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Tongue movements in the production of /l/ in children with and without speech sound disorders in different ages

Movimentos de língua na produção do /l/ em crianças com e sem distúrbios dos sons da fala em diferentes faixas etárias

Keywords

Speech Sound Disorders
Assessment
Ultrasonography
Speech Articulation Tests
Speech

ABSTRACT

Purpose: this study used the ultrasonography of the tongue movements and the dynamic models of speech production to characterize the articulatory gestures of in the production of /l/ at the Brazilian Portuguese in different age groups, comparing them between typical and atypical children. **Methods:** the sample consisted of 30 typical and 30 atypical children between ages of four and eight-years-old, who underwent speech-language and ultrasonographic evaluations. The evaluation was realized by recording words reproduction with the sound /l/ and the following vocalic contexts: /a/, /i/ and /u/, repeating six times for each word. The software for recording and analysis was *Articulate Assistant Advanced* (AAA). The quantitative analysis considered the 42 points that intercepted the tongue curves in each image to describe the articulatory gestures; the estimation of the mean lines of each curve and the confidence intervals between typical and atypical children groups; and the differences between the mean tongue contours curves according to age group. **Results:** the results presented a tongue tip elevation and dorsal and root retraction in /l/. Typical children, regardless of age, showed a greater refinement of articulatory tongue gestures than the atypical ones. In older children, there was more delimitation in the mean tongue contours from the tongue tip to the root. **Conclusion:** the ultrasonography of the tongue movements is a substantial implement to characterize the articulatory gestures of /l/, to the differentiation between typical and atypical productions in this sound, and observation of the development of the articulatory gestures.

Palavras-chave

Distúrbios dos Sons da Fala
Avaliação
Ultrassonografia
Testes de Articulação da Fala
Fala

RESUMO

Objetivo: este estudo utilizou a ultrassonografia dos movimentos de língua e modelos dinâmicos de produção de fala para caracterizar os gestos articulatórios na produção do /l/ no Português Brasileiro (PB) em diferentes faixas etárias, comparando-os entre crianças típicas e atípicas. **Método:** a amostra foi constituída por 30 crianças típicas e 30 atípicas, com idades entre 4 e 8 anos, submetidas a avaliações fonoaudiológica e ultrassonográfica. A avaliação foi realizada mediante gravação da produção de palavras com o som /l/ nos contextos vocálicos de /a/, /i/ e /u/, com seis repetições de cada palavra. O *software* utilizado foi o *Articulate Assistant Advanced* (AAA). Para as análises quantitativas foram considerados: os 42 pontos que interceptaram as curvas de língua em cada imagem para descrição dos gestos articulatórios; o cálculo das linhas médias de cada curva e os intervalos de confiança entre os grupos; e o cálculo das diferenças entre as curvas médias dos contornos de língua de acordo com a faixa etária. **Resultados:** houve elevação de ponta de língua e retração de dorso e raiz na articulação do /l/. As crianças típicas, independentemente da idade, apresentaram maior refinamento dos gestos articulatórios de língua do que as atípicas. Nas crianças mais velhas, houve maior delimitação nos contornos médios de língua desde a ponta até a raiz. **Conclusão:** a ultrassonografia dos movimentos de língua é uma importante ferramenta para a caracterização dos gestos articulatórios do /l/, para diferenciação entre as produções típica e atípica deste som, e observação do desenvolvimento dos gestos articulatórios.

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INTRODUCTION

Phonological acquisition of a language is linked to neuropsychomotor development, which determines the refinement and coordination of articulatory tongue gestures over time. Children gradually evolve their physical, cognitive, and socio-emotional capacities according to the maturation and to the adequate stimulation from both the family and school environment[1].

Immaturity, inadequate stimulation, and other biopsychosocial factors can be associated with language development impairments, such as Speech Sound Disorders (SSD). The existence of SSD interferes with language development, often at the linguistic-phonological level and at different levels of speech production[2].

Speech errors in children with SSD, specifically in phonological disorders, are omissions, substitutions, and distortions. In the phonological acquisition, each class of sounds is acquired at a different moment of development, wherein the Brazilian Portuguese (BP) the liquid consonants /l/, /ʎ/, /R/ and /ɾ/ belong to the later acquisition class of typical speech development, being the ones that more difficulties offer for children with SSD[3]. Especially in the sound /l/, the first of the liquid class to be acquired, there are two distinct articulatory gestures of the tongue, while in the /r/, there are also two distinct gestures of the tongue, however with greater tip constriction and retraction of the root[4].

In the study of the phonological acquisition, it is necessary to consider that the segments of a language must be seen from both the perspective of implementation, mechanics and from the perspective of the gradient nature of processes[5].

Thus, in contrast to static phonological models, dynamic models of speech production have emerged, as is the case with Articulatory Phonology (AP)[6-9], later called Gestural Phonology (FonGest) in Brazil[10]. These models, combined with instrumental assessment methods, as ultrasonography of tongue movements (USG), made it possible to conduct more accurate articulatory and acoustic studies, as well as documenting unpublished phonic facts[9].

Articulatory gestures are the primitive unit for analysis of the AP and they are at the same time phonological (cognitive) units, endowed with dynamically specified articulatory (physical) units of action. Dynamic models seek to unravel the nonexistent rupture between phonetics and phonology and interpret phenomena in children's speech that can be clarified by instruments such as USG of tongue movements[9, 11-13].

The importance of this type of scientific investigation lies in the possibility of direct observation of the articulators, where the gestural composition is contrasted, either by the absence of a given gesture or by the differences in parameters between the gestures, as degree and location of constriction. Through the USG of tongue movements, there is a direct translation of the dynamic into the symbolic, and the prediction of intermediate states between sounds, as duration and magnitude of tongue gestures[5].

This study utilizes the USG of tongue movements as a tool for speech analysis under the hypothesis that articulatory gestures of /l/ present greater articulatory refinement between typical and atypical older children at 6-8 years in relation to those 4-6 years, considering that they will improve gestures by the effects of maturation, age, and other environmental factors.

The objective of this research is to characterize the tongue articulatory gestures in the production of the consonant /l/ in BP in different age groups, comparing them between typical children and children diagnosed with SSD (atypical).

METHODS

This is an experimental, prospective, quantitative, and descriptive research. The research participants were children with adequate speech and language acquisition and development, named typical children (TC), and children with alterations in the language sound system, named atypical children (AC). The age of 6-year-old was chosen as the cutoff point between the two groups (TC and AC) because it coincided with the beginning of the literacy process (1st grade of elementary school). It is assumed that formal teaching emphasizes the awareness of the "sound-letter" relationship, which would influence the refinement of the articulatory gestures.

This research was approved by the Research Ethics Committee of the educational institution under number 442,786, according to Resolution 466/12. All participants were selected for convenience and the guardians signed the Free and Informed Consent Form (FICF).

Language and speech, hearing and ultrasonographic assessments were performed at the school clinic of this higher education institution. To constitute the research groups, the following evaluations were performed: articulatory examination; orofacial motricity and neurovegetative functions examination[14]; assessment of comprehensive and expressive language with sequencing and narration of facts[15]; hearing screening with portable audiometer in a silent environment at frequencies ranging from 500Hz to 6000Hz at 20dBNA; and phonological assessment for all children[15].

After the initial assessments, the following inclusion criteria were established for both AC and TC to participate in the research: being a monolingual BP speaker; not having received prior speech therapy or at the time of the beginning of the research; to have normal hearing in both ears; no complaints of chronic otitis media; to have expressive and comprehensive language development appropriate to mental age, with no learning-related complaints; and to attend kindergarten, preschool, or early grades of elementary school.

Sixty children were assessed, 30 TC and 30 AC. All TC had the sound /l/ established in speech production. Among the 30 AC, only two presented the sound /l/ partially acquired and not acquired, and the other 28 AC presented the sound /l/ acquired, but with alteration in other sounds. Thus, two groups were formed:

- AC Group: 30 atypical children aged between the ages of 4 and 8, 14 under 6 years of age and 16 over 6 years of age, 28 of which adequately produced the sound /l/.
- TC Group: composed of 30 children with typical speech development, matched for age in relation to ACG.

For both groups, USG tongue images were recorded during speech production, performed individually for approximately 30 minutes in a single session. For the ultrasonographic assessment, each participant should be seated comfortably in an acoustic booth, feet flat on the floor, upright, using the Probe Stabilizer Helmet (Articulate Instruments) that follows the Articulate Assistant Advanced (AAA) software. The ultrasound probe was fixed externally below the jaw, whose stability was guaranteed by the stabilizing helmet. In the probe, it was used a transducer gel, which enabled the capture and visualization of the tongue contour images, using a frequency of 5.0MHz. The SHURE unidirectional microphone was positioned at 10cm from the patient's mouth.

For the analysis of the tongue images, the sagittal plane/ Mode B was chosen because it allows seeing the tongue from the root to the tip. Images were captured, recorded, and analyzed using the AAA[17] software.

Participants were instructed to speak the same phrases with words that contained the sound /l/. All words were represented by figures, presented separately, and inserted in the phrase: "speak __target word__ again", in the order presented in Table 1. For each participant, 6 sequential repetitions of each word were recorded, always following the same order, in the same carrier phrase.

After recording the images, the outline of each participant's tongue was traced at each repetition in the image referring to the maximum elevation of the anterior tongue area in the sound /l/ (frame). The sounds were identified by speech spectrography, due to simultaneous analysis for audio and video, properly synchronized by the software feature.

After selecting the frame, the same fan angle was chosen for all participants (120°, available in the DP6600 ultrasound software itself). The fan has 42 radii projecting over the image. The radii that reach the image of the tongue contour are constituted by values (points of intersection), which correspond to the distances (in mm) from the beginning of each radius at the base of the fan to the curve of the tongue.

Thus, valid points, that is, those that intercepted each tongue curve, in each repetition, were copied from the software workspace to a spreadsheet containing 42 columns (numbered from 0 to 41). To enable understanding of the tongue contours and tongue regions represented in the images, three regions were estimated: anterior (comprising the tip), between splines 28 and 42; middle, between splines 14 and 28; and posterior (comprising the root), between splines 1 and 14. For this study, it was possible to demarcate approximate regions, subjectively, because for each participant there are variations depending on the placement of the probe in the submandibular region.

Furthermore, it is important to highlight that only valid points (100% agreement between marking the tongue surface contour and the image) were completed for each participant, in the repetition for each word. Two spreadsheets referring to the participants of each group (TC and AC) were created in Excel. After the spreadsheets were constituted, the data from each group were exported to the "R" statistical tool. In the "R" environment, the mean values of the tongue contours in the repetitions of each word by groups and their confidence intervals around each of the mean values were calculated. The intervals were obtained with 95% confidence around each of the midpoints of the tongue curves (*splines*), representing the minimum and maximum allowable variations for each tongue gesture.

Later, regions with significant differences (p-value <0.05) between the TC and AC groups were also verified by analyzing the 95% confidence interval for the mean difference between the tongue contours within each group, applying the Student's t-test. The regions that presented significant differences between the tongue gestures produced by the groups were those that did not contain the horizontal line referring to the zero value. In this context, when one of the limits of the interval (minimum or maximum) for a given spline overpass the line representing the null difference hypothesis, it is because in that region there is a significant difference between the tongue gestures produced by each group.

Table 1 presents the words with /l/ in stressed syllable, considering the following vowel contexts with the vowels /a/, /i/ and /u/.

Table 1. Words with /l/ considering the different vowel contexts following the vowels /a/, /i/, and /u/

[sa.'la.da] ("salad") (LA)	/l/	/a/
[fa.'li.da] ("bankrupt") (LI)	/l/	/i/
[ka.be.'lu.du] ('hairy") (LU)	/l/	/u/

RESULTS

Tables 2 and 3 contain the limits of mean gestures for spline (upper limit - UL, and lower limit - LL) calculated for all children aged 4 to 6 years old and 6 to 8 years old. The statistic used was Student's t-test with the associated p-value. It is noted that in regions where the minimum or maximum ranges exceed the zero-value line, the p-values for the difference between groups is significant ($p \leq 0.05$).

Table 2. Upper and lower limits of the mean contour of spline articulatory gestures for all children aged 4 to 6 years

	LA				LI				LU			
spline	LLim	ULim	t	p-value	LLim	ULim	t	p- value	LLim	ULim	t	p- value
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-15.02	1.66	-2.39	0.087	-	-	-	-	-	-	-	-
5	-12.83	-0.83	-3.02	0.033	-	-	-	-	-	-	-	-
6	-9.95	-0.68	-2.53	0.028	-	-	-	-	-7.00	0.62	-1.84	0.092
7	-8.84	0.81	-1.85	0.094	-7.45	2.35	-1.22	0.260	-6.39	1.23	-1.46	0.167
8	-8.47	0.46	-1.94	0.075	-13.88	9.41	-0.79	0.508	-9.92	1.05	-1.75	0.104
9	-7.35	2.98	-0.92	0.374	-7.49	2.21	-1.19	0.259	-8.89	1.97	-1.36	0.194
10	-7.90	2.51	-1.12	0.283	-9.08	0.27	-2.00	0.063	-9.33	1.47	-1.54	0.142
11	-7.09	2.78	-0.93	0.366	-9.04	-0.46	-2.32	0.032	-9.28	1.16	-1.64	0.120
12	-6.77	2.01	-1.13	0.271	-8.08	0.17	-2.01	0.059	-8.39	2.59	-1.11	0.281
13	-6.13	2.24	-0.97	0.344	-8.51	-0.33	-2.25	0.035	-7.71	2.20	-1.15	0.262
14	-5.55	2.76	-0.70	0.492	-8.58	-0.63	-2.40	0.025	-6.76	2.79	-0.86	0.397
15	-5.01	3.10	-0.49	0.629	-9.26	-1.14	-2.64	0.014	-5.97	2.84	-0.73	0.470
16	-4.30	3.51	-0.21	0.835	-9.27	-1.40	-2.79	0.010	-5.29	3.14	-0.53	0.604
17	-3.76	3.89	0.04	0.971	-9.14	-1.12	-2.64	0.014	-4.46	3.64	-0.21	0.836
18	-3.28	4.07	0.22	0.827	-9.08	-0.72	-2.42	0.024	-3.97	4.02	0.01	0.990
19	-2.96	4.11	0.34	0.738	-9.01	-0.27	-2.20	0.039	-3.53	4.29	0.20	0.842
20	-2.79	4.01	0.37	0.715	-8.77	0.21	-1.98	0.061	-3.17	4.50	0.36	0.723
21	-2.82	3.77	0.30	0.769	-8.34	0.70	-1.76	0.093	-3.01	4.56	0.42	0.676
22	-2.99	3.45	0.15	0.884	-7.69	1.28	-1.48	0.152	-3.17	4.50	0.36	0.724
23	-3.24	3.11	-0.04	0.965	-6.79	1.95	-1.15	0.263	-3.54	4.31	0.20	0.841
24	-3.65	2.70	-0.31	0.759	-5.95	2.57	-0.82	0.422	-4.04	3.99	-0.01	0.990
25	-4.18	2.21	-0.63	0.531	-5.13	3.17	-0.48	0.632	-4.66	3.51	-0.29	0.773
26	-4.81	1.71	-0.98	0.338	-4.59	3.61	-0.25	0.808	-5.82	2.61	-0.79	0.440
27	-5.48	1.14	-1.35	0.189	-4.33	3.81	-0.13	0.895	-6.58	1.82	-1.17	0.254
28	-5.23	1.10	-1.35	0.190	-3.82	4.22	0.10	0.919	-5.85	2.18	-0.95	0.354
29	-6.26	0.55	-1.73	0.096	-3.54	4.56	0.26	0.798	-6.70	1.36	-1.37	0.184
30	-7.36	-0.05	-2.09	0.047	-3.50	4.85	0.34	0.741	-7.46	0.93	-1.61	0.121
31	-7.88	0.01	-2.07	0.050	-4.03	4.62	0.14	0.889	-8.25	0.75	-1.73	0.098
32	-9.04	-1.35	-2.80	0.010	-5.86	3.41	-0.55	0.587	-9.55	-0.61	-2.37	0.028
33	-10.04	-0.41	-2.28	0.035	-6.77	4.00	-0.55	0.592	-10.44	-0.62	-2.37	0.029
34	-11.03	1.08	-1.78	0.099	-7.80	4.84	-0.50	0.623	-10.99	2.82	-1.32	0.216
35	-28.98	29.17	0.02	0.986	-10.89	15.59	0.61	0.592	-11.84	7.95	-0.51	0.634
36	-	-	-	-	-59.39	63.95	0.37	0.770	-37.45	37.45	-0.00	1.000
37	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-	-	-

LA: sound /l/ in “salad” [sa.’la.da]; LI: sound /l/ in “bankrupt” [fa.’li.da]; LU: sound /l/ in “hairy” [ka.be.’lu.du]. LLim - Lower Limit; ULim - Upper Limit; in bold, highlighting the statistically significant values. Student’s t-test (p≤0.05).

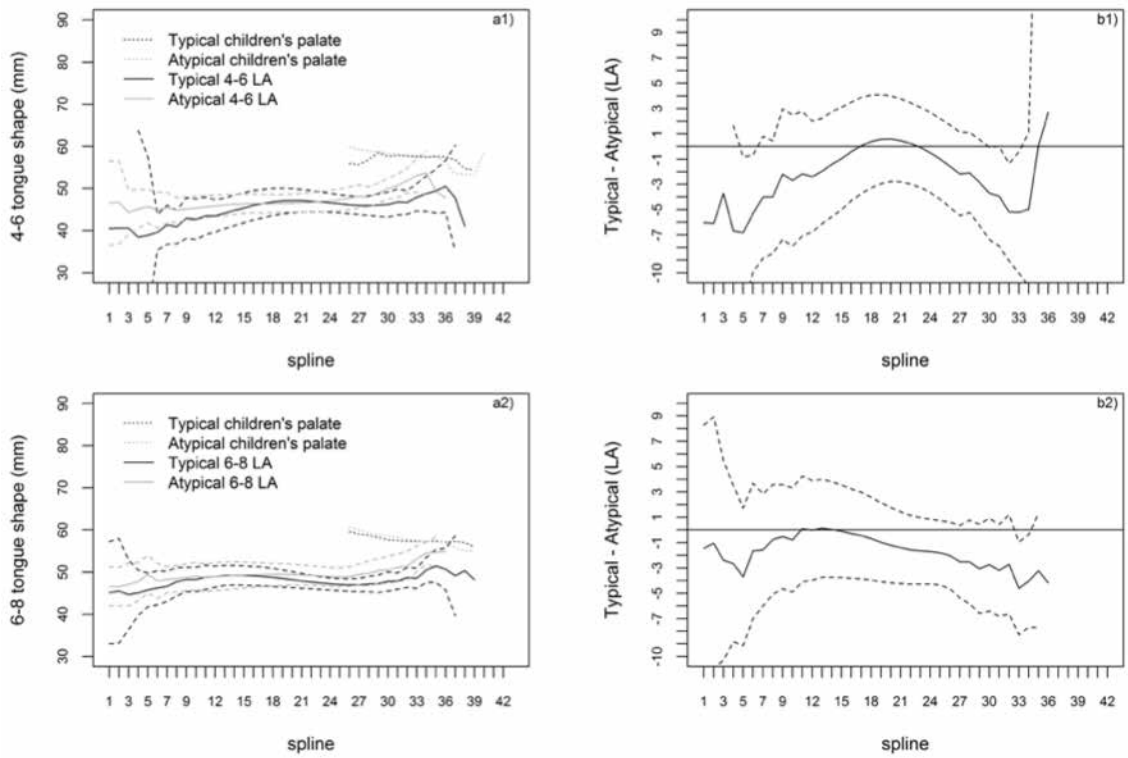
Table 3. Upper and lower limits of the mean contour of spline articulatory gestures for all children aged 6 to 8 years

	LA				LI				LU			
spline	LLim	ULim	t	p-value	LLim	ULim	t	p- value	LLim	ULim	t	p- value
1	-11.15	8.27	-0.44	0.686	-12.42	4.32	-1.42	0.238	-9.65	7.50	-0.32	0.759
2	-11.00	8.93	-0.31	0.773	-13.21	4.53	-1.46	0.230	-9.77	5.59	-0.67	0.530
3	-10.28	5.48	-0.76	0.480	-9.95	3.41	-1.22	0.271	-9.84	4.46	-0.85	0.417
4	-8.83	3.52	-0.95	0.363	-9.10	3.64	-0.95	0.365	-9.48	3.34	-1.05	0.317
5	-9.14	1.72	-1.47	0.164	-8.97	3.52	-0.96	0.358	-7.94	4.23	-0.65	0.525
6	-6.99	3.69	-0.65	0.523	-7.73	2.65	-1.05	0.311	-8.34	4.40	-0.66	0.519
7	-6.00	2.84	-0.75	0.465	-7.79	1.44	-1.48	0.162	-8.97	1.95	-1.35	0.194
8	-5.08	3.58	-0.36	0.723	-7.95	0.98	-1.65	0.118	-7.53	2.66	-0.99	0.334
9	-4.63	3.56	-0.27	0.791	-8.39	0.17	-2.03	0.059	-7.35	2.74	-0.95	0.354
10	-4.90	3.34	-0.39	0.700	-7.49	0.81	-1.68	0.109	-7.16	2.50	-0.99	0.330
11	-4.08	4.26	0.04	0.966	-7.11	1.90	-1.20	0.243	-6.93	3.72	-0.62	0.539
12	-3.96	3.92	-0.01	0.990	-7.49	1.64	-1.33	0.198	-6.74	3.24	-0.72	0.476
13	-3.74	4.01	0.07	0.943	-8.47	0.73	-1.74	0.095	-6.18	3.32	-0.62	0.541
14	-3.74	3.80	0.02	0.987	-8.94	0.16	-2.00	0.058	-5.98	2.97	-0.69	0.494
15	-3.75	3.56	-0.06	0.956	-9.24	0.04	-2.05	0.052	-5.59	2.47	-0.80	0.434
16	-3.81	3.25	-0.16	0.873	-9.12	0.15	-2.01	0.057	-5.16	2.18	-0.83	0.412
17	-3.85	2.98	-0.26	0.796	-8.81	0.23	-1.96	0.062	-4.83	1.94	-0.88	0.388
18	-3.95	2.59	-0.43	0.673	-8.26	0.54	-1.81	0.083	-4.72	1.75	-0.94	0.355
19	-4.09	2.15	-0.64	0.529	-7.63	0.61	-1.75	0.092	-4.64	1.73	-0.93	0.358
20	-4.17	1.77	-0.83	0.414	-6.93	0.77	-1.64	0.113	-4.49	1.78	-0.88	0.384
21	-4.23	1.45	-1.01	0.323	-6.27	0.85	-1.55	0.131	-4.31	1.85	-0.82	0.418
22	-4.29	1.14	-1.20	0.243	-5.69	0.85	-1.51	0.141	-4.18	1.90	-0.77	0.448
23	-4.28	0.97	-1.30	0.205	-5.07	0.93	-1.41	0.168	-4.02	1.97	-0.70	0.488
24	-4.26	0.85	-1.38	0.181	-4.48	1.10	-1.24	0.226	-3.91	2.02	-0.66	0.516
25	-4.34	0.74	-1.47	0.156	-3.65	1.74	-0.73	0.473	-3.91	2.06	-0.64	0.531
26	-4.64	0.62	-1.58	0.128	-3.13	1.99	-0.46	0.652	-4.10	2.00	-0.71	0.485
27	-5.36	0.35	-1.81	0.083	-2.45	2.44	-0.00	0.997	-4.35	1.98	-0.77	0.447
28	-5.83	0.78	-1.59	0.128	-2.47	2.38	-0.04	0.970	-4.30	2.43	-0.58	0.571
29	-6.57	0.45	-1.80	0.085	-2.41	2.83	0.16	0.870	-5.46	1.47	-1.20	0.244
30	-6.39	0.94	-1.54	0.137	-2.54	2.54	0.00	1.000	-5.90	0.44	-1.83	0.087
31	-6.82	0.43	-1.86	0.080	-3.17	2.88	-0.10	0.922	-5.59	0.82	-1.58	0.134
32	-6.63	1.21	-1.46	0.162	-3.45	2.57	-0.31	0.761	-4.60	0.42	-1.76	0.097
33	-8.27	-0.94	-2.66	0.017	-4.84	0.97	-1.46	0.172	-5.24	-0.36	-2.46	0.027
34	-7.69	-0.37	-2.32	0.033	-5.38	0.36	-1.92	0.080	-6.25	0.74	-1.70	0.113
35	-7.73	1.29	-1.57	0.144	-3.55	2.19	-0.54	0.601	-	-	-	-
36	-	-	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	-
41	-	-	-	-	-	-	-	-	-	-	-	-
42	-	-	-	-	-	-	-	-	-	-	-	-

LA: sound /l/ in "salad" [sa.'la.da]; LI: sound /l/ in "bankrupt" [fa.'li.da]; LU: sound /l/ in "hairy" [ka.be.'lu.du]. LLim - Lower Limit; ULim - Upper Limit; in bold, highlighting the statistically significant values. Student's t-test (p≤0.05).

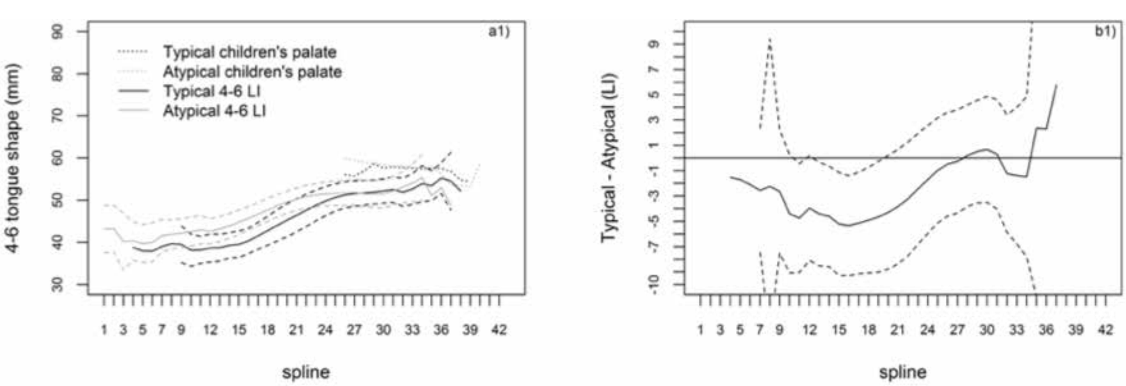
Hereafter, figures 1, 2, and 3 show the articulatory gestures characterized by the mean tongue contours of the sound /l/ and the ages researched, comparing ACG and TCG of the same age group. The figures are arranged in: a) (example a1) - which corresponds to the mean tongue curves for each group (TCG and ACG); b) (example b1) - which shows the result of regions in which all ranges exceed the zero line (up or down), which correspond to the statistically significant, that is, they differ between TCG and ACG.

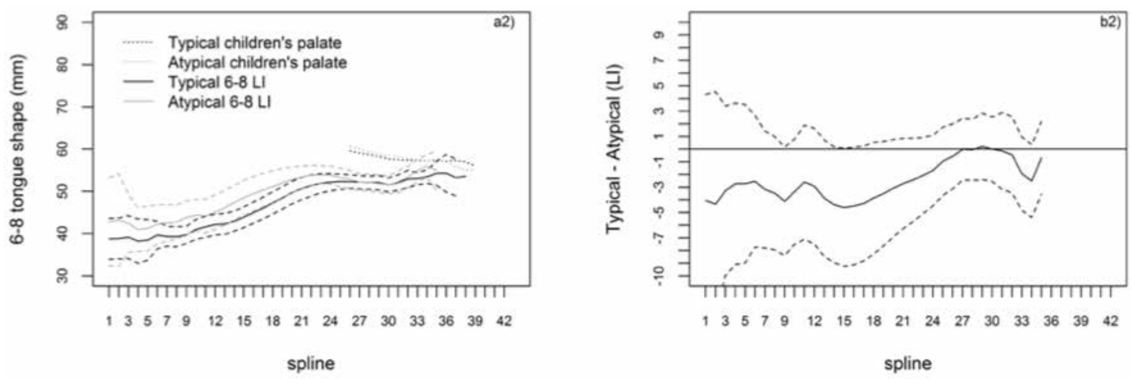
Figure 1. Mean contours of the tongue curves for /l/ in the word "salada" – "*salad*" (LA) for typical and atypical children (a), and differences between ACG and TCG (b) by age groups



a1) Confidence intervals for the mean tongue contours in /l/ in the word "*salada*" – "*salad*" (LA) between TCG and ACG at ages 4 to 6 years; a2) 6 to 8 years; b1) Confidence interval for the difference in tongue curves between TCG and ACG at ages 4 to 6 years; b2) from 6 to 8 years to /l/ in the respective word. Root splines 1 to 14, tip splines 28 to 42.

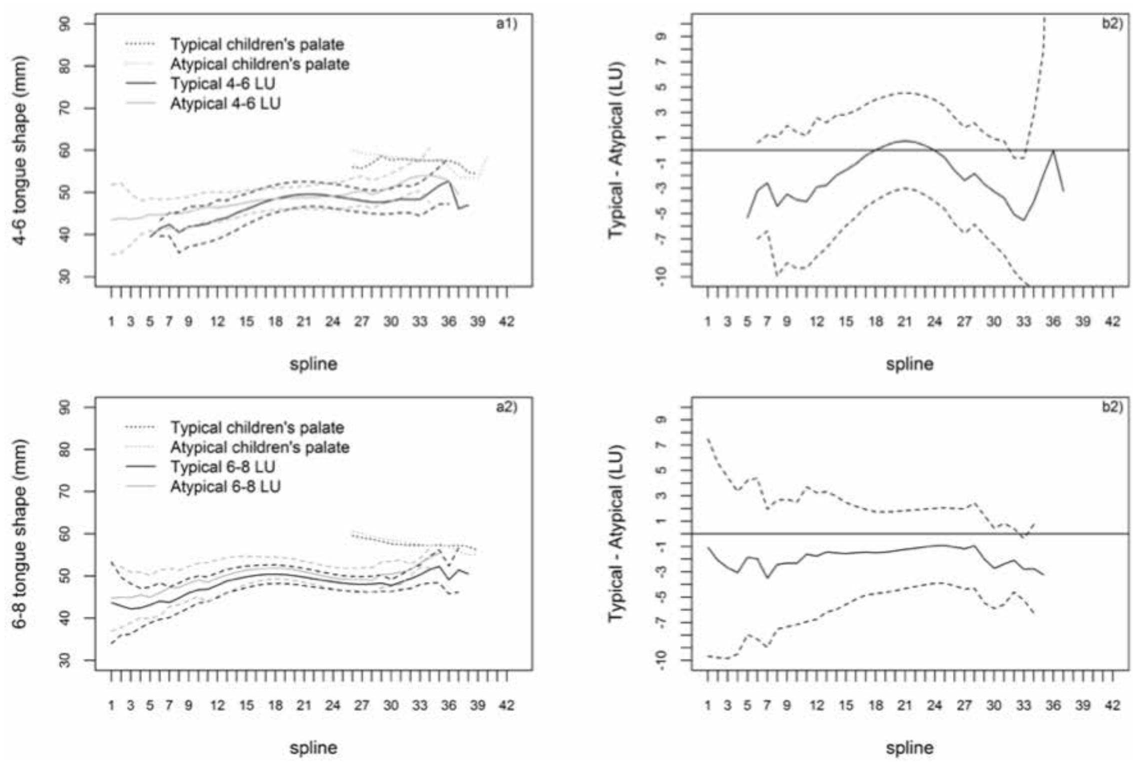
Figure 2. Mean contours of the tongue curves for /l/ in the word "falida" – "*bankrupt*" (LI) for typical and atypical children (a), and differences between ACG and TCG (b) by age groups





a1) Confidence intervals for the mean tongue contours in /l/ in the word "*falida*" – "*bankrupt*" (LI) between TCG and ACG at ages 4 to 6 years; a2) 6 to 8 years; b1) Confidence interval for the difference in tongue curves between TCG and ACG at ages 4 to 6 years; b2) from 6 to 8 years to /l/ in the respective word. Root splines 1 to 14, tip splines 28 to 42.

Figure 3. Mean contours of the tongue curves for /l/ in the word "cabeludo"- "*hairy*" (LU) for typical and atypical children (a), and differences between ACG and TCG (b) by age groups



a1) Confidence intervals for the mean tongue contours in /l/ in the word "*cabeludo*" – "*hairy*" (LU) between TCG and ACG at ages 4 to 6 years; a2) 6 to 8 years; b1) Confidence interval for the difference in tongue curves between TCG and ACG at ages 4 to 6 years; b2) from 6 to 8 years to /l/ in the respective word. Root splines 1 to 14, tip splines 28 to 42.

DISCUSSION

Coordination of articulatory gestures over time is a skill that involves both mastering the necessary articulatory gestures of the native language, and learning to coordinate these gestures according to the rules of the language[4]. The USG of tongue movements combined with dynamic speech production models, such as AP, have been a very interesting research tool for speech analysis, specifically for articulatory gestures of adults and children[18,19]. Especially in children, speech errors are presented as gradients, that is, often these errors are their attempts to speak correctly, and not just simple speech sounds substitutions or omissions[20].

During the process of acquiring language sounds, children begin to establish some correspondences between their listening and the articulatory movements that result in certain acoustic effects[21].

As with any other motor learning, tongue movements have significant characteristics according to age and the acquisition of articulatory gestures has important repercussions on the child's development. In the phonological acquisition, in any language, it is observed that the phonic repertoire is unstable initially but tends to greater stability during development until it productively incorporates all the phonic contrasts involved[22].

In this study, it was possible to notice that, for both typical (without SSD) and atypical (with SSD) children, the articulatory production of /l/ involved gestures of tongue tip elevation and tongue dorsum and root retraction.

Older children over 6 years of age, regardless of speech development, presented greater articulatory refinement and delimitation of the tongue tip conformation when compared to children under 6 years of age.

Differences between the average tongue curves for the word "salada" ("salad" - [sa.'la.da] - LA) in children at 4-6 years occurred in the tip (anterior) and root (posterior) regions of the tongue, whereas in children at 6-8 years these differences occurred only in the tip (anterior region) of the tongue (Figure 1), which demonstrates greater differentiation of gestures of /l/ between groups for this vowel context in younger children.

In the word "falida" ("bankrupt" - [fa.'li.da] - LI), a difference was observed between tongue curves on the back (middle region) and tongue root (posterior region) only for children aged 4 to 6 years old. (Figure 2), reiterating greater differentiation between the TCG and ACG groups for the younger ones.

In the word "cabeludo" ("hairy" - [ka.be.'lu.du] - LU), there was a difference between the tongue curves at the tip (anterior region) for children from 4 to 6 years old and for children from 6 to 8 years old. However, in children from 4 to 6 years old, the statistically different interval was longer. (Figure 3). The results indicate greater articulatory refinement in older children, evidenced by smaller statistical differences between the TCG and ACG groups at ages 6 to 8 years.

Therefore, it was observed in this study that the younger children, typical and atypical, present immature gestural patterns in the articulatory production of the sound /l/, which demonstrates less articulatory refinement. Nevertheless, the gestural tongue patterns of /l/ production are similar to the patterns of older children, both typical and atypical.

This is because the phonological development of atypical children occurs in a similar order to the phonological acquisition order of typical children, however, later on[3,23,24]. It is important to highlight that the mean tongue contours, regardless of the phonological acquisition, suggest a way towards a pattern of differentiation of the tongue gestures, although there is a tendency for better coordination of the gestures of the root and tip of the tongue in typical children.

Less differentiation in the conformation patterns of tongue gestures in younger children points to the acquisition of the phonological system, which occurs gradually until the age of five, and it may extend to the age of seven[25-28]. In the case of 6-year-old children, there is a lower incidence of speech disorders, which may be justified by better coordination of articulatory gestures. In this study, this hypothesis was confirmed by the greater precision and coordination of tongue movements in the production of liquid /l/ in LA, LI, and LU.

It should also be emphasized that 6-year-old children begin the 1st year of the first cycle of elementary school, in which language development is improved through learning, improved communication, and enhanced contact with writing. The formal teaching of writing has a significant influence on speech production since the child needs training in alphabetic writing rules to be able to identify sounds individually, that is, the formal and systematic teaching of correspondence between phonemic elements of speech and the graphemic elements of writing[26].

The intrinsic relationship between speech and other human motor systems rescues the interrelationship between the development of motor patterns from the moment the child is introduced to other forms of gesture representation, for example, when literacy begins, writing being another representational modality of language[29]. Thus, the time of exposure to certain sound structures, in addition to the neuromotor system maturation and schooling are factors that influence the child's linguistic performance[30].

CONCLUSION

The use of USG of tongue movements as a tool for speech analysis allowed the characterization of the articulatory gestures of the tongue in the production of consonant /l/ in BP. Moreover, it was possible to qualitatively compare the gestures between typical children and children with SSD, and in two age groups, confirming the hypothesis that articulatory gestures would present greater articulatory refinement in older children, over 6 years of age, compared to younger children. These findings were obtained by direct observation of the articulators and the contrast of the gestural composition of the sound.

Tongue gestures for /l/ were characterized for all children with tongue tip elevation and dorsum and root retraction. Typical children, regardless of age, presented greater refinement of articulatory gestures than atypical ones, with significant differences in mean tongue curves. In typical children, regardless of age, and in older atypical children, there was a greater delimitation in the mean tongue contours from the tip to the root in relation to the younger ones. The greater ability in the articulatory production of older children suggests the influence of the effects of maturation and modification of environmental stimuli, with the beginning of school age and contact with the written language.

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Author contributions

LSB was responsible for conducting the research and data collection, bibliographic research and manuscript writing. CRP assisted in data collection, bibliographic survey, as well as in the writing of the manuscript. DAOM contributed to the formulation of the scientific methodology and elaboration of the statistical analysis, as well as revision of the manuscript. LCB participated in the research as a coadvisor, assisting in conducting the research and revising the manuscript. MKS participated in this research as an advisor, assisting in conducting the research and analysing the data, as well as reviewing the manuscripto.

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