 2004. Acoustical and perceptual analysis of the voicing distinction in
 433 Dutch initial plosives: the role of pre-voicing. *Journal of Phonetics* 32(4), 455–491.
- 434 Van Den Berg, Janwillem. 1958. Myoelastic-Aerodynamic theory of voice production. *Journal of Speech*
 435 *and Hearing Research* 1(3), 227–243.
- 436 Veloso, João. 1995. *Aspectos da percepção das “oclusivas fricativizadas” do Português: Contributo para a*
 437 *compreensão do processamento de contrastes alofónicos*. Provas de Aptidão Pedagógica e Capacidade
 438 Científica, Universidade do Porto, Porto, Portugal.
- 439 Viana, Maria C. 1984. *Étude de deux aspects du consonantisme du portugais: fricatisation et devoisement*.
 440 Ph.D. dissertation, Université de Sciences Humaines de Strasbourg, Strasbourg, France.