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Case reports

Comparison of plosive sounds in monolingual and bilingual children, using the voice onset time acoustic parameter: cases report

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ABSTRACT

The purpose was to compare differences in production of plosive phonemes through the voice onset time (VOT) measurement in the speech of monolingual children, speakers of Brazilian Portuguese and bilingual children, speakers of both Brazilian Portuguese and English. The sample consisted of three monolingual children and three bilingual children; average age was 7 years. A speech emission was recorded for the investigation, which had the following vehicle phrase: "*Diga 'papa' baixinho*" ("Say 'papa' quietly"). *Papa* was then replaced by "*baba*", "*tata*", "*dada*", "*caca*" and "*gaga*". The measurements of the acoustic signals were performed through broadband spectrograms, and VOT was descriptively analyzed for the non-voiced sounds [p, t, k] and voiced [b, d, g] plosive sounds. Monolingual children presented higher average VOT values for [p, t, k] compared to bilingual children. For the [b, d, g] sounds, monolingual children had lower average VOT values, as compared to bilingual children. It was concluded that in the comparison of VOT measures of the speech samples, the monolingual children of Brazilian Portuguese presented higher values for the non voiced ones and lower for the voiced ones in relation to the bilingual children speakers of Brazilian Portuguese and English.

Keywords: Speech Acoustics; Child; Multilingualism; Voice

INTRODUCTION

With respect to the voicing, in Brazilian Portuguese (BP), non-voiced sounds are found [p, t, k] that do not have any vocal fold vibration mode (PPVV). These sounds contrast with voiced sounds [b, d, g], which present with some vocal fold vibration (voice source) and coordinated actions with the cartilages and muscles of the larynx[1-5].

Voicing is a property acquired gradually through development in children. It is known that they use different strategies to control and synchronize the adjustments required to produce the various articulation patterns[6-10]. In other languages, such as English, Japanese and Korean, there is the presence or absence of aspiration, in addition to voicing. It should be noted that each language has a distinct voicing characteristic, as well as the aspiration in certain plosive sounds[11,12].

The voice onset time (VOT) is defined as the time interval between the clearance of the oral obstruction of plosive sound, identified by the burst, and the beginning of the vibration of the vocal cords identified on a broadband spectrogram through the vertical spline[13-15].

It is a simple duration measure that contributes to facilitating a check of the relationship between speech sound production and perception[9,15-18]. The VOT also makes it possible to evaluate the synchronization between the articulatory gestures[6,18-22]. In this way, the VOT enables establishment of whether a continuum exists in the development of laryngeal adjustments according to age and if the acoustic specificities are related to the gradient of the articulatory gesture[7,8,14,15].

VOT measures were compared in the speech production analysis [p, t, k] in bilingual adults (Portuguese and English). In was possible to notice in the results that the VOT values were lower in English when compared to PB[23].

Another study that was also conducted with adults[21], analyzed the differences between the VOT duration measures of plosive consonants [p, t, k] in the speech production of 14 bilingual individuals (Spanish-English), aged 18 to 24 years. The group was consisted of 11 women and 3 men; 11 already knew both languages before age 6 (six) years and 3 (three) of them learned the second language later. Participants performed spontaneous conversation tasks about important dates in Mexico City and talked about the same topic while they were also assembling puzzles. Researchers found lower VOT values among subjects who learned both languages before reaching age 6 years, and the difference was more significant for English.

Another study analyzed the values of VOT measurements in non-voiced plosive sounds [p, t, k] of BP and English in five bilingual children from 8 to 9 years old. The authors reported the following VOT values in the first study: for BP, [p] = 48ms, [t] = 60ms, and [k] =70ms and for English, [p] = 40ms, [t] = 56ms, and [k] = 65ms[24].

With respect to children's speech as well, 40 children aged between 8 and 10 years old participated in another study, of which 20 were monolingual (BP) and 20 bilingual (BP/English). Differences were reported between the averages obtained by monolingual and bilingual children in producing aspirated plosive sounds in English. According to the author, it may suggest a strong influence of the first language of participants (BP) in the production of the aspirated plosive sounds in English[25].

Another study on infant speech during the phase of language acquisition examined plosive sounds in bilingual participants who could speak BP and a German dialect. The material consisted of 12 oral interviews, and acoustic analyses were performed with VOT measurement in plosive segments in the two groups. The authors found higher VOT indexes for the bilingual group when compared to the monolingual group and suggested that this difference may lead infants to confuse BP non-voiced plosive with German-voiced subjects[26].

Given that the VOT allows to investigate whether or not children and adults issue voiced and non-voiced sounds according to the standards of their language[3,8,15,17,27], the interest generated by the topic is based on the possibility of using a robust track to assist in the evaluations and therapies of speech-language pathology[5-7,21,22]. The data from some studies conducted with BP monolingual children[6,7] and with bilingual children[24,25] and bilingual adults[23,26,28] were considered as a parameter for standardization

Based on the above, the research suggests the following hypothesis: there is a difference in the trait of voicing among children who are exposed to a single language and bilingual childrenand VOT therefore may present specific characteristics for each language[11,29]. In addition, the amount and form of each individual's language exposure will affect sound production[23,30].

There as a noticeable increase in the number of bilingual schools in society and therefore in the number of bilingual children. Considering the lack of researches

with voiced and non-voiced sounds that compare monolingual and bilingual children, this research will be of great importance to speech-language pathology.

To address this question, the objective of this study was to compare plosive sounds by means of VOT in Brazilian Portuguese (BP) monolingual children with bilingual children (BP/English).

CASE PRESENTATION

This study was approved by the Research Ethics Committee of the Pontifical Catholic University of São Paulo, under the process number 019/2007. Parents and/or guardians signed the Free and Clarified Consent Term (FCCT) and children signed the Term of Assent (TA).

The sample consisted of six children, of whom three were monolingual native speakers of BP and three were BP–English bilingual. The ages of the three monolingual children (CM), all girls, were 7y3m (CM1), 7y6m (CM2), and 7y9m (CM3). Ages of the bilingual children (BC) were 7y5m for BC1 and BC2 and 7y6m for BC3. The three CM children studied in Brazilian schools, and their parents spoke BP as their first and only language. The three bilingual children learned both languages simultaneously because they lived in the United States until they were 6 years old, and each of them had one Brazilian and one American parent.

For the speech sample collection, children were placed in a quiet room of the school, where a decibel meter was used to confirm that the noise was lower than 30dB. In order to record sounds, girls sat in an armless chair, with their feet on the floor, and the Shure SM7A, a dynamic unidirectional low-impedance microphone, positioned 10 cm away from the mouth[6]. Each of the girls recorded three repetitions of the following sentences:"Diga 'papa' baixinho" ("Say 'papa' quietly"); "Diga 'baba' baixinho"; "Diga 'tata' baixinho"; "Diga 'dada' baixinho"; "Diga 'caca' baixinho"; and "Diga 'gaga' baixinho".[6] These sentences were repeated alone and the researcher, seated on the right side of the child confirmed perceptually that the sentence was reproduced, while the recording technician, on the left side, was responsible for observing the sound wave on the computer screen. Both the researcher and technician, were using headphones, so if they identified something that sounded unusual, they would repeat the recording of that child another day. Before making the measurements, the researcher also listened to a couple of sentences with "pata" and "bata" and conducted a hearing assessment to verify whether the production was in accordance with the stimulus[3]. The audio files were converted into WAVE files and the inspection of the acoustic signal was manually performed considering the wave form and the broadband spectrogram with PRAAT v5.2 software[6].

The VOT acoustic parameter expressed in milliseconds (ms) is regarded as a decisive time interval in the accurate perception of non-voiced [p, t, k] and voiced [b, d, g] plosive sounds. Because VOT is within the scope of measures of duration, it may sufferfrom interference from external factors and therefore usually requires some standardization procedure[4,17].To avoid interference, we decided to "control" the speech rate of the sentences–vehicle, among other factors[3,16].

We calculated the VOT (ms) positive measurements of non-voiced [p / t / k] plosive sounds, which was considered from the burst to the onset of the vowel, and the negative measurements of the voiced [b / d / g] plosive sounds, which was considered from pre-voicing to the burst[3,13,16].

RESULTS

Table 1 describes and compares the measurements of the VOT (ms) values obtained from the speech samples of the three monolingual children (CM1, CM2, and CM3) and the three bilingual children (CB1, CB2, and CB3). The measures for non-voiced plosives [p, t, k] for monolingual children had higher values than those of bilingual children, with the exception of the plosive /k/, for which CM3 and CB3 presented equivalent values.

Table 1. Voice onset time (ms) values for non-voiced plosive phonemes /p/, /t/, and /k/ for the three monolingual children (CM1, CM2, CM3) and three bilingual children (CB1, CB2, CB3)

Phonemes	CM1	CM2	CM3	CB1	CB2	CB3
/p/	14	12	13	13	9	11
/t/	13	19	20	11	10	17
/k/	31	39	39	28	25	39

In Figure 1, we present a comparison of the averages of the three monolingual vs the three bilingual children for the VOT (ms) parameter for the non-voiced plosive sounds [p, t, k]. The monolingual children showed higher values when compared to the bilingual group.

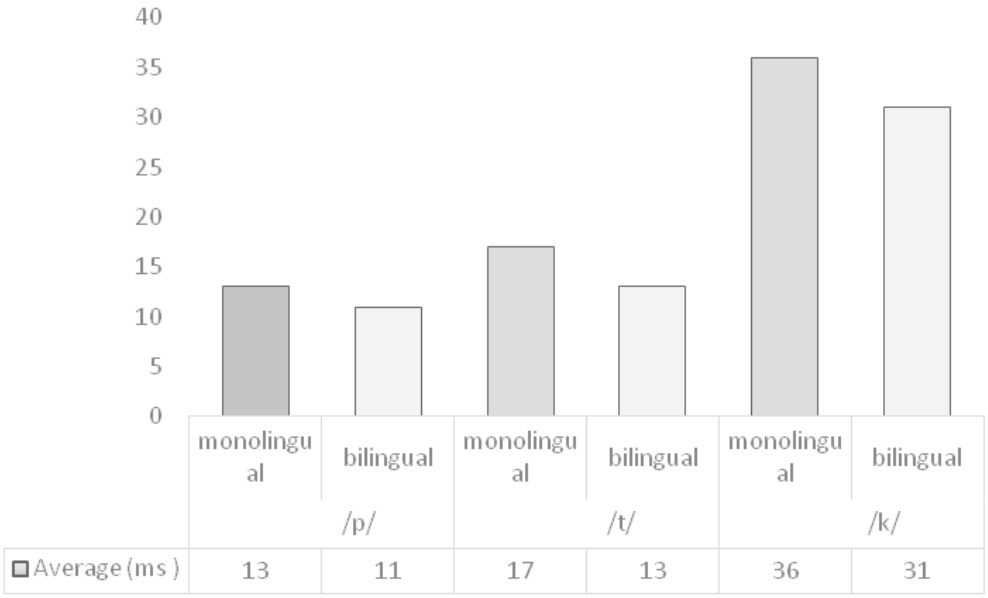

Figure 1. Comparison between averages obtained for monolingual and bilingual children for the voice onset time (ms) parameter of the non-voiced plosive sounds /p/, /t/, and /k/

Table 2 describes and compares VOT (ms) values for the three monolingual and three bilingual children. The three monolingual children had lower values for the voiced plosive sounds /b/, /d/ and /g/ compared to bilingual children.

Table 2. Voice onset time (ms) values for voiced plosive phonemes /b/, /d/, and /g/ for the three monolingual children (CM1, CM2, CM3) and three bilingual children (CB1, CB2, CB3)

Plos /children	CM1	CM2	CM3	CB1	CB2	CB3
/ b /	-91	-89	-71	-92	-113	-92
/ d /	-101	-86	-84	-111	-83	-93
/ g /	-94	-70	-62	-120	-77	-84

Figure 2 shows a comparison between the VOT (ms) averages for the monolingual and bilingual children for the voiced plosive sounds [b, d, g]. Monolingual children showed lower values ([b] = -91ms, [d]= -90ms, [g] =-75ms) compared to averages for the bilingual children ([b] =-92ms, [d]= -95 ms, [g] = -94ms).

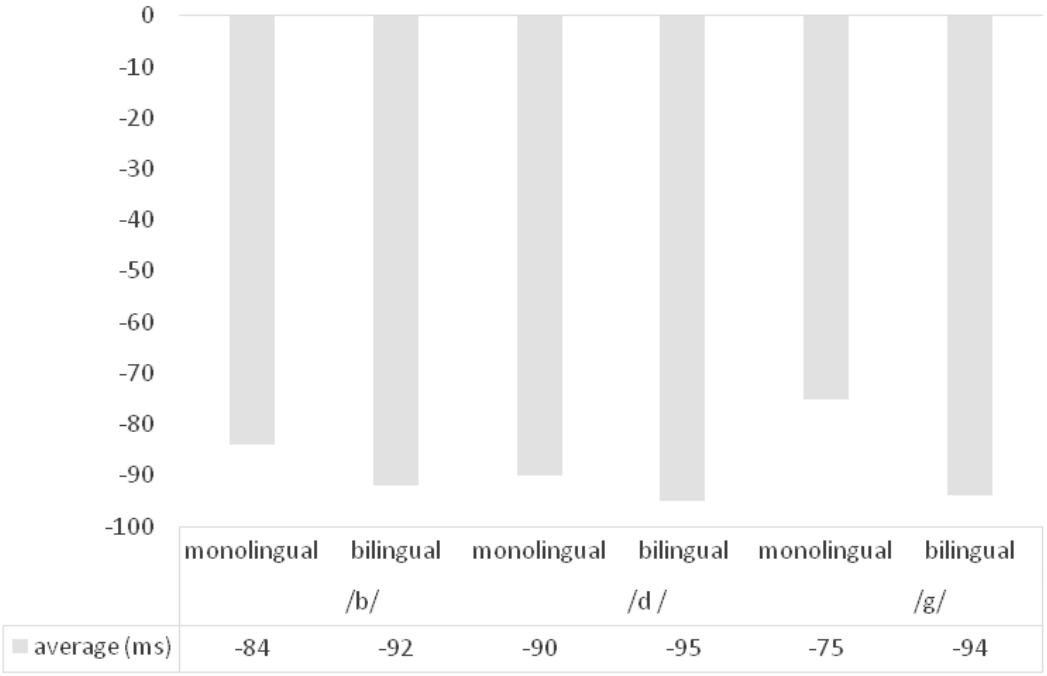

Figure 2. Comparison between averages obtained for monolingual and bilingual children for the voice onset time (ms) parameter of the voiced plosive sounds /b/, /d/, and /g/

DISCUSSION

Languages rely on sounds that result from a combination of many mechanisms involving the use of airflow and the chambers associated withit, such as the lungs, larynx, and the soft palate[1-3]. 3The larynx is not solely responsible for modulating airflow and producing sounds, which are chained and articulated in sequences characteristic for each language[3,4]. The production of speech sounds also depends on the plasticity of certain organs of the speech apparatus that creates numerous configurations in the vocal tract, which also include the vocal folds[1-4].

Voicing characteristics arise from synchronization between adjustment of laryngeal activity and oral articulation[1-3,10]and can be detected by means of perceptual–auditory assessment or analysis of various acoustic clues[6,8,23,27]. These issues are essential for learning a language, as well as to the differentiation between the languages[25].

Studies indicate that some particularities, such as aspiration, breathiness, and voicing interruptions or absence, may be found in the study of speech production in monolingual and bilingual children of BP, English, Spanish and German[6,15,17,24,29].

We found differentiation in VOT values when comparing data from speech productions between monolingual and bilingual children, as shown in Figure 1 and 2 and as observed by some children's speech[8,25] and adult's speech researchers[23,26,28].

Some authorshave reported that there is some mode of vibration of vocal cords for the production of plosive sounds and that the use of some features to allow voicing is often required. This voicing can be identified on the sound bar before the burst event.On the other hand, non-voiced plosive sounds have no mode of vibration of vocal cords and are produced at short intervals and with no aspiration because after the burst, there is a slight air release.

In the VOT results for the three monolingual girls, we found VOT values (Table 1) that are compatible with

those reported in the literature[2,3,13] and also in some studies by other researchers[23,25].

In English, the presence or absence of aspiration usually determines voicing contrast, the plosive [p, t, k] values. Sounds with an absence of aspiration present a shorter VOT while sounds with aspiration present a longer VOT, ranging from 25ms to 100 ms. The VOT is negative for voiced sounds, [b, d, g], but presents shorter values, with a slight variation around zero, because the release of the obstruction of the plosive and the beginning of voicing are almost simultaneously[2,3,11,13].Considering these characteristics, we were able to obtain VOT values for our bilingual children that were consistent with those previously reported by other researchers[23,24], as shown in Table 1 and 2.

The data from the bilingual children (Figure 2) are in accordance with results from a study conducted with bilingual adults who presented higher values of VOT measures by the presence of aspiration[23]. For children's speech, other earlierfindings35 were also similar;unlike values for the monolingual children, this previous studyuncoveredthe presence of a slight aspiration in VOTs of bilingual children between the ages of 8 and 9 years[24].

The VOT values of monolingual children of this research (Figure 1) are also in line with data presented by bilingual children of a research that analyzed the differences relating to VOT patterns in non-voiced sounds produced by monolingual (BP) and bilingual (BP/English) children. The authors of such study[25], as in this study, found differences between the averages obtained by monolingual and bilingual children, in the production of plosive sounds in English, and suggested that it could indicate an influence of the first language of participants in the production of the aspirated plosive sounds in English[25].

When compared to findings in bilingual children, we found higher VOT values (Table 1) for non-voiced plosive sounds in the monolingual children group studied and lower VOT values (Table 2) for the voiced plosive sounds.

Based on the results obtained, even with a small number of subjects, it is clear that when children are exposed to a single language, the voicing becomes more evident and it causes a highest value. With respect to bilingual children, the value was lower, but the identity of the plosive sound was maintained.

Thus, based on literature[3,10,22] it is worth noting that the distinct VOT values observed in the results (Table 1 and 2 and Figure 1 and 2) are probably due to different laryngeal adjustments and also subtle changes in the phonetic conduction of a speech-language pathology contrast in monolingual and bilingual individuals since childhood[3,10,22].

Despite lack of statistical tests due to the small number of subjects, it was possible to notice that the analysis of acoustic data of the VOT, which was chosen for this study, is valid since it showed differences in the values of voiced and non-voiced plosive sounds in children exposed to another language. There was an understanding, still based on literature, that the aspiration might have been responsible for differences in the VOT values, mainly for the voiced plosive sounds.

Therefore, VOT may be a complementary tool in the speech–language clinic with monolingual and bilingual children, useful in evaluations of and therapies for language disorders. It also can facilitate helping children exposed to more than one language to ameliorate mistakes when speaking and difficulties when writing and thus assist in treatment planning.

CONCLUSION

Compared with the three bilingual children in this study, the three monolingual children produced higher voice onset time values for non-voiced plosive sounds and lower values for voiced plosive sounds.

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