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# Phonological Assessment Instrument (INFONO): A pilot study

## *Instrumento de Avaliação Fonológica (INFONO): estudo piloto*

### Keywords

Speech articulation tests  
Articulation disorders  
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### Descritores

Testes de articulação da fala  
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### ABSTRACT

**Purpose:** To analyze the recognizability and effectiveness of items in the Phonological Assessment Tool (*Instrumento de Avaliação Fonológica* – INFONO) at eliciting target words, as well as to evaluate the internal consistency of the instrument and compare performance between genders, school types and typical vs. atypical phonological development. **Method:** Participants were 48 children ( $n=26$  with typical phonological development and  $n=22$  with atypical development) categorized by age (6 age groups ranging from 3 years and 8 years 11 months), type of school (public vs. private) and gender (male vs. female). Data were collected by the spontaneous naming task of the INFONO. Recognition rates, scores, recognition difficulties and internal consistency were examined in 116 items. Performance in a final set of 84 items was also compared between genders, school types and typical/atypical phonological development. **Results:** Most target words achieved high recognition rates were considered suitable for use in the INFONO. Some images had to be redesigned to facilitate the spontaneous production of target words, while other items were excluded from the instrument altogether. The instrument demonstrated excellent internal consistency. There were no statistically significant differences between genders and school types, though differences were observed between typically and atypically developing children. **Conclusion:** The images in the INFONO were successfully recognized by participants and were effective at eliciting the target words. The final set of items contained the minimum number of target words which would allow for an assessment of all phonemes in Brazilian Portuguese in different word and syllable positions, and these items presented excellent internal consistency.

### RESUMO

**Objetivo:** Analisar a adequação dos itens propostos para o Instrumento de Avaliação Fonológica (INFONO) quanto ao reconhecimento e à produção da palavra-alvo, bem como analisar a consistência interna dos itens selecionados e comparar entre as variáveis sexo, tipo de escola e desenvolvimento fonológico (típico e atípico). **Método:** Participaram 48 crianças ( $n=26$  com desenvolvimento fonológico típico e  $n=22$  com desenvolvimento fonológico atípico) categorizadas por: idade (seis faixas etárias de 3 a 8 anos e 11 meses); tipo de escola (pública e privada), e sexo (feminino e masculino). Utilizou-se o INFONO por nomeação espontânea para a coleta dos dados da fala. Analisou-se o percentual de reconhecimento e produção dos itens ( $n=116$ ), as dificuldades de reconhecimento destes, a consistência interna para o total de itens, e o desempenho das crianças ( $n=84$ ), considerando as variáveis sexo, tipo de escola e desenvolvimento fonológico. **Resultados:** A maioria dos itens apresentou um percentual de reconhecimento alto, sendo estes considerados adequados para compor o INFONO. Algumas imagens precisaram ser reelaboradas para facilitar a produção espontânea do alvo e outras foram excluídas do instrumento. O instrumento demonstrou excelente consistência interna dos itens. Não houve diferença estatisticamente significante entre as variáveis sexo e tipo de escola, mas sim quanto ao desenvolvimento fonológico. **Conclusão:** O INFONO permitiu a correta identificação das imagens e a produção do alvo desejado. Ainda, obteve-se uma quantidade mínima de itens que possibilitam a avaliação de todos os fonemas do Português Brasileiro em diferentes posições na sílaba e na palavra, e esses itens apresentaram excelente consistência interna.

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## INTRODUCTION

The ability to produce speech sounds begins to develop in infancy and shows significant expansion in the pre-school age group. The frequency of phoneme deletions and substitutions decreases with chronological age, showing a rapid decline in the early years (ages two to three) and little to no change in the final years (ages four to six)<sup>(1,2)</sup>.

Phonological development begins with the production of the first sounds and continues until age five<sup>(3)</sup>, at which point the acquisition of speech sounds is usually complete. Sound classes are acquired in the following order: plosives and nasals; fricatives, and liquids<sup>(4)</sup>. As for syllable structures, the acquisition order in Brazilian Portuguese (BP) is as follows: Consonant-Vowel (CV), Consonant-Vowel-Vowel (CVV), Consonant-Vowel-Consonant (CVC) and, lastly, Consonant-Consonant-Vowel (CCV)<sup>(4)</sup>.

Adequate phonological development requires the learning of articulatory movements involved in sound production (phonetic factors) as well as familiarity with the organizational or structural aspects of the language's phoneme inventory (phonological factors)<sup>(5,6)</sup>. This process can be particularly difficult for some children, and result in alterations to one or both of these factors.

Common phonological impairments include the deletion and/or substitution of phonemes, especially consonants, as well as consonant cluster deletion at an age where these alterations should no longer occur<sup>(5)</sup>. This is known as a phonological disorder. Such phenomena have been widely studied in the scientific literature and are highly prevalent in infancy<sup>(5,7-10)</sup>.

Children with phonological disorders may have difficulty pronouncing certain words if the necessary phonemes are absent from their phonological inventory. This is especially problematic for children with more significant alterations, such as those with moderate to severe phonological disorders<sup>(6,10)</sup>, whose speech may be difficult to comprehend. Unintelligible speech, in turn, can interfere with communication and social interaction<sup>(5,6,9,10)</sup>. Phonological disorders may also influence academic performance, since speech is essential for literacy acquisition, and speech errors can be reproduced in writing. Early diagnosis and intervention are crucial to prevent the aggravation of these issues<sup>(5)</sup>.

The international literature presents a number of instruments to evaluate phonological aspects of speech, such as the Clinical Assessment of Articulation and Phonology – CAAP<sup>(11)</sup>, the *Test para Avaliar Processos de Simplificação Fonológica* – TEPROSIF-R<sup>(12)</sup> and the Goldman Fristoe 2 – Test of Articulation – GFTA 2<sup>(1)</sup>. All of these underwent several stages of development as well as psychometric studies to establish their validity and reliability. Normative data was also collected to allow for their use as diagnostic tools for children with suspected phonological disorders.

In Brazil, the most commonly used instruments for this type of evaluation are the Children's Phonological Assessment (*Avaliação Fonológica da Criança* – AFC<sup>(13)</sup>) and the Child Language Test - Phonology (ABFW - *Teste de Linguagem Infantil – Fonologia*)<sup>(14)</sup>. Both have made

important contributions to speech pathology and to the assessment and chronological characterization of phonological development in children from two regions of Brazil (South and Southwest). However, neither of these instruments have had their validity and reliability examined. Psychometric studies are essential to establish the adequacy of an instrument and ensure that it serves the purpose for which it was developed.

The lack of instruments with sound psychometric properties may interfere with therapeutic strategies, intervention planning<sup>(15)</sup> and with assessment-based decision making regarding the continuation or discontinuation of treatment. There is, as such, a clear need for clinical instruments developed and/or adapted using consistent and rigorous methodological techniques, such as psychometric studies, to ensure their validity, reliability and replicability<sup>(16-20)</sup>. These observations led to the development of the Phonological Assessment Instrument (Instrumento de Avaliação Fonológica – INFONO)<sup>(21)</sup>.

### Phonological Assessment Instrument: INFONO<sup>(21)</sup>

The INFONO<sup>(21)</sup> is a software tool which evaluates phonological disorders. The instrument was developed as a software product in order to increase the speed and ease of administration, and increase its appeal to the target population (i.e. children).

Several procedures were involved in the construction of this instrument, namely: (1) literature review and selection of stimulus words; (2) content validity ratings by expert judges; (3) content validity assessment by non-specialist judges (children), and (4) pilot study. The pilot study will be presented in the present article.

Stage 1 - Literature review and stimulus selection: existing tests in BP and an expressive vocabulary list were screened for potential stimulus words for a phonological assessment test. Items were also selected based on their ability to be represented as images which children could easily recognize<sup>(2)</sup>.

Stage 2 - Content validity ratings by expert judges: this stage involved 11 judges (five speech pathologists with doctoral training, three linguists with doctoral training and three clinical speech pathologists). The raters were asked to select stimulus words for the instrument from the list created in Stage 1<sup>(22)</sup>. The words selected by judges based on their theoretical and clinical knowledge were then illustrated, and the resulting images were presented to the non-expert judges (children).

Stage 3 - Content validity assessment by non-expert judges: this stage involved 72 children with typical phonological development who were asked to rate their familiarity with the items selected<sup>(22)</sup>. Children were also asked whether or not they could name each image. Their responses were classified into one of the following categories: unfamiliar (does not know the item); somewhat familiar (knows the item, cannot name it, but knows what it does/what it is used for) and familiar (knows the item, can name it and knows what it is for). After assessing the familiarity of each item, children were asked to name it using the following prompt: "What is this?". Their answer was classified into one of the following categories: produced the correct stimulus word; produced a similar word (synonym); produced an incorrect word; or did not respond.

Once the responses of non-expert judges were scored and categorized, it was possible to determine which items should remain in the instrument. The final set of stimuli was selected based on the responses of non-specialist judges, as well as the need to ensure that each phoneme occurred with a similar frequency in different word and syllable positions. Some items had to be adapted to ensure they were correctly named. After these adjustments, the items were administered to a pilot sample (described in this article).

These procedures contributed to the evaluation of the instrument's content validity. Content validity refers to the comprehensiveness and representativeness with which a set of items capture a target construct<sup>(17)</sup>. The constructs targeted by the INFONO<sup>(21)</sup> and which the instrument is expected to capture in a comprehensive and representative manner pertain to phonology. As such, the instrument had to include at least one item evaluating each phoneme in BP in every possible syllable and word position. The ease of lexical access for the items was also considered.

Therefore, the aim of this study was to analyze the adequacy of the items proposed for the INFONO<sup>(21)</sup> in terms of their recognizability and ability to elicit the production of the target word, as well as examine the internal consistency of the items and compare their performance between genders, school types and phonological development profiles (typical or atypical).

## METHOD

This was a quantitative, descriptive, prospective cross-sectional study. The investigation was approved by the Research Ethics Committee (REC) of a higher education institution under protocol number 23081.005433/2011-65.

All children received written parental consent to participate in the study. Oral assent from the children was also sought before data collection was initiated.

### Participants

The sample was recruited from public and private schools after permission was obtained from their respective principals. Consent was also obtained from the parents of attending students. The sample consisted of 48 children matched according to the following criteria: phonological development (n = 26 typical and n = 22 atypical); age (n = 8 children in each of six age groups ranging from 3 years to 8 years 11 months); type of school (n = 24 from public schools and n = 24 from private schools) and gender (n = 24 girls and n = 24 boys).

### Inclusion and Exclusion Criteria

Inclusion criteria consisted of written parental consent, assent to participate in the study, completion of the assessment required for classification as typically or atypically developing, and meeting the previously mentioned criteria for age, school type and gender.

The following exclusion criteria were then applied: significant impairments in language and/or vocabulary; phonetic alterations (speech impediments such as lisps or tongue thrusts); signs (or complaints) of hearing problems (repeated ear infections,

difficulty hearing), neurological and/or psychological conditions, and previous speech therapy.

### Sample selection

The parents of participating children were first administered a questionnaire with items such as the following: "Has your child ever had any hearing difficulties?"; "Does your child have any difficulty speaking or understanding speech? Explain."; "Has your child ever received speech therapy, or undergone treatment for other conditions (e.g. neurological, psychological)?" Teachers also completed questionnaires about the children's classroom behavior, academic performance and presence of any hearing, vision, speech or comprehension difficulties.

After analyzing the questionnaires, two doctoral students in speech pathology with previous experience in this area of study carried out an informal conversation with each child for approximately 15 minutes, in order to identify any speech and language impairments, especially phoneme deletion or substitution. These alterations were later used to determine whether the children's phonological acquisition process was progressing as expected for their age groups<sup>(4)</sup>. The clinical assessment by the speech pathologists was therefore used to determine whether children should be classified as typically or atypically developing in further analyses.

The sample was also classified in terms of age, type of school and gender. At this stage, children were also screened for language and/or vocabulary impairments as well as phonetic alterations such as speech distortions (e.g. interdental speech impediments).

Sample characteristics are shown in Table 1.

**Table 1.** Characteristics of participants with regards to phonological development status, gender, school type and gender

Age	3.0 - 3.11 (n=8)	4.0 - 4.11 (n=8)	5.0 - 5.11 (n=8)	6.0 - 6.11 (n=8)	7.0 - 7.11 (n=8)	8.0 - 8.11 (n=8)
TPD	Public (M/F)	1/1	1/1	1/1	1/1	1/1
	Private (M/F)	1/1	1/1	1/1	1/1	1/2
APD	Public (M/F)	1/1	1/1	1/1	1/1	1/1
		1/1	1/1	1/1	1/1	1/0

**Captions:** TPD = Typical Phonological Development; APD = Atypical Phonological Development; M = Male; F = Female

No female private school students aged 7 to 8 were classified as having atypical phonological development. The two participants with these characteristics were both typically developing. The inclusion of children from both public and private schools ensured that the sample was representative of different socioeconomic backgrounds. However, this variable was not investigated separately in the present study.

## Material

Data were collected using a beta version of the INFONO<sup>(21)</sup> software, developed to evaluate children aged 3 years or older. Beta software consists of a development version of a program which is suitable for use, but may still have some issues which must be repaired before the final version is released. Beta testing allows for the anticipation of future software issues.

The Beta version of the INFONO<sup>(21)</sup> consisted of a spontaneous naming task with 116 items. The items provided at least three opportunities for children to produce every phoneme in BP in different word/syllable positions. The words varied with regards to the position of the target phoneme, the number of syllables and stress patterns in order to balance item difficulty.

Each item in the INFONO<sup>(21)</sup> contains a prompt to be used by the examiner to elicit the target word, such as, “The boy will give a...?” (kiss); “He will use the pencil to...?” (write), “What animal is this?” (horse), etc. The prompt and the images guide the child toward the target words. The examiner can also use other questions to elicit the stimulus words if necessary.

In the Beta version of the software, examiners rated responses according to the following scoring systems: produced the word correctly; produced the word with alterations; produced a related word; and did not produce the stimulus word. “Produced the word correctly” was selected when the child was able to pronounce the stimulus word with no deletions or substitutions. “Produced the word with alterations” indicated that the child produced the correct word but showed phoneme deletion or substitution errors. The option “produced a related word” was selected when the child provided an incorrect word that was nevertheless related to the target. Whenever this occurred, examiners were asked to write down the word produced by the child. Lastly, “did not produce the word” was selected when the child was unable to produce the stimulus word or provided unrelated responses.

During the assessment, the examiner entered the child’s responses into the software in real time. The software provided options for the phonetic transcription of the target-word, including transcriptions of the correct pronunciation as well as possible alterations, allowing the examiner to quickly record the answers, thereby speeding up the testing procedure. The phonetic transcription alternatives were provided based on existing descriptions of possible pronunciations of each target word (both correct and incorrect).

The Beta version of the INFONO<sup>(21)</sup> also allowed the examiner to enter additional, unlisted transcriptions using a virtual keyboard containing all phonemes in the international phonetic alphabet (Doulos SIL).

## Procedures

Data were collected by two doctoral students in speech pathology with experience in the area of study, who had been previously trained in the use of the INFONO<sup>(21)</sup> software. Data were collected through spontaneous naming, in order to verify the extent to which participants could recognize and elicit the target words in the INFONO<sup>(21)</sup>. Children were shown a picture of each item on the computer screen and asked to name it, at which point the examiner would score their

response (produced the word correctly, produced word with alterations, produced a similar word, did not produce the word).

During the assessment, the examiner would use the prompts given in the software, such as, “The boy will give a...?” (kiss). In some cases, children produced the target word before the examiner could read out the prompt. When the prompt failed to elicit the target word from a participant, the examiner would use a different question, which they would write in the “Observations” field of the software.

The results of each assessment were stored in HTML format and entered into an Excel spreadsheet containing the responses of all participants to the 116 items in the software. This data was used to calculate the internal consistency of the INFONO<sup>(21)</sup> (Beta version) using Cronbach’s alpha, as well as the percent recognition for each item based on the frequency of responses categorized as “produced the word correctly” or “produced the word with alterations”. This method was chosen because when a stimulus led to the production of the correct target word - with or without alterations - it could be assumed that the child had recognized the image, and it is easier for children to recognize a picture than to pronounce its name correctly<sup>(22)</sup>.

The items were then divided into lists according to the target phoneme and syllable position, in descending order of recognition accuracy. This data was used to analyze difficulties in the recognition and production of target words considering the degree of syllable complexity, which was categorized as follows: (1) Words with complex onsets (COs); (2) Words with target phonemes in coda position; (3) Words with simple onsets, beginning with phonemes with restricted positional distribution such as /p/, /z/, /f/, /g/.

Percent recognition was classified based on the following cutoffs: 80% or more: item retained in the instrument; 60 to 79%: changes made to the image or prompt to ensure the target word was produced; 60% or less: item removed from the instrument. Preference was given to items with higher recognition rates. When fewer than three target words contained a phoneme in a particular position, items in the 60-79% range were included, with adjustments to ensure they would be more easily recognized and lead to the production of the target word.

Additionally, if the instrument contained more than three words which assessed a phoneme in a given word position (even if all items had a recognition rate above 80%), some were eliminated in order to reduce the number of items in the INFONO<sup>(21)</sup> and ensure the frequency of presentation was balanced across phonemes, and no target sounds were over- or under-represented in the test. Before an item was excluded, care was taken to ensure that all phonemes - especially those with a lower frequency in the instrument - were still represented by at least three remaining items. This allowed for a reduction in the number of items in the INFONO<sup>(21)</sup>. The internal consistency of the final item set was evaluated at the end of the study.

## Data Analysis

The responses of children in the pilot sample were analyzed using descriptive statistics. The adequacy of items in the INFONO<sup>(21)</sup> was analyzed based on recognition rates and production accuracy for the target words. This allowed for

the assessment of recognition issues, target-word familiarity, adequacy of item prompts and internal consistency of the beta and final versions of the INFONO(21).

Recognition rates were calculated based on the frequency of responses classified as “produced the word correctly” and “produced the word with alterations” for each item. Internal consistency was assessed using Cronbach’s alpha. Each item retained in the final version of the INFONO(21) was then re-scored in the following manner: 0, did not produce the word; 1, produced a related word; 2, recognized and named the target with alterations, and 3, recognized and named the target correctly. Mean values were then calculated for each item so as to compare results between genders, types of school and phonological development status. This was done using Mann-Whitney U tests. Results were considered significant at  $p > 0.05$ . Data were analyzed using SPSS, version 22 for Windows.

## RESULTS

Overall, the items displayed high recognition rates. Ninety-three (80.2%) items had values over 80%, and 69 of these (74.2%) had a score over 90%. Sixteen items scored between 60 and 79%, while only seven scored lower than 60%. The results are presented as tables, in decreasing order of syllable complexity (COs, Coda, Onset). The items were also divided according to the target phoneme and its syllable/word position.

For COs (Table 2), the largest possible number of items with satisfactory recognition scores was retained. Only items with very low recognition scores (below 60%) were excluded from the instrument, such as those corresponding to the phonemes /bl/ (blouse, “blusa” [‘bluza]; sweater, “blusão” [‘bluzão]), /kl/ (clear, “clara” [‘klara]; class, “classe” [‘klase]) and /gl/ (glaze, “glacê” [gla’sê]). No target words with these onset clusters could be included in the final version of the instrument. The reason for this was an absence of target words which could be illustrated through images and were in the vocabulary of young children. For other consonant clusters, only a single word was included. This was the case of /vr/ (book, “livro” [‘livro]), which was only assessed as a CO, since this consonant cluster cannot occur in word-onset position in BP.

**Table 2.** Recognition rates of items which evaluate Complex Onsets

Onset Clusters	Correct IO	% recognition % (n)	Correct MO	% recognition % (n)
/pr/	prato [‘prato] (plate)	100 (48)	soprar [so‘prar] (blow)	91.67 (44)
	presente [pre‘zente] (present)	97.92 (47)		
/pl/	plástico [‘plastiko] (plastic)	72.92 (35)	-	-
	placa [‘plaka] (sign) *	64.58 (31)	-	-

Onset Clusters	Correct IO	% recognition % (n)	Correct MO	% recognition % (n)
/br/	brinco [‘brinko] (earring)	97.92 (47)	cobra [‘kɔbra] (snake)	91.67 (44)
	bruxa [‘bruja] (witch)	95.83 (46)	zebra [‘zebra] (zebra)	87.50 (42)
	branco [‘brãko] (white)	91.67 (44)		
/bl/	blusão [‘blu‘zãw] (sweater)	35.42 (17)	biblioteca [biblio‘tɛka] (library)*	68.75 (33)
	blusa [‘bluza] (blouse)	25.00 (12)	bíblia [‘biblia] (bible)	31.25 (15)
/tr/	trem [‘trem] (train)	100 (48)	estrela [es‘trela] (star)	95.83 (46)
	travesseiro [trave‘sejro] (pillow)	87.50 (42)	letra [‘letra] (letter)	85.42 (41)
/dr/	dragão [dra‘gãw] (dragon)	85.42 (41)	pedra [‘pɛdra] (rock)	93.75 (45)
			vidro [‘vidro] (glass)	79.17 (38)
/kr/	cruz [‘kruz] (cross)	64.58 (31)	escrever [eskre‘ver] (write)	83.33 (40)
	crocodilo [kroko‘dilo] (crocodile)	64.58 (31)	microfone [mikro‘fone] (microphone)	81.25 (39)
/kl/	clara [‘klara] (clear)	37.50 (18)	bicicleta [bisi‘kleta] (bicycle)	93.75 (45)
	classe [‘klase] (class)	25.00 (12)	chiclete [i‘klɛte] (bubble gum)	62.50 (30)
/gr/	grama [‘grama] (grass)	87.50 (42)	magro [‘magro] (thin)	87.50 (42)
	gritar [gri‘tar] (scream)*	66.67 (32)	igreja [i‘greʒa] (church)*	72.92 (35)
/gl/	glacê [gla’sê] (glaze)	4.17 (2)	-	-
/fr/	fralda [‘frawda] (diaper)	89.58 (42)	refri [ʒe‘fri] (soda)*	77.08 (37)
	fruta [‘fruta] (fruit)	85.42 (41)	chifre [‘ʃifre] (horn)	64.58 (31)
/fl/	flor [‘flor] (flower)	97.92 (47)	-	-
	floresta [flo‘rɛsta] (forest)	66.67 (32)	-	-
/vr/	-	-	livro [‘livro] (book)	97.92 (47)

**Captions:** IO = Initial onset; MO = Medial onset; Bold = Words retained in the final version of the INFONO

\* alterations made to item; - no target words available for children in the age group studied

As for the coda position (Table 3), most items retained in the instrument had a recognition rate of at least 80%, suggesting the images were effective at eliciting the target words. However, the images corresponding to items with recognition rates between 60 and 79%, such as plastic (“plástico” [‘plastiko]), cross (“cruz” [‘krus]), forest (“floresta” [flo‘rɛsta]) and scream (“gritar” [gri‘tar]), were redrawn to facilitate the production of the target word. All of these items remained in the instrument due to the need to evaluate these phonemes in COs.

**Table 3. Recognition rate of items which evaluate phonemes in Coda position**

Words	% recognition	Words	% recognition
MC	% (n)	FC	% (n)
<b>Nasals</b>			
língua [ˈlingwa] (tongue)	97.92 (47)	trem [ˈtrem] (train)	100 (48)
presente [preˈzente] (present)	97.92 (47)	batom [baˈtõn] (lipstick)	97.92 (47)
brinco [ˈbrinko] (earring)	97.92 (47)	nuvem [ˈnuven] (cloud)	87.50 (42)
/n/ dente [ˈdente] (tooth)	91.67 (44)		
ventilador [ventiˈlador] (fan)	91.67 (44)		
branco [ˈbranko] (white)	91.67 (44)		
laranja [laˈranʒa] (orange)	83.33 (40)		
<b>Fricatives</b>			
escada [esˈkada] (stairs)	100 (48)	óculos [ˈokulos] (glasses)	100 (48)
espelho [esˈpe.ɫo] (mirror)	97.92 (47)	lápiz [ˈlapis] (pencil)	95.83 (46)
estrela [esˈtrela] (star)	95.83 (46)	tênis [ˈtenis] (sneakers)	95.83 (46)
/S/ pastel [pasˈtɛw] (pastry)	89.58 (43)	nariz [naˈris] (nose)	87.50 (42)
escrever [eskreˈver] (write)	83.33 (40)	cruz [ˈkruz] (cross)	64.58 (31)
plástico [ˈplastiko] (plastic)*	72.92 (35)		
floresta [floˈrɛsta] (forest)	66.67 (32)		
<b>Liquids</b>			
porta [ˈpɔrta] (door)	100 (48)	flor [ˈflor] (flower)	97.92 (47)
porco [ˈporko] (pig)	97.92 (47)	colher [ko.ʎer] (spoon)**	97.92 (47)
garfo [ˈgarfo] (fork)	95.83 (46)	ventilador [ventiˈlador] (fan)	91.67 (44)
/r/ jornal [ʒorˈnaw] (newspaper)	83.33 (40)	soprar [soˈprar] (blow)	91.67 (44)
		escrever [eskreˈver] (write)	83.33 (40)
		gritar [griˈtar] (scream)*	66.67 (32)
		zíper [ˈziper] (zipper)	33.33 (16)
/L/** calça [ˈkawsa] (pants)	100 (48)	anel [aˈnɛw] (ring)	89.58 (43)
bolsa [bowˈsa] (purse)	97.92 (47)	pastel [pasˈtɛw] (pastry)	89.58 (43)
fralda [ˈfrawda] (diaper)	89.58 (43)	jornal [ʒorˈnaw] (newspaper)	83.33 (40)

**Captions:** MC = Medial Coda; FC = Final Coda; bold = words retained in the final version of the INFONO

\*adjustments made to item; \*\* phoneme nasalized in this position; \*\*\* phoneme pronounced as a semivowel in this position

As for the onset structure (Table 4), the images corresponding to most target words had a recognition rate of at least 80%, suggesting the items were able to ensure the production of the target word. The items with lower recognition rates were those which evaluated the production of phonemes in COs or Coda position. Images corresponding to the target words library (“biblioteca” [biblioˈtɛka]), kiss (“beijo” [ˈbeizɔ]), cross (“cruz” [ˈkruz]), horn (“chifre” [ˈʃifre]), earth (“terra” [ˈtɛʁa]), plastic (“plástico” [ˈplastiko]), scream (“gritar” [griˈtar]), forest (“floresta”

[floˈrɛsta]), bubble gum (“chiclete” [ʃiˈklɛte]), sign (“placa” [ˈplaka]), glass (“vidro” [ˈvidro]), zero (“zero” [ˈzɛro]), soda (“refri” [ˈʁɛfri]), church (“igreja” [iˈgreʒa]) and ship (“navio” [naˈviw]) were redrawn and retained in the instrument. All of these words were retained in order to evaluate COs, with the exception of zero (“zero” [ˈzɛro]), kiss (“beijo” [ˈbeizɔ]), earth (“terra” [ˈtɛʁa]), and ship (“navio” [naˈviw]).

**Table 4. Percent recognition of items which evaluate phonemes in onset position**

Correct IO	% recognition % (n)	Correct MO	% recognition % (n)
<b>Nasals</b>			
mesa [ˈmeza] (“table”)	100 (48)	cama [ˈkâma] (bed)	100 (48)
macaco [maˈkako] (monkey)	97.92 (47)	grama [ˈgrâma] (grass)	87.50 (42)
mão [ˈmâw] (hand)	97.92 (47)	caminhão [kamiˈnâw] (truck)	87.50 (42)
/m/ magro [ˈmagro] (thin)	87.50 (42)	tomate [toˈmate] (“tomato”)	81.25 (39)
microfone [mikroˈfone] (microphone)	81.25 (39)		
nuvem [ˈnuven] (cloud)	87.50 (42)	chinelo [ʃiˈnɛlo] (slipper)	100 (48)
nariz [naˈris] (nose)	87.50 (42)	banana [baˈnâna] (banana)	100 (48)
navio [naˈviw] (ship)	66.67 (32)	panela [paˈnɛla] (pot)	95.83 (46)
/n/		tênis [ˈtenis] (sneakers)	95.83 (46)
		anel [aˈnɛw] (ring)	89.58 (43)
		jornal [ʒorˈnaw] (newspaper)	83.33 (40)
		microfone [mikroˈfone] (microphone)	81.25 (39)
-	-	galinha [gaˈlɪna] (hen)	91.67 (44)
/ɲ/		passarinho [pasaˈriɲo] (bird)	91.67 (44)
		caminhão [kamiˈnâw] (truck)	87.50 (42)
<b>Plosives</b>			
/p/ pé [ˈpɛ] (foot)	100 (48)	sapo [ˈsapo] (frog)	100 (48)
porta [ˈpɔrta] (door)	100 (48)	sapato [saˈpato] (shoe)	97.92 (47)
/p/ porco [ˈporko] (pig)	97.92 (47)	copo [ˈkɔpo] (cup)	97.92 (47)
panela [paˈnɛla] (pot)	95.83 (46)	espelho [esˈpe.ɫo] (mirror)	97.92 (47)
pedra [ˈpɛdra] (rock)	93.75 (45)	lápiz [ˈlapis] (pencil)	95.83 (46)
passarinho [pasaˈriɲo] (bird)	91.67 (44)	tapete [taˈpete] (rug)	95.83 (46)
/p/ pastel [pasˈtɛw] (pastry)	89.58 (43)	chapéu [ʃaˈpɛw] (hat)	95.83 (46)
		zíper [ˈziper] (zipper)	33.33 (16)
bola [ˈbɔla] (ball)	100 (48)	cabelo [kaˈbelo] (hair)	95.83 (46)
banana [baˈnâna] (banana)	100 (48)	rabo [ˈʁabo] (tail)	89.58 (43)
/b/ bolsa [bowˈsa] (purse)	97.92 (47)	bebê [beˈbe] (baby)	87.50 (42)
batom [baˈtõn] (lipstick)	97.92 (47)		
bicicleta [bisiˈkleta] (bicycle)	93.75 (45)		
barriga [baˈʁiga] (belly)	91.67 (44)		
/b/ bebê [beˈbe] (baby)	87.50 (42)		
biblioteca [biblioˈtɛka] (library)*	68.75 (33)		
beijo [ˈbeizɔ] (kiss)	64.58 (31)		
bíblia [ˈbiblia] (bible)	15 (31.25)		



**Table 4.** Continuation...

Correct	% recognition	Correct	% recognition
IO	% (n)	MO	% (n)
relógio [ʁe'lo:ʒio] (clock)	97.92 (47)	cachorro [ka'ʃo:ʁo] (dog)	97.92 (47)
/ʃ/ rabo [ˈʁabo] (tail)	89.58 (43)	barriga [ba'ʁiga] (belly)	91.67 (44)
roda [ˈʁoda] (wheel)	87.50 (42)	terra [ˈtɛʁa] (earth)	68.75 (33)
refri [ʁe'fri] (soda)*	77.08 (37)		
		cadeira [ka'dejra] (chair)	100 (48)
		coração [kora'sāw] (heart)	97.92 (47)
		vassoura [va'sowra] (broom)	97.92 (47)
		jacaré [ʒakarɛˈ] (alligator)	95.83 (46)
		tesoura [te'zowra] (scissors)	95.83 (46)
		girafa [ʒi'rafa] (giraffe)	93.75 (45)
/t/ -	-	passarinho [pasa'riɲo] (bird)	91.67 (44)
		nariz [na'ris] (nose)	87.50 (42)
		travesseiro [trave'sejro] (pillow)	87.50 (42)
		laranja [la'ranʒa] (orange)	83.33 (40)
		zero [ˈzɛro] (zero)*	70.83 (34)
		floresta [flo'rɛsta] (forest)	66.67 (32)
		clara [ˈklara] (clear)	37.50 (18)
livro [ˈlivro] (book)	97.92 (47)	cavalo [ka'valo] (horse)	100 (48)
língua [ˈlingwa] (tongue)	97.92 (47)	bola [ˈbɔla] (ball)	100 (48)
lápiz [ˈlapis] (pencil)	95.83 (46)	óculos [ˈɔkulos] (glasses)	100 (48)
luva [ˈluva] (glove)	91.67 (44)	chinelos [ʃi'nɛlo] (slipper)	100 (48)
letra [ˈletra] (letter)	85.42 (41)	relógio [ʁe'lo:ʒio] (clock)	97.92 (47)
/l/ -	-	laranja [la'ranʒa] (orange)	83.33 (40)
		cabelo [ka'belo] (hair)	95.83 (46)
		estrela [es'trela] (star)	95.83 (46)
		panela [pa'nɛla] (pot)	95.83 (46)
		galinha [ga'liɲa] (hen)	91.67 (44)
		ventilador [venti'lador] (fan)	91.67 (44)
		crocodilo [kroko'dilo] (crocodile)	64.57 (31)
		espelho [es'peʎo] (mirror)	97.92 (47)
		colher [ko'ʎer] (spoon)	97.92 (47)
/ʁ/ -	-	coelho [ko'eʎo] (rabbit)	97.92 (47)
		folha [fo'ʎa] (leaf)	95.83 (46)
		joelho [ʒo'eʎo] (knee)	79.17 (38)

**Captions:** IO = Initial onset; MO = Medial onset; bold = word retained in the final version of the INFONO

\*Adjustments made to item; - does not occur in Brazilian Portuguese

In addition to the image, the question prompt for the target word ship (“navio” [na'viw]) (66.67%) had to be changed. Several children initially described the image as a boat (“barco” [ˈbarko]). It was important to retain this item to ensure children had three opportunities to produce the /n/ phoneme in IO. The image was changed to that of a pirate ship, and the prompt was changed from “What is this?” to “This is a pirate...?” (“É de pirata, é um ...?”).

The illustrations were also altered based on the observations made by examiners during the administration of the INFONO<sup>(21)</sup>.

The picture representing the target ‘bubble gum’ (“chiclete” [ʃi'klɛtɛ]), for instance, often elicited the word ‘balloon’ (“balão” [ba'lāw]). To ensure children would produce the correct word, the image was changed to a GIF (an animation composed of several images compressed into a single file, giving the appearance of movement). The resulting animation showed a boy chewing gum, blowing a bubble, then popping it so that the gum was shown sticking to his face. A similar procedure was carried out for the target words kiss (“beijo” [ˈbeizɔ]) and scream (“gritar” [gri'tar]), whose production was greatly facilitated by the use of animation.

The image of the target word earth (“terra” [ˈtɛʁa]) was described by several children as ‘wet sand’. It was therefore changed to an animation of a boy planting a tree sapling. The prompt was changed from “What is this?” to “The boy is planting in the...?”

The target ‘glass’ (“vidro” [ˈvidro]) was often described as a ‘window’ (“janela” [ʒa'nɛla]), with children failing to produce the correct target word. The image was therefore changed to that of a stone breaking a window, and the prompt changed from “The window has...?” to “The stone broke the...?”

For the target ‘plastic’ (“plástico” [ˈplastiko]), only the prompt was changed, to “This cup is not made of glass, it is made of...?” The image corresponding to the target ‘zero’ was also redesigned. The original picture contained the sequence “0 1”, which was increased to “0 1 2 3”. The number zero was also animated to increase in size, since many children would name the numeral [ˈdes] or the open vowel [ɔ]. All items in the INFONO<sup>(21)</sup> were therefore changed to animated gifs, either to increase clarity, or make the instrument more appealing.

Some items could also be excluded while still providing children with at least three opportunities to produce the phonemes in different word positions. Words such as stairs (“escada” [es'kada]), glove (“luva” [ˈluva]), tomato (“tomate” [to'mate]), glasses (“óculos” [ˈɔkulos]), and banana (“banana” [ba'nāna]) were therefore removed to reduce the number of items in the instrument.

After these modifications, the INFONO<sup>(21)</sup> was left with 84 target words represented as animated images, resulting in a test that was easy and quick to administer. The mean duration of administration was approximately 15 minutes. The Cronbach’s alpha revealed excellent internal consistency for both the initial version with 116 items (beta version) ( $\alpha = 0.98$ ) as well as the final version of the INFONO<sup>(21)</sup> with 84 targets ( $\alpha = 0.97$ ), demonstrating adequate item reliability. The number of items in the instrument containing each phoneme in different positions, as well as the number of syllables and stress patterns of target words, are shown in Table 5.

Mean performance on the task was also compared between genders, school types, and phonological development status (typical vs. atypical). These results are shown in Table 6. The findings did not reveal any significant differences between genders or school types, demonstrating that these variables did not influence the production of words in the INFONO<sup>(21)</sup>. However, in 60 items (76.19%), children with atypical phonological development obtained lower scores than their typically developing peers.

**Table 5.** Number of items in the final version of the INFONO, divided according to target phoneme, number of syllables in target word, and word stress patterns

Number of items x Position																			
	/m/	/n/	/ɲ/	/p/	/b/	/t/	/d/	/k/	/g/	/f/	/v/	/s/	/z/	/ʃ/	/ʒ/	/l/	/ʎ/	/r/	
IO	3	3	-	4	7	3	3	11	3	3	3	4	2	4	3	4	-	3	-
MO	3	5	3	5	3	16	4	7	4	4	5	5	4	3	3	7	4	3	8
MC	-	5	-	-	-	-	-	-	-	-	-	6	-	-	-	3	-	-	3
FC	-	3	-	-	-	-	-	-	-	-	-	4	-	-	-	3	-	-	6

  

Number of items x Number of syllables																			
	/m/	/n/	/ɲ/	/p/	/b/	/t/	/d/	/k/	/g/	/f/	/v/	/s/	/z/	/ʃ/	/ʒ/	/l/	/ʎ/	/r/	
Monosyllables	1	1	-	1	0	0	0	0	0	0	0	1	0	0	0	0	-	0	1
Disyllables	4	11	0	5	6	10	4	10	5	5	4	9	4	4	2	10	2	3	8
Trisyllables	1	2	2	2	2	6	0	7	2	1	2	6	2	3	4	6	2	3	5
Polysyllables	1	2	3	1	2	3	1	1	0	1	2	3	0	0	0	1	0	0	3

  

Number of items x Stress patterns																			
	/m/	/n/	/ɲ/	/p/	/b/	/t/	/d/	/k/	/g/	/f/	/v/	/s/	/z/	/ʃ/	/ʒ/	/l/	/ʎ/	/r/	
Stressed	2	9	1	5	4	7	4	5	3	5	5	3	4	2	0	12	1	2	13
Unstressed	4	5	2	4	5	12	1	13	4	2	3	16	2	5	6	5	3	4	4

Captions: IO = Initial onset; MO = Medial onset; MC = Medial coda; FC = Final coda

**Table 6.** Comparison of INFONO scores between genders, school types and typical/atypical phonological development

Correct	Gender*					School*					Phonological Development				
	Female (n = 14)		Female (n = 12)		p	Public (n = 12)		Private (n = 14)		p	Typical (n = 26)		Atypical (n = 22)		p
	M	DP	M	DP		M	DP	M	DP		M	DP	M	DP	
horse ("cavalo")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.68	0.57	<b>0.005</b>
scream ("gritar")	2.57	0.94	2.00	1.35	0.347	1.83	1.47	2.71	0.61	0.231	2.31	1.16	1.18	1.14	≤ 0.001
frog ("sapo")	2.93	0.27	3.00	0.00	0.781	3.00	0.00	2.93	0.27	0.781	2.96	0.20	3.00	0.00	0.358
witch ("bruxa")	2.93	0.27	2.83	0.39	0.705	2.92	0.29	2.86	0.36	0.820	2.88	0.33	2.05	0.49	≤ 0.001
alligator ("jacaré")	2.93	0.27	3.00	0.00	0.781	3.00	0.00	2.93	0.27	0.781	2.96	0.20	2.18	0.73	≤ 0.001
bubble gum ("chiclete")	2.43	1.02	2.00	1.28	0.494	2.33	1.23	2.14	1.10	0.631	2.23	1.14	1.59	1.14	<b>0.035</b>
bed ("cama")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.86	0.35	0.054
book ("livro")	2.79	0.58	2.83	0.39	0.980	2.92	0.29	2.71	0.61	0.560	2.81	0.49	2.23	0.43	≤ 0.001
cloud ("nuvem")	2.79	0.58	2.83	0.58	0.820	2.83	0.58	2.79	0.58	0.820	2.81	0.57	2.32	1.09	<b>0.043</b>
plate ("prato")	2.93	0.27	2.83	0.39	0.705	2.92	0.29	2.86	0.36	0.820	2.88	0.33	2.27	0.46	≤ 0.001
clock ("relógio")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.41	0.73	≤ 0.001
hair ("cabelo")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.45	0.91	≤ 0.001
letter ("letra")	2.64	0.93	2.75	0.45	0.781	2.58	0.90	2.79	0.58	0.667	2.69	0.74	1.82	0.91	≤ 0.001
cross ("cruz")	2.14	1.41	2.33	1.23	0.820	1.75	1.54	2.64	0.93	0.193	2.23	1.31	1.32	1.29	<b>0.005</b>
kiss ("beijo")	3.00	0.00	2.75	0.87	0.742	3.00	0.00	2.79	0.80	0.781	2.88	0.59	2.41	1.10	<b>0.027</b>
giraffe ("girafa")	2.93	0.27	2.92	0.29	0.980	2.92	0.29	2.93	0.27	0.980	2.92	0.27	2.05	0.72	≤ 0.001
tongue ("língua")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.45	0.74	≤ 0.001
leaf ("folha")	2.93	0.27	2.83	0.58	0.940	3.00	0.00	2.79	0.58	0.560	2.88	0.43	2.50	0.60	<b>0.004</b>
flower ("flor")	2.79	0.58	2.83	0.39	0.980	2.75	0.62	2.86	0.36	0.899	2.81	0.49	2.27	0.46	≤ 0.001
rabbitt ("coelho")	2.93	0.27	3.00	0.00	0.781	3.00	0.00	2.93	0.27	0.781	2.96	0.20	2.50	0.74	<b>0.002</b>
write ("escrever")	2.93	0.27	2.83	0.58	0.940	3.00	0.00	2.79	0.58	0.560	2.88	0.43	1.68	0.89	≤ 0.001
sign ("placa")	2.29	1.27	2.00	1.35	0.631	2.17	1.34	2.14	1.29	0.980	2.15	1.29	1.41	1.22	0.019
star ("estrela")	2.93	0.27	2.83	0.39	0.705	2.92	0.29	2.86	0.36	0.820	2.88	0.33	2.14	0.71	≤ 0.001
shoe ("sapato")	2.93	0.27	3.00	0.00	0.781	3.00	0.00	2.93	0.27	0.781	2.96	0.20	2.86	0.47	0.445
house ("casa")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.82	0.39	<b>0.025</b>
fruit ("fruta")	2.86	0.53	2.50	0.80	0.297	2.92	0.29	2.50	0.85	0.347	2.69	0.68	1.91	0.81	≤ 0.001
cup ("copo")	2.86	0.53	3.00	0.00	0.781	2.83	0.58	3.00	0.00	0.742	2.92	0.39	2.86	0.35	0.252
pencil ("lápis")	2.86	0.53	3.00	0.00	0.781	3.00	0.00	2.86	0.53	0.781	2.92	0.39	2.73	0.55	0.061
knife ("faca")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.91	0.29	0.120
present ("presente")	2.93	0.27	2.83	0.39	0.705	2.92	0.29	2.86	0.36	0.820	2.88	0.33	2.18	0.66	≤ 0.001
finger ("dedo")	3.00	0.00	2.75	0.87	0.742	2.75	0.87	3.00	0.00	0.742	2.88	0.59	2.91	0.43	0.929

Table 6. Continuation...

Correct	Gender*					School*					Phonological Development				
	Female (n = 14)		Female (n = 12)		p	Public (n = 12)		Private (n = 14)		p	Typical (n = 26)		Atypical (n = 22)		p
	M	DP	M	DP		M	DP	M	DP		M	DP	M	DP	
plastic ("plástico")	2.57	1.09	2.50	1.17	0.940	2.50	1.17	2.57	1.09	0.940	2.54	1.10	1.77	1.15	0.005
mirror ("espelho")	2.93	0.27	3.00	0.00	0.781	3.00	0.00	2.93	0.27	0.781	2.96	0.20	2.50	0.74	<b>0.002</b>
soda ("refri")	2.50	1.02	2.58	0.79	0.980	2.75	0.62	2.36	1.08	0.527	2.54	0.90	1.95	0.72	<b>0.004</b>
dog ("cachorro")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.45	0.60	$\leq$ <b>0.001</b>
thin ("magro")	2.79	0.80	2.75	0.62	0.742	2.92	0.29	2.64	0.93	0.781	2.77	0.71	2.00	0.98	$\leq$ <b>0.001</b>
microphone ("microfone")	2.43	1.09	2.75	0.45	0.781	2.25	1.14	2.86	0.36	0.212	2.58	0.86	1.50	1.01	$\leq$ <b>0.001</b>
nose ("nariz")	2.71	0.83	2.83	0.39	0.980	2.67	0.89	2.86	0.36	0.899	2.77	0.65	1.91	1.15	$\leq$ <b>0.001</b>
belly ("barriga")	2.79	0.80	3.00	0.00	0.781	3.00	0.00	2.79	0.80	0.781	2.88	0.59	2.41	0.96	<b>0.006</b>
grass ("grama")	2.50	1.09	2.75	0.62	0.781	2.75	0.87	2.50	0.94	0.432	2.62	0.90	2.05	0.95	<b>0.003</b>
truck ("caminhão")	2.50	1.02	2.83	0.58	0.560	2.83	0.58	2.50	1.02	0.560	2.65	0.85	2.64	0.79	0.627
sneakers ("tênis")	3.00	0.00	2.83	0.58	0.742	3.00	0.00	2.86	0.53	0.781	2.92	0.39	2.82	0.50	0.244
mesa ("table")	2.93	0.27	3.00	0.00	0.781	3.00	0.00	2.93	0.27	0.781	2.96	0.20	2.91	0.29	0.459
ring ("anel")	2.93	0.27	2.83	0.58	0.940	3.00	0.00	2.79	0.58	0.560	2.88	0.43	2.55	1.01	0.235
fork ("garfo")	2.79	0.80	2.67	0.89	0.705	2.92	0.29	2.57	1.09	0.781	2.73	0.83	2.41	0.50	<b>0.002</b>
glass ("vidro")	2.36	1.08	2.50	1.00	0.860	2.17	1.27	2.64	0.74	0.494	2.42	1.03	2.05	0.79	<b>0.030</b>
church ("igreja")	2.43	1.02	2.58	0.79	0.820	2.25	1.14	2.71	0.61	0.462	2.50	0.91	1.59	1.05	$\leq$ <b>0.001</b>
train ("trem")	2.93	0.27	2.83	0.39	0.705	2.92	0.29	2.86	0.36	0.820	2.88	0.33	2.23	0.43	$\leq$ <b>0.001</b>
box ("caixa")	2.86	0.53	3.00	0.00	0.781	3.00	0.00	2.86	0.53	0.781	2.92	0.39	2.50	0.74	<b>0.003</b>
rock ("pedra")	2.57	1.09	2.83	0.39	1.000	2.67	0.89	2.71	0.83	0.940	2.69	0.84	2.09	0.61	$\leq$ <b>0.001</b>
scissors ("tesoura")	2.86	0.53	2.92	0.29	0.980	2.92	0.29	2.86	0.53	0.980	2.88	0.43	2.36	0.73	$\leq$ <b>0.001</b>
newspaper ("jornal")	2.43	1.16	2.83	0.39	0.742	2.67	0.89	2.57	0.94	0.860	2.62	0.90	1.91	0.97	$\leq$ <b>0.001</b>
diaper ("fralda")	2.79	0.58	2.67	0.65	0.667	2.92	0.29	2.57	0.76	0.374	2.73	0.60	2.09	0.75	$\leq$ <b>0.001</b>
pillow ("travesseiro")	2.71	0.61	2.75	0.62	0.860	2.58	0.79	2.86	0.36	0.595	2.73	0.60	1.95	0.95	$\leq$ <b>0.001</b>
slipper ("chinel")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.68	0.48	<b>0.002</b>
purse ("bolsa")	2.86	0.53	3.00	0.00	0.781	3.00	0.00	2.86	0.53	0.781	2.92	0.39	2.82	0.39	0.128
blow ("soprar")	2.79	0.58	2.67	0.89	0.899	2.58	1.00	2.86	0.36	0.860	2.73	0.72	2.14	0.71	$\leq$ 0.001
fire ("fogo")	2.86	0.53	3.00	0.00	0.781	3.00	0.00	2.86	0.53	0.781	2.92	0.39	2.86	0.35	0.252
zebra	2.64	0.93	2.83	0.39	1.000	2.67	0.89	2.79	0.58	0.899	2.73	0.72	2.00	0.62	$\leq$ <b>0.001</b>
cow ("vaca")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.91	0.29	0.120
spoon ("colher")	2.93	0.27	2.92	0.29	0.980	3.00	0.00	2.86	0.36	0.560	2.92	0.27	2.27	0.70	$\leq$ <b>0.001</b>
hat ("chapéu")	2.86	0.53	3.00	0.00	0.781	2.83	0.58	3.00	0.00	0.742	2.92	0.39	2.59	0.73	0.013
gato ("cat")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.86	0.35	0.054
forest ("floresta")	2.43	0.94	2.33	0.98	0.860	2.33	0.98	2.43	0.94	0.860	2.38	0.94	1.73	0.88	<b>0.011</b>
baby ("bebê")	2.71	0.73	2.83	0.58	0.820	2.67	0.78	2.86	0.53	0.705	2.77	0.65	2.73	0.70	0.828
pastry ("pastel")	2.57	0.94	3.00	0.00	0.374	3.00	0.00	2.57	0.94	0.374	2.77	0.71	2.32	0.95	<b>0.015</b>
zero	2.36	1.28	2.17	1.27	0.742	1.92	1.38	2.57	1.09	0.297	2.27	1.25	1.82	1.10	0.049
door ("porta")	2.93	0.27	2.75	0.45	0.462	2.83	0.39	2.86	0.36	0.940	2.85	0.37	2.55	0.51	<b>0.024</b>
earring ("brinco")	2.93	0.27	2.83	0.39	0.705	2.92	0.29	2.86	0.36	0.820	2.88	0.33	2.18	0.66	$\leq$ <b>0.001</b>
die ("dado")	2.36	1.28	3.00	0.00	0.374	2.50	1.17	2.79	0.80	0.705	2.65	0.98	2.50	1.10	0.554
tooth ("dente")	2.57	1.09	3.00	0.00	0.560	2.75	0.87	2.79	0.80	0.980	2.77	0.82	2.64	0.90	0.313
hen ("galinha")	2.79	0.80	3.00	0.00	0.781	3.00	0.00	2.79	0.80	0.781	2.88	0.59	2.45	0.96	0.013
lipstick ("batom")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.82	0.66	0.120
bicycle ("bicicleta")	2.79	0.58	2.83	0.39	0.980	2.83	0.39	2.79	0.58	0.980	2.81	0.49	2.27	0.77	<b>0.002</b>
tail ("rabo")	2.57	0.85	3.00	0.00	0.374	2.67	0.78	2.86	0.53	0.705	2.77	0.65	2.50	0.80	0.074
earth ("terra")	2.57	0.85	2.42	1.08	0.820	2.25	1.14	2.71	0.73	0.403	2.50	0.95	1.77	1.31	<b>0.024</b>
horn ("chifre")	1.93	1.49	2.42	1.08	0.494	2.25	1.36	2.07	1.33	0.781	2.15	1.32	1.50	1.10	0.018
ship ("navio")	2.50	1.02	2.67	0.78	0.820	2.50	0.90	2.64	0.93	0.705	2.58	0.90	1.95	1.09	<b>0.033</b>
dragon ("dragão")	2.50	1.02	2.75	0.45	0.940	2.75	0.62	2.50	0.94	0.595	2.62	0.80	2.00	0.76	$\leq$ <b>0.001</b>
library ("biblioteca")	2.50	1.02	2.50	0.90	0.940	2.50	0.90	2.50	1.02	0.940	2.50	0.95	1.64	1.05	<b>0.002</b>
pants ("calça")	3.00	0.00	3.00	0.00	1.000	3.00	0.00	3.00	0.00	1.000	3.00	0.00	2.73	0.46	<b>0.005</b>
fan ("ventilador")	2.93	0.27	2.83	0.58	0.940	3.00	0.00	2.79	0.58	0.560	2.88	0.43	2.23	1.02	$\leq$ <b>0.001</b>
bird ("passarinho")	2.79	0.58	2.92	0.29	0.781	2.75	0.62	2.93	0.27	0.667	2.85	0.46	2.18	0.80	$\leq$ <b>0.001</b>
snake ("cobra")	2.64	0.74	2.67	0.65	0.940	2.92	0.29	2.43	0.85	0.212	2.65	0.69	2.18	0.66	<b>0.004</b>

Captions: \*Comparisons of gender and school type were only made between children with typical phonological development

## DISCUSSION

The internal consistency of the items as a whole, as well as the recognition rates for individual items, were mostly high. This confirms the adequacy of the items and images selected for the INFONO<sup>(21)</sup>. It is important to ensure that the stimuli reliably elicit the target words in order to provide sufficient opportunities for the children to produce all phonemes in every possible syllable and word position.

Throughout the development of an assessment tool, it is important to have a clear definition of its goal and target population; to evaluate the adequacy of its items; and to describe the type of words included and the methods used to select the target words<sup>(16,18)</sup>. When selecting individual items, it is important to ensure that the words are familiar to small children and are culturally relevant, considering regional differences and related factors<sup>(1)</sup>.

This is important for any assessment instrument, as it contributes to diagnostic precision and helps determine the instrument's sensibility (accurate detection of impairments in children with atypical development) and specificity (accurate determination of lack of impairment in typically developing children)<sup>(16,18)</sup>.

An accurate assessment is an important contributor to reliable clinical diagnosis and treatment planning. The INFONO<sup>(21)</sup> was developed in the form of a software program in order to collect a comprehensive sample of speech, including at least three target words with each consonant in BP occurring in different word and syllable positions.

The recognition rates for the items confirmed that the target words were in the children's vocabulary, since accurate naming requires familiarity with the image or action presented. The process of visual naming occurs in three stages: (1) identification of the object in the visual representation; (2) access to the corresponding semantic representation, to allow for recognition, and (3) lexicalization, or activation of the phonological processes through which the name of the image is recovered and pronounced<sup>(23)</sup>. Lexical development is related to the acquisition of the phonological inventory, and there is a need for studies which show how lexical and phonological factors can influence speech production, and apply this information to the diagnosis and treatment of children with atypical phonological development<sup>(24)</sup>.

One of the goals of the INFONO<sup>(21)</sup> was to provide children with at least three opportunities to produce each phoneme in BP in every possible position, and two opportunities to produce each CO. However, this could not be achieved for the phoneme /z/ in IO and for some COs (/kl/, /kr/, /gl/, /bl/) due to the low recognition rates of potential stimulus words. There may be several reasons for this. The words may have been absent from the children's vocabulary, or difficult to illustrate in a way that could be easily recognized by children<sup>(22, 25)</sup>. It is also possible that the low frequency of these phonemes in the lexicon of BP results in a smaller pool of potential stimulus words in the language as a whole.

Nevertheless, the INFONO<sup>(21)</sup> was able to evaluate all phonemes in BP in every possible word and syllable position,

as the target words that remained in the instrument provided enough information to map children's phonetic and phonological inventories. This is especially important for instruments which evaluate speech through spontaneous naming, since a definitive conclusion regarding the absence of a phoneme from the child's phonological inventory must be based on several observations of the inability to produce a given sound despite having multiple opportunities to do so<sup>(26,27)</sup>. There is no research to indicate the exact number of opportunities which children should be given to evaluate whether they can or cannot produce a given sound. However, since a sound is considered to be in a child's phonetic inventory after being produced once or twice, it stands to reason that children should have at least two opportunities to produce each phoneme in order to determine whether they are able to do so<sup>(28)</sup>.

The analysis also showed that the initial set of stimuli provided more than eight opportunities for the production of phonemes such as /p/ and /k/ in IO and MO; /b/ in IO; /t/, /r/ and /l/ in MO, which would have been unnecessary. Some of the target words were therefore excluded to reduce the number of items in the instrument, although care was taken to ensure that these changes did not restrict the number of opportunities for the production of less frequent phonemes such as COs or /d/, /g/, /f/, /s/, /z/ in IO. As a result, to preserve the occurrence of COs and less frequent phonemes in the instrument, some words had to be retained, and very frequent phonemes still occurred in more than three target words.

In a previous study<sup>(27)</sup> of 11 standardized assessment tools for English speakers, researchers verified whether the instruments included enough items to assess children's consonant inventories. The results showed that, although the tests contributed to the detection of phonological disorders, they did not provide sufficient opportunities for children to produce all consonants in the language. These instruments should therefore be complemented with an assessment of additional phonetically controlled words, in order to determine whether any sounds were absent from the children's phonological inventory.

The same study<sup>(27)</sup> underscored the need to test phoneme production in more than one target word, to control for the effects of the phonetic context. The INFONO<sup>(21)</sup> evaluates each phoneme through at least three target words which have different syllable numbers, stress patterns and phonetic contexts. The INFONO<sup>(21)</sup> includes mono-, di-, tri- and polysyllabic target words, with the target phoneme in both stressed and unstressed syllables, whenever possible. These variables can influence a child's ability to produce a target phoneme<sup>(22,27,28)</sup>.

Tests which do not include words of varying complexity<sup>(27)</sup> or rely exclusively on highly frequent words in the lexicon<sup>(26)</sup> may not allow for the accurate diagnosis of a phonological disorder or fail to reflect the child's skills as they appear in everyday speech. The balance of these characteristics across target words is thought to be a major contributor to the reliability of speech assessments<sup>(22)</sup>.

The analysis of group differences with regards to gender, type of school and phonological development revealed that performance on the instrument was not influenced by gender or school type. However, children with atypical phonological

development performed worse than their typically developing peers. This was to be expected, since the INFONO<sup>(21)</sup> was developed precisely to help speech pathologists distinguish between typical and atypical phonological development. These results also confirmed that the final set of items in the instrument could provide an accurate identification of phonological impairments.

This pilot study fulfilled the final requirements for the completion of the INFONO software<sup>(21)</sup>. However, the instrument must still undergo additional psychometric testing to determine its validity and reliability, and establish normative values. The items in the INFONO<sup>(21)</sup> can be used to evaluate participants in three different ways: through repetition, spontaneous naming and connected speech. In this pilot study, data were collected exclusively through spontaneous naming, since this format was thought to provide several advantages over the alternatives. Spontaneous naming allows for the assessment of every phoneme in all possible word and syllable positions. It also prevents children from imitating the examiner, which could lead to artificial improvements in speech. Lastly, spontaneous naming facilitates the comprehension of the child's speech by the examiner, since connected speech is sometimes unintelligible<sup>(27)</sup>.

## CONCLUSION

This study analyzed the use of the beta version of the INFONO(21) software in a real assessment setting. Most of the images in the instrument were recognized by the participants and were therefore effective at eliciting the production of the target words. Only a few images had to be redesigned to facilitate this process. The instrument was also reduced to contain the minimum sufficient target words to allow for an effective assessment of children's entire phonetic and phonological inventories. This ensured that the phonemes were represented by a similar number of items, preventing over- or underrepresentation. The internal consistency of the test was also deemed adequate.

The INFONO<sup>(21)</sup> provides at least two opportunities for the assessment of every phoneme, which allows the examiner to determine whether it is present or absent from the child's phonetic inventory, and present, partly present or absent from their phonological inventory. Additionally, the INFONO<sup>(21)</sup> includes target words with different numbers of syllables in which the target sound is presented in both stressed and unstressed syllables, whenever possible.

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### Authors contributions

*MIC was responsible for writing the project proposal, data collection, data entry, study design, study execution and manuscript drafting; MBG was responsible for data collection and manuscript drafting; CRO contributed to data entry and manuscript drafting, and was responsible for statistical analysis; MKS was responsible for the project proposal, study design, supervision of the study, and revision of the manuscript.*