RESEARCH PAPER

Relationship between speech production and perception in children with Speech Sound Disorders

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This study investigated the relationship between speech production and perception in children with Speech Sound Disorders (SSD). We hypothesized that there might be a positive correlation and the difference between speech and perceptual data for children with SSD; and that the positive correlation between speech production and speech perception errors might depend on the phonological class involved. Thirty-three children with SSD were evaluated during a speech production task and a phonological contrast identification test. The Percentage of Correct Consonant -Revised (PCC-R) and the Percentage of Correct Identification (PCI) were calculated for each child. The results of the paired t-test showed a higher perception performance mean (PCI = 87.41%) when compared to the production performance mean (PCC-R = 74.97%). The overall results of Pearson's correlation test was also statistically significant, showing a moderate, positive correlation (r = 0.49) between production and perception performances in children with SSD. The results of the correlation analyses between speech production and speech perception errors by class show that only in the fricative class, the correlation was statistically moderately significant (r = 0.52). Stops and sonorants showed no correlation. The results confirmed the relationship between speech production and speech perception, but speech perception does not mirror speech production. The positive correlation between speech production and speech perception errors depends on the phonological class.

Keywords: speech perception; speech production; speech sound disorder

1. Introduction

During the process of phonetic-phonological acquisition, researchers highlight the role performed by children's articulatory and auditory skills, besides the sensory-motor connections that underlie such a process (Munson, Edwards & Beckman, 2005; Howard, 2010; Panneton & Newman, 2011). Therefore, language contrasts are perceived and produced whenever learners master perceptual and articulatory skills.

Every language has specific sets of phonological contrasts that provide informative aspects of the linguistic system. There is a specific standardization of which and how many segments may occur within a syllable. In the case of Brazilian Portuguese (BP), the syllables have the maximal structure $C_1C_2VVC_3C_4$. At least a vowel should occur in a BP syllable. BP has a vocalic inventory composed of seven vowels (/i, e, ɛ, a, ɔ, o, u/). Five these vowels (/i, e, a, o, u/) can be nasalized phonetically or phonologically. When two vowels co-occur, one will be a glide (/y/ or /w/), which may precede or follow the other vowel. In the case of two co-occuring prevocalic consonants, C_2 will necessarily

be a liquid: /r/ or /l/. The C1 position may be filled by 19 consonantal phonemes: six stops (/p,b,t,d,k,g/), six fricatives (/f,v,s,z,ʃ,ʒ/), three nasals (/m,n,ɲ/), two lateral liquids (/l, ʎ/) and two non-lateral liquids (/r, R/).[1]

When one post-vocalic consonant occurs, this position may be filled by four archiphonemes: vibrant /R/, lateral /L/, fricative /S/ and nasal /N/; whereas when C_4 occurs, this consonant will necessarily be /S/. C_3 may be filled by /L/, /R/ or /N/ (Barbosa & Albano, 2004; Silva, 1999).

Although most six year-olds children already master their native phonological system, some of them are seen to differ from their peers regarding the application of phonological rules and the phonetic repertoire, without any organic causes that justify developmental differences, thus suggesting the presence of Speech Sound Disorders (SSDs) (ASHA, 2018).

Children with Speech Sound Disorders exhibit inappropriate and inaccurate speech production in comparison to their peers of the same age (Lewis et al., 2006). In general, the exact etiology of SSD is unknown. The existing literature has claimed that the main difficulties of children with SSD are phonological representation, motor abilities, and speech perception (Grunwell, 1990; Ingram, 1997; Howard, 2010; Rvachew, 2013; Farquharson, 2015). One research line suggests that these children exhibit underlying perceptual deficits when distinguishing similar phonemes, thus presenting particular deficits for those phonemes produced incorrectly (Rvachew & Jamieson, 1989; Munson et al., 2005; Nijland, 2009; Cabbage, Hogan & Carrell, 2016).

However, different studies have shown discrepant results regarding the relationship between speech production and speech perception in children with SSD. On the one hand, some authors assume that children's perception of speech sounds is a critical variable influencing the way sounds are produced. That is, the perceptual ability of children with SSD may have some influence on their speaking abilities (Rvachew & Jamieson, 1989; Munson et al., 2005; Nijland, 2009; Cabbage, Hogan & Carrell, 2016). On the other hand, some authors guarantee that there is too little evidence to support the claim that children with SSD are deficient in their ability to perceive speech sounds (Locke, 1980; Bird & Bishop, 1992; Nagao et al., 2012).

Rvachew and Jamieson (1989), for instance, investigated the relationship between speech perception and speech production errors in children with SSD. The authors found evidence to support the hypothesis that some children with SSD present a concomitant perceptual disorder. In general, children with SSD demonstrated speech perception difficulties that are specific to the misarticulated and/or substituted sound (involving the contrast phonemics /s/ vs /ʃ/ and /s/ vs /θ/), rather than perceptual difficulties that are generalized to other speech sounds. Munson et al. (2005), based on a series of studies, affirmed that children with SSD present both articulatory and perceptual knowledge deficits. Nijland (2009) found significant correlations between production and perception scores in children with SSD, suggesting that a link between perception and production seems to be evident. More recently, Cabbage, Hogan & Carrell (2016) reported a lower perceptual accuracy of words containing the phonemes produced incorrectly by children with SSD.

However, Locke (1980) found that a child may misperceive a substituted contrast and yet may correctly perceive another substituted contrast, arguing there is no direct relationship between speech production and speech perception. In the same direction, Bird

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[1] It is important to highlight that, although /R/ in syllable onset is treated as a liquid in Brazilian Portuguese, this phoneme is phonetically produced as a posterior fricative in the presence of numerous allophones. The /R/ phoneme is variously produced as an unvoiced or voiced fricative that may be velar [x] or [ɣ], uvular [χ] or [ʁ], or glottal [h] or [ɦ]. The sound realization depends on the speaker's dialectal region of Brazilian Portuguese as well as on individual preferences (Silva, 1999; Cagliari, 2009).

and Bishop (1992) claimed that children with SSD showed some ability to discriminate contrasts they could not produce. Similarly, Nagao et al. (2012) examined the relationship between speech perception and speech production in children with SSD. They observed a considerable variation in perceptual performance, so that children with SSD can be classified into different subgroups based on speech production and speech perception measures. A specific group of those children might have poor perceptual abilities to identify phonemic sounds, even though they do not commit articulation errors.

In a recent study (Hearnshaw, Baker & Munro, 2018), the authors presented the differences in perceptual performance in children with and without SSD's in a more sophisticated way: in terms of the relationship between overall of speech perception accuracy and speech production abilities using the same target words, as well as in terms of the relationship between overall perceptual accuracy and the proportion of speech perception of target words produced correctly. Summarizing the results, the authors reported that children with SSD perceived speech less accurately than their peers presenting typical development, despite the large variability in the group of children with SSD. They also found a positive correlation between the overall speech perception and speech production scores. Still, there was no significant relationship between the children's abilities to produce and perceive the targeted four specific phonemes accurately, that is, there was no univocal relationship between speech errors and perception errors.

Given the contradictory results obtained so far, it seems to be necessary to extend the investigation concerning the perceptual performance of children with SSD to comprehend the relationship between speech production and speech perception in this group of children. The present study will extend the literature in two ways. First, we will describe the perceptual and the production performance of a group of children with SSD (n = 33). Secondly, we will consider the 19 consonantal phonemes of BP, which may occur in C1 position, in the analysis of both speech production and speech perception. It is important to highlight that the findings reported above came from studies involving in English-speaking children. In addition to that, the studies investigated a very restricted set of contrasts of English. These studies often assess perceptual ability, using standardized tests with target phonemes that are not related to the child's articulation errors. In general, standardized speech perception tests have been through too few trials to guaranntee a reliable assessment of the child's ability. In this study, differently, we will explore all consonantal phonemic contrasts of BP within the phonemic classes: stops, fricatives, and sonorants (nasals and liquids). To date, we do not have data correlating speech perception and speech production for BP.

This study has the original purpose of investigating the relationship between speech production and speech perception in children with SSD speaking Brazilian Portuguese. Notably, we will compare and correlate the speech and general perceptual performances in children with SSD; and investigate the correlation between speech production and speech performance errors according to the phonemic class.

Assuming that children's perception of speech sounds is a critical variable influencing the way these sounds are produced, the hypotheses are:

H1: positive correlation between speech and perceptual data for children with SSD;

H2: difference between production and perception performance scores by children with SSD;

H3: positive correlation between speech production and speech perception errors could depend on the phonological class.

2. Methods

This research study was approved (n°2.040.322) by the Ethics Committee of the School of Philosophy and Science – São Paulo State University (Faculdade de Filosofia e Ciências – UNESP/Marília – State of São Paulo – Brazil). Both the children and their parents and or legal guardians agreed and signed the Informed Consent Form (ICF). This study was based on guidelines and regulatory standards for research involving human beings as determined by the National Health Council resolutions 466/12 and 510/16, respectively.

2.1. Participants

Thirty-five children diagnosed with SSD (A_{age} = 68 months, sd = ±12,25), assessed by a Speech-Language Pathologist, were recruited at the Speech-Language Therapy Clinic of the UNESP (Marília – Brazil).

The inclusion criteria to select the children was: children with SSD without the presence of comorbidities, such as the presence of language impairment or the presence of anatomical and morphological alterations, which impaired speech production process (e.g., cleft lip and palate); while the exclusion criteria was the presence of otological/hearing disorders. All children were monolingual speakers of Brazilian Portuguese.

A speech-language pathologist carried out speech-language and hearing screenings to identify possible alterations in spoken language, voice, orofacial motricity, and otological/hearing alterations. For the speech-language testing, specific protocols were used, while for the hearing screening, the Interacoustic AD-28 audiometer was used with TDH-39 headphones in an acoustic booth. The frequencies of 1000, 2000, and 4000 Hz were investigated at an intensity of 20 dB HL (decibel hearing level).

Among the 35 children recruited, two children presented alterations in the hearing screening and were referred for specific services at the Speech-Language Therapy Clinic of the UNESP (Marília), and e excluded from this study. **Chart 1** shows the characterization of the participants.

2.2. Procedure

2.2.1. Speech Production Task

Each child performed a picture naming task where the IAFAC instrument (Berti, Lacava & Pagliuso, 2009) was used as an assessment of speech production. The IAFAC consists of 96 words represented by corresponding pictures.[2] This instrument makes the analysis of the phonological and phonetic system possible, since it includes all the 19 consonant phonemes of Brazilian Portuguese in simple syllabic onset (six stops: /p,b,t,d,k,g/, six fricatives: /f,v,s,z,ʃ,ʒ/, three nasals: /m,n,ɲ/, two laterals: /l,ʎ/, two non-laterals: /r,R/). Through a recreational activity, the children were shown the pictures and asked to say the target word aloud. The naming task was recorded with the help of a digital recorder (Marantz, type PMD 670), attached to a cardioid dynamic vocal microphone (SHURE, type 8800).

The recordings were trimmed using PRAAT (Boersma & Weenink, 2019) to isolate each word produced by each child. The trimming process was performed by a trained research assistant using PRAAT in order to create the stimuli for the perceptual experiments. The cuts were made by identifying a portion before and after the onset of the speech waveform.

The production data were transcribed and judged independently by four Speech-Language Pathologists (SLPs). A miminum agreement percentage of 75% among the judgments of each production segment was established for final transcription.

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[2] Speech evaluation instrument for acoustical analysis based on Brazilian Portuguese linguistic criteria.

Chart 1: Characterization of the participants (n = 33).

Child with SSD	Age	Sex	PCC-R	Phonological Process
1	74	M	50.42	Obstruent devoicing, Obstruent fronting, Liquid substitution, Liquid gliding, Liquid deletion, Cluster reduction
2	60	F	66.96	Fricative Fronting, Liquid substitution, liquid gliding, cluster reduction
3	62	F	89.7	Obstruent devoicing, cluster reduction
4	45	F	29.26	Weak syllable deletion, Final fricative deletion, Final liquid deletion, Stopping, Stop fronting, Liquid substitution, Liquid gliding, Liquid deletion, Cluster reduction
5	47	M	50	Obstruent devoicing, Obstruent fronting, Liquid substitution, Liquid gliding, Cluster reduction
6	75	M	86.76	Liquid substitution, cluster reduction
7	58	M	60.2	Obstruent devoicing, Fricative backing, Liquid substitution, Liquid gliding, Cluster reduction
8	76	M	85.2	Obstruent devoicing, Fricative froting
9	49	M	85	Fricative fronting, Liquid substitution, Cluster reduction
10	48	M	96.4	Liquid substitution
11	73	M	75	Fricative backing, Liquid substitution
12	46	M	82.35	Fricative fronting, Liquid substitution, Cluster reduction
13	60	F	94.11	Fricative fronting, Cluster reduction
14	56	M	47	Obstruent devoicing, Stop fronting, Fricative backing, Liquid substitution, Liquid gliding, Cluster reduction
15	58	M	87.05	Obstruent devoicing, Fricative fronting, Cluster reduction
16	74	F	92.3	Liquid substitution, Cluster reduction
17	80	F	69.16	Obstruent devoicing, Obstruent backing, Liquid gliding, Cluster reduction
18	79	F	84.7	Obstruent devoicing, Fricative fronting, Liquid substitution, Cluster reduction
19	75	F	84.4	Fricative fronting, Liquid gliding, Liquid substitution, Cluster reduction
20	48	M	25.42	Weak syllable deletion, Final fricative deletion, Final liquid deletion, Stopping, Obstruent fronting, Obstruent devoicing, Liquid substitution, Liquid gliding, Liquid deletion, Cluster reduction
21	75	M	87.7	Obstruent devoicing, Liquid substitution, Cluster reduction
22	81	M	74	Obstruent devoicing, Liquid substitution, Liquid gliding, Cluster reduction
23	76	M	83.8	Obstruent devoicing, Liquid substitution, Cluster reduction
24	75	M	77.9	Fricative fronting, Liquid gliding, Liquid substitution, Cluster reduction
25	72	M	71.5	Obstruent devoicing, Fricative fronting, Liquid substitution, Cluster reduction
26	80	M	98.82	Liquid substitution
27	79	M	89.2	Obstruent devoicing, Fricative backing
28	81	M	69.54	Obstruent devoicing, Obstruent fronting, Liquid gliding, Liquid deletion, Cluster reduction
29	78	M	80.8	Fricative backing, Liquid substitution, Cluster reduction
30	78	M	86.2	Obstruent devoicing, Liquid gliding, Liquid substitution, Cluster reduction
31	77	M	74	Obstruent devoicing, Fricative fronting, Liquid substitution, Cluster reduction
32	72	F	82.3	Fricative backing, Liquid substitution, Cluster reduction
33	77	F	56.9	Obstruent devoicing, Obstruent fronting, Liquid deletion, Liquid gliding, Cluster reduction

The PCC-R value (Percentage of Consonant Correct Revised, proposed by Shriberg, Austin, Lewis, McSweeny, & Wilson (1997) was then calculated for each child, corresponding to the performance score of their speech production.

2.2.2. Speech perception task

An assessment of auditory perception (focusing on the identification of phonic contrasts in BP) was performed using the PERCEFAL instrument (Berti, 2017a). The PERCEFAL instrument comprises a subset of four experiments that evaluate the identification of contrasts among vocalic phonemes separately, and among stops, fricative and sonorant consonant phonemes. For this study, we used the tests involving consonantal contrasts: stops, fricatives, and sonorants.

The perception experiments were composed of an identification task (also known as a forced-choice minimal-pair identification task) involving the phonemic contrasts in separate consonantal classes.

The stimuli used in the identification task consisted of a typical adult's recording of familiar disyllabic words (minimal pairs) contrasting the consonant phonemes according to their respective classes.[3] For instance, in the stops experiment, six stops were combined in order to form 15 minimal pairs (/'**g**atu/ (cat) x /'**p**atu/ (duck); /'**b**ola/ (ball) x /'**g**ola/ (shirt-collar) and the like). In the same way, for the fricatives experiment, 15 minimal pairs contrasting six fricative phonemes were used (/'**f**aka/ (knife) x /'**v**aka/ (cow); /'**f**aka/ (knife) x /'**ʒ**aka/ (jackfruit), etc). In the sonorants experiment, nasal (/m,n,ɲ/) and liquid phonemes (two laterals /l,ʎ/ and two non-laterals: /r,R/) were combined, creating 21 minimal pairs (/'**l**ata/ (can) x /'**m**ata/ (forest), (/'**R**ata/ (mouse) x /'**n**ata/ (sour cream), and so on).

The perceptual experiments included three stages: word recognition, training, and testing, with an approximate 15-minute overall duration for each experiment. All steps were run by the PERCEVAL software (Perception Evaluation Auditive & Visuelle) (André, Ghio, Cavéc, & Teston, 2009), in which the presentation times of the stimuli were controlled.

The word recognition stage consisted of presenting the visual and auditory input (cues) to the children to verify whether they knew the words and or pictures used in the experiments. After the children were familiar with the experiment input (the cues), we checked whether they knew the words. A threshold of 80% of correct answers would lead the children to the training and testing stages. The training stage was carried out automatically by the software and aimed to enable the participants to understand and become familiar with the task. This step consisted of a perceptual identification task, but the results were not computed. The stimuli were randomized, and 10 presentations were selected. Afterwards, we began the testing stage.

For the testing stage, the children were comfortably placed in front of a computer screen inside an acoustic booth (with the software PERCEVAL installed) and wore KOSS headphones. The acoustic stimuli were presented to each child (with binaural presentation), and they needed to choose between two pictures displayed on the computer screen, according to each stimulus heard.

The results of the perception experiments were analyzed and the Percentage of Correct Identification (PCI) was calculated, corresponding to the percentage of correct answers in the identification test, that is, the percentage of correct answers in the phonic contrasts in the identification task of the BP consonant phonemes.

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[3] The expression "minimal pair" refers to a pair of words, such as *pin* and *bin,* differing by only one sound in the same position in each word, especially when such a pair is taken as evidence for the existence of a phonemic contrast between the two sounds (from dictionary.com available in: < https://www.dictionary.com/>.

2.3. Statistical Analysis

For the analysis, the STATISTICA software (version 7.0) was used. The PCC-R (production performance) and PCI (perceptual performance) scores were compared and correlated through a paired t-test and a Pearson's correlation test, respectively. Correlation is a measure of the relation between two or more variables. Correlation coefficients can range from –1.00 to +1.00. The value of –1.00 represents a perfect negative correlation, while a value of +1.00 represents a perfect positive correlation. A value of 0.00 represents a lack of correlation. The PCC-R and PCI values were considered dependent variables in these tests. P values were deemed to be significant if they were lower than .05. For the multiple correlations, Bonferroni's correction control for Type I error was performed.

3. Results

Table 1 shows the descriptive and inferential statistical results for the speech production performance (measured by PCC-R), as well as the perceptual performance (PCI – measured by the percentage of correct identification).

The mean PCC-R of the children with SSD was 74.97% (SD 18.15), while the mean PCI (percentage of correct identification) was 87.41% (SD 9.51). Pearson's correlation test was statistically significant, showing a moderate positive correlation strength ($r = 0.49$) between the performances (see **Figure 1**).
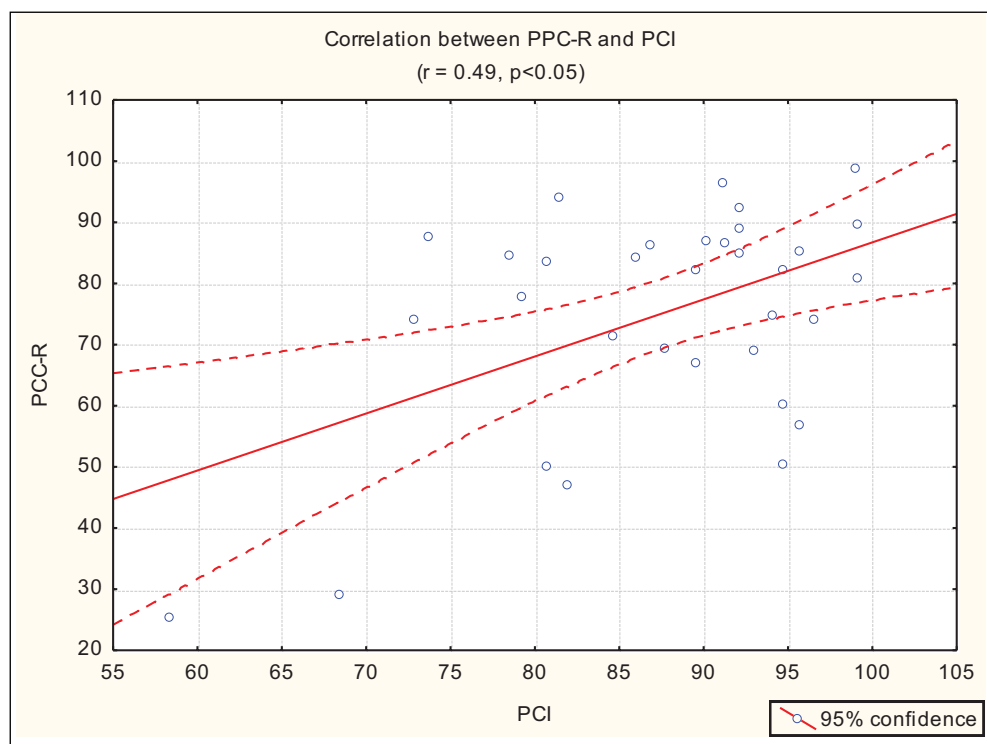

Figure 1: Correlation between speech perception and speech production performances.

Table 1: Statistical analysis for speech production and speech perception performances.

Skills	Mean of the performances (%)	Standard Deviation	Correlation between performances Pearson correl. Test	Comparison between performances t-test
Speech Perception	87.41	9.51	$r = 0.49$	$t(32) = 4.50$
Speech production	74.97	18.15	$p > 0.05$	$p > 0.00$

When comparing the production and perception performances, the paired-sample t-test showed that the mean speech perception performance (M = 87.41%, SD = 9.51) was significantly higher than the mean speech production performance (M = 74.97%, SD 18.15). **Figure 2**, below, illustrates that.
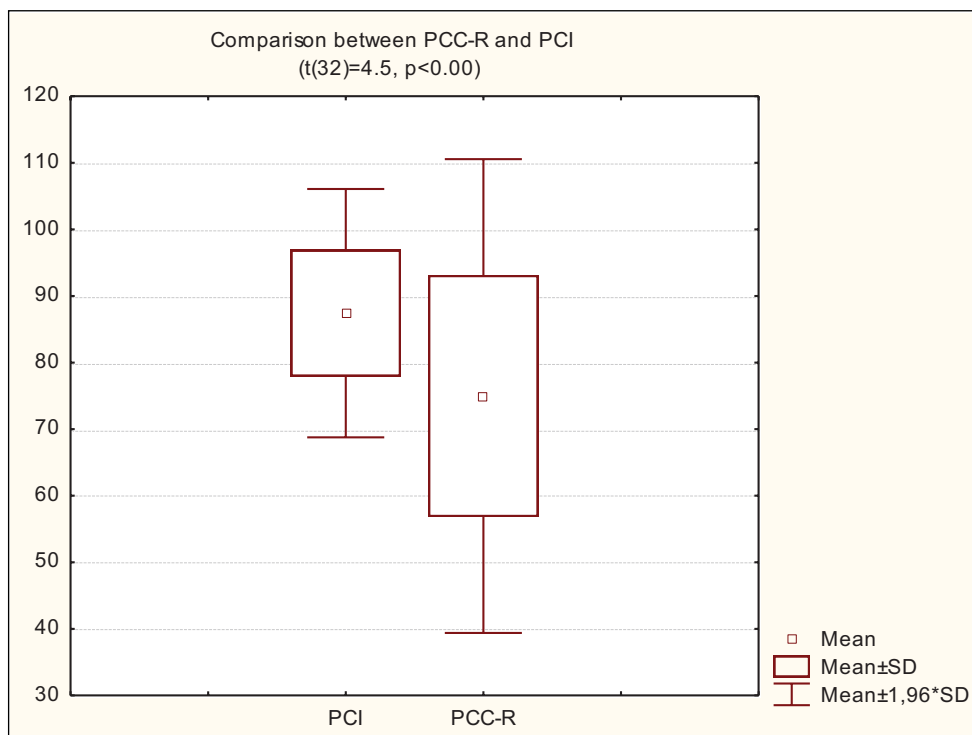

Figure 2: Boxplot of comparison between speech production and speech perception performances.

Table 2 shows the statistical results for the percentage of errors in speech production and speech perception according to phonological classes.

Table 2: Statistical analysis of the errors in speech production and speech perception.

Phonological class	% of errors in speech perception (Mean and SD)	% of errors in speech production (Mean and SD)	Correlation between % of errors Pearson correl. test
Stops	16.96 (±12.10)	16.52 (±20.58)	$r = 0.19$ ($p > 0.01$)
Fricatives	16.15 (±12.11)	30.07 (±25.00)	$r = 0.52$ (**$p < 0.01$**)
Sonorants	14.99 (±11.91)	17.94 (±15.93)	$r = -0.02$ ($p > 0.01$)

Correlation coefficients were computed between the percentage of errors in the speech production and speech perception considering the three phonological classes. Using the Bonferroni control approach for Type I error across the three correlations, a p-value of less than 0.01 (0.05/3 = 0.01) was required for significance. The results of the correlation analyses show that, only in the fricative class, the correlation was statistically significant with moderate strength ($r = 0.52$), such as illustrated in **Figure 3**.

Summarizing the results presented, there is a moderate positive correlation strength ($r = 0.49$) between speech production and speech perception performances. The mean speech perception performance was significantly higher than the mean speech production performance. However, in the correlation analyses of the errors, only the fricative class shows a statistically significant correlation.
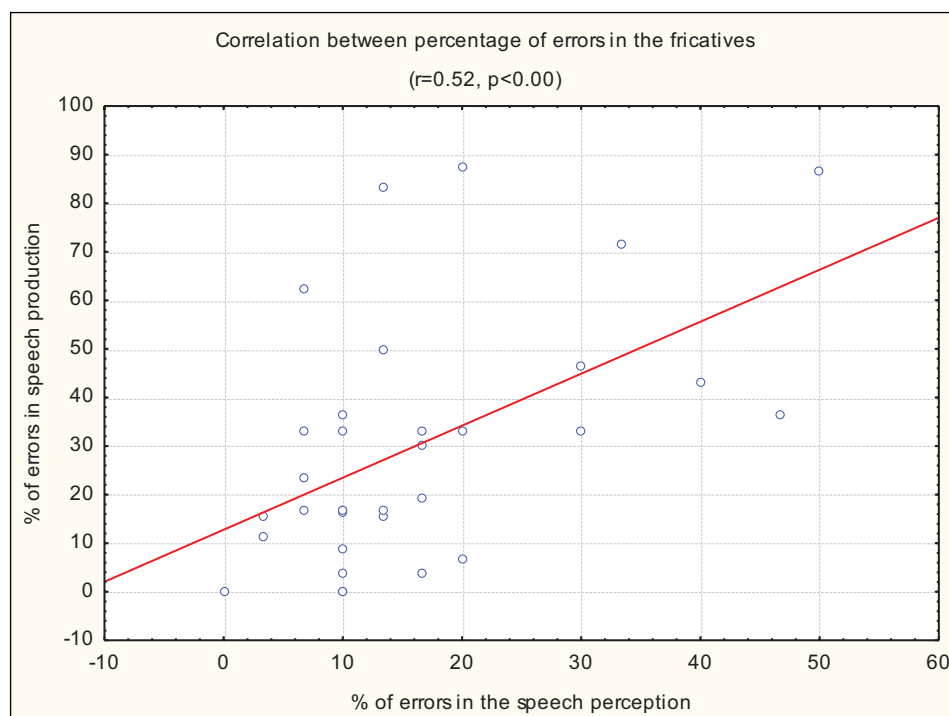
Figure 3: Correlation between speech perception errors and speech production errors in the fricatives class.

4. Discussion

The purpose of the present study was to investigate the relation between speech production and perception in children with SSD. Considering the controversy in the literature supporting the evidence regarding the relationship between speech production and speech perception in children with SSD, three hypotheses were formulated, assuming that children's perception of speech sounds is a critical variable influencing the way these sounds are produced: H1: a positive correlation between the production and perception data for children with SSD; H2: a difference between overall accuracy of speech production and speech perception in the children with SSD; and H3: a positive correlation between speech production and speech perception errors could depend on the phonological class.

The first hypothesis was confirmed, as the Pearson's correlation test showed a moderate positive correlation strength ($r = 0.49$) between speech production and speech perception performances. This result corroborates previous studies that point to a relationship between perception and production (Rvachew & Jamieson, 1989; Munson et al., 2005; Nijland, 2009; Cabbage, Hogan & Carrell, 2016; Hearnshaw et al., 2018).

The presence of a positive correlation between speech production and speech perception is explained by the researchers cited above, considering the underlying representation of the contrasts. That is, if a child has not established the underlying representation for a determined phonological contrast, this will affect both speech production and speech perception, because these skills require access to a symbolic system. Therefore, the presence of a representation deficit, which is the case of children with SSD, causes or contributes to speech production and speech perception deficits.

Additionally, we can consider Hearnshaw et al. (2018)'s argument regarding the explanation for a significant positive correlation between overall speech production and perception accuracy found in their study. According to them, because children with SSD have poorer perceptual accuracy than children with typically developing speech (i.e.,

adequate speech production skills), children with SSD may more probably have poorer perceptual representations.

The second hypothesis, regarding the difference between speech production and speech perception performances by children with SSD, was also confirmed. The results showed a higher perceptual accuracy when compared to their production accuracy.

Three reasons may explain these findings. The first possible one is related to the motor performance of children with SSD. Research on motor speech performance with children with SSD has reported the presence of abnormal movement patterns, interpreted as a suggestion for motor differences (Gibbon, 1999; Gibbon & Wood, 2002; Goozée et al., 2007; Berti, de Boer & Bressmann, 2016). Although we have not investigated the children's motor performance in this study, they may present some degree of motor difficulty, justifying their poorer speech production compared to their perceptual performance.

The second reason is related to development. As might be expected, speech perception precedes speech production. In general, in the language acquisition process, children are firstly capable to discriminate and identify a phonological contrast perceptually and afterwards to produce this contrast. Rvachew & Jamieson (1989), for instance, highlighted the fact that children with speech perception difficulties were found not to have normal production skills, suggesting that perception precedes production.

The third possible reason is related to speech perception phenomena. Speech perception is an auditory-visual event, since it involves the integration of auditory and visual cues into a unitary phonological entity (Dodd, Mcintosh, Erdener, & Burnham, 2008). Consequently, considering that the perceptual dimension encompasses other aspects (such as visual cues and/or semantic information), the children with SSD who participated in this study may have used additional information for aid in the phonic contrast identification task (Burnhan, Tyler & Horlyck, 2002).

We also need to consider, according to **Table 1**, the performance variability in speech production among children with SSD, based on the standard deviation values we found. The standard deviations for speech production were higher than the standard deviation for speech perception. This finding could reflecti the heterogeneity of children with SSD. Some studies (Dodd et al., 2008; Nagao et al., 2012; Hearnshaw et al., 2018) highlight the importance of considering theSSD subtypes in speech production and speech perception tasks as well.

Finally, the third hypothesis, regarding the possibility that a positive correlation between speech production and speech perception errors depends on phonic class, was also confirmed. In the correlation analysis between the speech production and speech perception errors, we found that only in the fricative class, the correlation was statistically significant with moderate strength ($r = 0.52$).

Regarding the presence of a positive correlation between speech production and speech perception errors in children with SSD, Edwards (1974) claimed that the relationship between speech production errors and speech perception ability may not exist for all phonemic contrasts, because the role of auditory perception in the development of articulation skills may vary depending on the particular phoneme being learned.

The fricative class, in BP, consists of six phonemes (/f,v,s,z,ʃ,ʒ/), which could pose more difficulty for children during the acquisition process. A previous study of BP described that fricative class caused the highest incidence of acquisition problems for children with SSD (Patha & Takiuchi, 2008). Berti (2017b) verified that the children's auditory perceptual accuracy was dependent on the phonemic class, with lower perceptual accuracy for the fricative class. This author reinforces the important interaction between acoustic features and anatomical-physiological features of the human ear when explaining these results.

From an acoustic perspective, the fricatives are usually present with aperiodic energy distributed in the frequency spectrum according to the length of the front cavity resulting from production. More specifically, the shorter the front cavity length in the fricatives, the higher will be the resonance frequencies (Kent & Read, 1992). In terms of human ear sensibility, the neural signal is not in a one-to-one relationship with the loudness of frequencies over 5,000 Hz and are less salient than lower frequencies in the presence of background noise (Johnson, 1997).

Associated with these explanatory possibilities, there is the fact that children with SSD, being at scholar age, could present recurrent otitis media. Because recurrent otitis media is associated with fluctuations in hearing sensitivity during the preschool years, thatmight interfere with learning to identify the acoustic cues that are critical for perceiving fricative contrasts. Another potential factor is environmental noise, because high noise levels at home and the school environment impact negatively the perceptual performance of children.

This study has had some limitations. The group of participants was heterogeneous, presenting a large diversity of speech production errors and different phonological disorder severity degrees. In future studies, these aspects need to be considered.

5. Conclusion

The results showed that the mean speech perception performance was significantly higher than the mean speech production performance, there is a positive correlation between speech production and speech perception performances in children with SSD, as well as there is a positive correlation between speech production and speech perception errors which depends on the phonological class. Fricatives show a strong relationship between production and perception.

It is important to highlight the necessity to deepen the investigation about the relationship between speech production and speech perception with other languages since most studies are done in majority English speaking contexts. Therefeore, the findings of such studies may not transfer to non-majority English speaking contexts. The results confirmed the relationship between speech production and speech perception. Speech perception seems to be a critical variable influencing the way children with SSD produce these sounds. However, speech perception does not mirror speech production; that is, there is no univocal relationship between speech production and speech perception.

Competing Interests

The authors have no competing interests to declare.

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