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Research Article

Prosodic Boundary Effects on Syntactic Disambiguation in Children With Cochlear Implants

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Purpose: This study investigated prosodic boundary effects on the comprehension of attachment ambiguities in children with cochlear implants (CIs) and normal hearing (NH) and tested the absolute boundary hypothesis and the relative boundary hypothesis. Processing speed was also investigated.
Method: Fifteen children with NH and 13 children with CIs (ages 8–12 years) who are monolingual speakers of Brazilian Portuguese participated in a computerized comprehension task with sentences containing prepositional phrase attachment ambiguity and manipulations of prosodic boundaries.
Results: Children with NH and children with CIs differed in how they used prosodic forms to disambiguate sentences. Children in both groups provided responses consistent with half of the predictions of the relative boundary hypothesis. The absolute boundary hypothesis did not characterize the syntactic disambiguation of children with CIs. Processing speed was similar in both groups.
Conclusions: Children with CIs do not use prosodic information to disambiguate sentences or to facilitate comprehension of unambiguous sentences similarly to children with NH. The results suggest that cross-linguistic differences may interact with syntactic disambiguation. Prosodic contrasts that affect sentence comprehension need to be addressed directly in intervention with children with CIs.

Children with cochlear implants (CIs) exhibit deficits in prosody perception (e.g., Meister, Landwehr, Pyschny, Walger, & von Wedel, 2009; Peng et al., 2017; Straatman, Rietveld, Beijen, Mylanus, & Mens, 2010). However, it is unclear which aspects of prosody are affected and to what extent their prosodic processing differs from children with normal hearing (NH). The few studies that examined prosody in children with CI found an overall prosodic deficit in discrimination of rising intonation on the last word of questions (Meister et al., 2009; Straatman et al., 2010), in identification and discrimination of stress in minimal word pairs (Meister et al., 2009), and in discrimination of talkers and gender (Meister et al., 2009). Previous studies on prosody in CI users have focused primarily on lexical tones (Peng et al., 2017) and stimuli at word level, leaving prosody at the sentence level little understood. Many children with CIs have deficits in sentence comprehension (e.g., Caselli, Rinaldi, Varuzza, Giuliani, & Burdo, 2012; Tobey et al., 2013), but until now, prosody has not been considered as a factor in their syntactic deficits, despite its potential impact on language comprehension (e.g., Carlson, Clifton, & Frazier, 2001; Kitagawa & Hirose, 2012; Snedeker & Casserly, 2010; Stoyneshka, Fodor, & Fernández, 2010). This study examined whether children with CIs benefit from prosodic information in syntactic disambiguation. We applied a theoretically driven system of prosodic characterization (Pierrehumbert, 1980) as a framework consistent with a substantial literature in this area to investigate the prosody–syntax interface in children with CIs. By testing two hypotheses on the basis of this framework, we explore if prosody interacts with syntax on attachment disambiguation in the NH and CI pediatric population in the same manner. Understanding this interaction will allow segregating syntactic from prosodic causes of sentence miscomprehension, which currently is generally attributed to a syntax-only deficit in children with CIs.

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Prosodic Boundaries and Syntactic Disambiguation

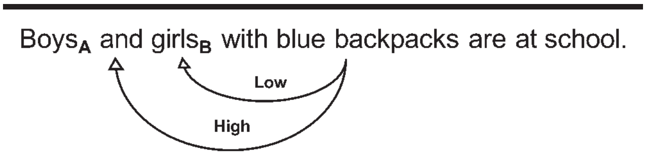
Comprehension of a sentence depends on several factors, such as the lexical content at a word level, the structure at a syntactic level, and the prosodic form in which it is delivered. Prosody may influence lexical and syntactic interpretations and may affect the resolution of lexical and syntactic ambiguities (e.g., Cooper & Paccia-Cooper, 1980; Kitagawa & Hirose, 2012; Stoyneshka et al., 2010). If someone says, *I want chocolate cake and milk,* with no prosodic boundary (a break in the continuum of the sentence) between *chocolate* and *cake,* it means she wants a piece of chocolate cake and milk. However, if she puts a prosodic boundary between *chocolate* and *cake,* it means that she wants some chocolate, a piece of cake, and some milk. Prosodic boundaries also have an effect on disambiguation of syntactic attachment ambiguities (Carlson et al., 2001; Clifton, Carlson, & Frazier, 2002; Diehl, Friedberg, Paul, & Snedeker, 2015; Schafer, 1997; Snedeker & Casserly, 2010). For example, the sentence in Figure 1 has two possible interpretations. The prepositional phrase *with blue backpacks* can be attached to *girls* or to *boys and girls*. If a low attachment is employed, only *girls* have blue backpacks. In contrast, *boys and girls* have blue backpacks when high attachment is employed.

Two hypotheses aim to explain the relationship between prosody and syntactic ambiguity. Both hypotheses rely on how prosodic boundaries affect the resolution of ambiguity. The absolute boundary hypothesis (e.g., Watson & Gibson, 2005) focuses on the effect of a single prosodic boundary immediately preceding the ambiguously attached phrase (marked as B) in (a) suggesting that the absence of a boundary at B favors low attachment (*only girls have blue backpacks*), whereas the presence of a boundary at B favors high attachment (*boys and girls have blue backpacks*). The relative boundary hypothesis (on the basis of the informative boundary hypothesis, e.g., Carlson et al., 2001; Clifton et al., 2002) suggests that prosodic boundaries interact with each other and the effect of the boundary at B depends on the size of any earlier relevant boundary (for example A). When boundary at A is more salient than B, low attachment is favored (*only girls have blue backpacks*); when boundary at B is more salient than A, high attachment is favored (*boys and girls have blue backpacks*); when the two boundaries are equivalent, neither low nor high attachment is favored.

Most studies analyzing the effect of prosodic boundaries on syntactic ambiguity resolution assume a phonological system that categorically specifies the size of a boundary and distinguishes between a word boundary (0), an intermediate phrase boundary (ip), and an intonational phrase boundary (IPh). The ends of prosodic boundaries are associated with changes in F_0, duration, and pauses, with intonational phrases involving more extreme changes than intermediate phrases and word boundaries. This description follows the Tones and Break Indices coding system, a prosodic annotation procedure (Pierrehumbert, 1980) that represents the relative prominence of words in an utterance and their prosodic grouping. By adopting that system, Snedeker and Casserly (2010) developed specific predictions for the absolute and relative boundary hypotheses (see Table 1). All predictions related to the placement of prosodic boundary pairs in high and low positions. In the current study, boundary pairs are referred to as high boundary or low boundary to indicate which boundary type (0, ip, or IPh) was placed in each position (high and low).

According to the absolute boundary hypothesis, sentences with a high IPh have higher probabilities of high attachment than sentences with a high ip, which, in turn, have higher probabilities of high attachment than sentences with a high word boundary. For the relative boundary hypothesis, sentences in which the high boundary is more salient than the low boundary have higher probabilities of high attachment than sentences in which the high and low boundaries are equal, which, in turn, have higher probabilities of high attachment than sentences in which the high boundary is less salient than the low boundary.

Figure 1. Illustration of high and low attachment interpretations of the sentence *Boys and girls with blue backpacks are at school*. A = high prosodic boundary; B = low prosodic boundary.



Acoustic Characteristics of Prosodic Boundaries

One acoustic change that contributes to a prosodic boundary is a pause (brief period of silence). Perception of this cue requires temporal resolution, which is the ability of the auditory system to respond to rapid changes in the envelope of a sound stimulus (Shinn, Chermak, & Musiek, 2009). Temporal resolution is typically evaluated by presenting two stimuli that are separated in time by a gap (i.e., a brief period of silence) to determine the smallest interval that a listener can detect, which is also known as *the gap detection threshold*. Gap detection thresholds in adults with NH range from 1 to 3 ms (Phillips, 1999) or marginally higher (Phillips & Smith, 2004).

Temporal resolution develops in childhood, during the process of language acquisition. Studies of infant's gap detection show that thresholds of 6–12-month-old infants are poorer than those of adults (Trehub, Schneider, & Henderson, 1995) and that children who are 3;6 (years; months) still show immature gap detection (F. Wightman, Allen, Dolan, Kistler, & Jamieson, 1989). Barreira et al. (2011) found minimal improvement with age on the Gaps-in-Noise Test (Musiek et al., 2005) in Brazilian children (7;0–12;0) with NH. This is comparable to findings for 7–18-year-olds in the United States (Shinn et al., 2009); temporal resolution reached adult values by age 7 years. The gap detection thresholds obtained in the Brazilian study (4.75 to 5.65 ms) were nearly identical to the American

Table 1. Specific predictions of the absolute boundary hypothesis (ABH) and the relative boundary hypothesis (RBH) of high attachment responses according to the type of boundaries in A, B, and general likelihood of specific predictions being confirmed for children with cochlear implants considering acoustic salience of 0, ip, and IPh boundaries.

Hypotheses	Predictions of high attachment responses under the hypotheses	Likelihood of prediction confirmation considering acoustic salience
RBH	IPh, 0 < 0, 0	More likely
	ip, 0 < 0, 0	Unlikely
	IPh, ip < 0, ip	More likely
	ip, ip < 0, ip	Unlikely
	IPh, ip < ip, ip	Less likely
ABH	0, 0 < ip, ip	Unlikely
	IPh, 0 < IPh, ip	Unlikely
	ip, 0 < IPh, ip	Less likely
	0, ip < 0, IPh	Less likely
	0, ip < ip, IPh	Less likely

Note. IPh = intonational boundary; ip = intermediate boundary; 0 = null boundary.

thresholds (4.45 and 5.18 ms, for 11- and 7-year-olds, respectively). In general, behavioral studies with adults and children with CIs have found that the mean gap detection threshold is approximately 20–30 ms with a wide range from 1.8 and 128 ms (Sharma & Yadav, 2015; Wei, Cao, Jin, Chen, & Zeng, 2007), meaning that the auditory system of adults and children with CIs needs a gap that is on average eight times larger than adults and children with NH to perceive changes in the envelope of a sound stimulus.

Preboundary vowel length, which is also largely mediated by acoustic correlates of duration, is another characteristic of prosodic boundaries. Previous research found increased segmental duration of preboundary vowel according to prosodic boundary type; durations are longer near stronger prosodic boundaries (C. W. Wightman, Shattuck-Hufnagel, Ostendorf, & Price, 1992). Adults with CIs do not identify synthetic and natural vowel duration as well as adults with NH (Morris, Magnusson, Faulkner, Jönsson, & Juul, 2013). These temporal resolution dissimilarities may reflect the listener's ability to perceive and apply prosodic boundary information during sentence comprehension.

Another acoustic characteristic of prosodic boundaries is a change in F_0. Frequency discrimination is typically measured by comparing a stimulus tone to a reference tone in order to determine the minimum difference in Hertz that the listener requires to differentiate the two tones (frequency discrimination threshold). The frequency discrimination thresholds for adults with NH are between 2 Hz and 3 Hz for standard frequencies at or below 500 Hz and higher at or above 1000 Hz (Wei et al., 2007). Adults with CIs usually have frequency discrimination thresholds that are 10 to 100 times poorer than adults with NH at 500 Hz and have difficulties discriminating frequencies above 500 Hz (Wei et al., 2007). A difference of 2.5 semitones is sufficient for children with NH to identify two stimuli as different (Straatman et al., 2010). Children with a CI and a hearing aid require an average difference of at least 6.5 semitones, whereas children with a CI only need an average of 10 semitones (Straatman et al., 2010). While the hearing loss itself and the use of CIs may impair the ability to identify gaps and vowel duration and to discriminate frequencies when compared with NH, the acoustic changes of prosodic boundaries are generally larger than the thresholds in psychoacoustic studies with nonlinguistic stimuli obtained by most CI users. However, these nonlinguistic acoustic thresholds for pitch perception (and, perhaps, temporal features) may overestimate identification and discrimination of acoustic changes in linguistic contexts (Heeren et al., 2012). The acoustic characteristics of the boundaries may be perceptible but may not be integrated with syntactic knowledge. Thus, it remains unclear whether children with CIs are able to apply these acoustic cues at the sentence level.

Caregivers provide infant-directed speech containing F_0 changes, preboundary word and vowel lengthening, and pause duration regardless of the hearing status of their infants (Kondaurova & Bergeson, 2011; Silva & Name, 2014). Children as young as 10 months old may be sensitive to intermediate phrase boundaries, depending on the prosodic structure of the language. Gout, Christophe, and Morgan (2004) showed that English-speaking children between 10 and 13 months are sensitive to the effect of intermediate phrase in the recognition of lexical units. In contrast, babies exposed to French only revealed this sensitivity at 16 months (Millotte, Margules, Dutat, Bernal, & Christophe, 2010), possibly due to fewer or weaker prosodic cues in French.

Sensitivity to intonational phrase has been reported in 5-month-old infants who were exposed to German (Männel & Friederici, 2009). Similar to adults in the study, 5-month-old infants presented responses to stimuli in the presence of different cues that mark the intonational phrase (F_0 variation, lengthening, and pauses). However, responses of 5-month-old infants were absent when pause cues were removed, which was not observed in adults. Brazilian children who are 13 months old are sensitive to intonational phrase and use that information to understand infant-directed speech as shown by a preferential looking paradigm (Silva & Name, 2014). In that study, intonational phrases of infant-directed speech were characterized by increases in pauses, F_0, and length of tonal vowels preceding the boundary.

It is important to note that sensitivity to prosodic boundaries at the word level does not necessarily imply an ability to apply prosodic boundary cues in syntactic disambiguation. Korean-speaking children between 3 and 4 years used prosodic information to resolve lexical ambiguities but were not able to use prosodic information to resolve syntactic ambiguities at 5 or 6 years of age (Choi & Mazuka, 2003). Similarly, Snedeker, and Trueswell (2001) reported that mothers of 4- to 6-year-olds varied their prosody systematically depending on the targeted interpretation, but their children were unable to use prosody to resolve syntactic ambiguity. Other cognitive abilities may also play a role on the prosody–syntax interface. Working memory may contribute to these outcomes because of the demands of retaining and comparing prosodic information (Lewandowsky & Oberauer, 2009; Oberauer, 2010) and interference between prosodic and syntactic cues. Maturation of such executive function abilities may interact with the ability to apply prosodic cues to syntactic processing. Children with CIs may exhibit additional difficulties given their poorer executive functions (Beer et al., 2014; Pisoni, Conway, Kronenberger, Henning, & Anaya, 2010) and the reduced acoustic input that the CI provides (e.g., Sharma & Yadav, 2015; Straatman et al., 2010; Wei et al., 2007). This might affect their segmentation of phrases and consequently cause comprehension deficits.

Brazilian Portuguese Intonation: A Cross-Linguistic Comparison

Intonational structures differ across languages. Brazilian Portuguese is a stress-timed language (Cruttenden, 1997), as is English (Abercrombie, 1967), in which basic rhythm is mainly determined by the stressed syllables and the duration between two stressed syllables is equal. However, the location of stress in Brazilian Portuguese is less stress timed and more predictable than in English (the penultimate syllable of a word is the most often stressed, whereas English has a dominant trochaic pattern, but also, many words have an iambic pattern).

The acoustic parameters of stress are complex, with a mixture of pitch, intensity, and duration (Fant, Kruckenberg, & Nord, 1991). In Brazilian Portuguese and English, stressed syllables have a higher pitch, are more intense, and longer than unstressed syllables, although, for Brazilian Portuguese, duration is more consistent (Konopczynski & Maneva, 2001). As a contrastive example, French (Gibbon & Williams, 2007) is a syllable-timed language (the duration of every syllable is equal), and stress is not placed on a particular syllable; the final syllable of each rhythm group has a rising pitch (Lian, 1980). Spanish is in between stress and syllable timed, mainly because closed syllables are rare and because there is a tolerance for large discrepancies in the interstress intervals (Bertinetto, 1989). Its stress is predictable on the penultimate syllable in 80% of the cases (Delattre, 1965). There are also variations across language dialects; Brazilian Portuguese is not as strongly stress timed as European Portuguese (Hyman, 1975).

Although intonational systems and pitch accent distribution in sentences vary considerably among languages, the categories of word, intermediate phrase, and intonational phrase boundaries occur across many languages. For instance, English and Brazilian Portuguese differ intonationally but still have intermediate and intonational phrases (Millotte, Wales, & Christophe, 2007; Snedeker & Trueswell, 2001). However, it remains unclear whether differences in intonational systems and pitch accent distribution across languages affect predictions of the absolute and relative boundary hypotheses. In word segmentation, listeners rely on the rhythmic structure of their language (Cutler, Mehler, Norris, & Segui, 1986). The same could occur at a sentence level: Intonation may influence prosodic unit categories (Monnin & Grosjean, 1993), and listeners may rely on the length of the previous prosodic units to predict the length of the current unit. This could constrain the syntactic constructions they expect and interfere with prosodic boundary cues to syntactic attachment. If the effects of higher level prosodic structure are similar to the effects of rhythmic structure, then prosodic phrasing may differ across languages. Thus, it is important to study a language other than English (as Brazilian Portuguese in the current study) given the amount of work in English.

In general, the studies on sentence interpretation and prosodic boundaries in Brazilian Portuguese are more limited in scope, focusing only on whether a prosodic boundary affects the comprehension of ambiguous sentences. For example, a reading and listening study of ambiguous sentences that could be resolved by gender agreement (Lourenço-Gomes, 2008) revealed greater acceptance of sentences with forced local attachment caused by a high boundary. In the auditory experiment, prosodic boundaries were created by inserting pauses, thus ignoring changes in F_0 and word/syllable lengthening that co-occur with pauses to create prosodic boundaries. Other studies have focused on the relative importance of the individual acoustic parameters of prosodic boundaries on the interpretation of syntactically ambiguous sentences in Brazilian Portuguese (e.g., Fonseca & Magalhães, 2007; Serra & Frota, 2009). Serra and Frota (2009) concluded that not all cues are relevant for the perception of prosodic boundaries. In a perception task, the pauses were the primary clue to the perception of an IPh boundary and consequent comprehension; F_0 variation was a less consistent cue. In contrast, a study that manipulated the prosody of test sentences in four different conditions (F_0 elevation, vowel lengthening, silent pause, and neutral reading), but not specific prosodic types, such as intonational or intermediate phrase boundaries, found that F_0 elevation was the most significant clue to interpretation of syntactic ambiguity of Brazilian Portuguese (Fonseca & Magalhães, 2007). Pauses may take priority over F_0 as cues to Brazilian Portuguese intonational phrases, whereas F_0 may be the dominant cue in Brazilian intermediate phrases. To the best of our knowledge, studies on Brazilian Portuguese have not yet focused on prosodic boundary strength and its role in syntactic disambiguation as proposed by the relative boundary hypothesis and the absolute boundary hypothesis.

Purposes and Hypotheses

This study examined whether children with CIs who are speakers of Brazilian Portuguese use prosodic boundary cues to aid syntactic disambiguation. We contrasted the relative boundary hypothesis (Carlson et al., 2001; Clifton et al., 2002) and the absolute boundary hypothesis (Watson & Gibson, 2005) in children with CIs and a group of age-matched children with NH. The predictions of the relative boundary hypothesis and the absolute boundary hypothesis have yet to be tested in children with CIs. These two hypotheses provide a controlled method for the investigation of the ability of children with CIs to use prosodic information to process syntactically ambiguous sentences. In addition to accuracy, response times for children with NH and with CIs were compared to determine whether there might be underlying processing challenges in sentence comprehension for children with CIs when disambiguating prosodic information is available.

We predicted that the decreased ability to perceive the acoustic cues for prosodic boundaries (i.e., pause, F_0, and vowel lengthening perception) by children with CIs compared with their peers with NH would interfere with the prosody–syntax interface. More acoustically salient prosodic boundaries, such as an intonational phrase, would be better perceived by children with CIs. If boundary salience directs syntactic disambiguation in these children, the absolute boundary and relative boundary predictions would not hold true. For example, predictions involving the contrast between an intonational phrase and a word boundary would be more likely to be confirmed than predictions involving a contrast between an intermediate phrase and an intonational phrase and, in turn, would be more likely to be confirmed than predictions about a contrast between intermediate and a word boundary. These predictions are illustrated in Table 1; the specific prediction of the relative boundary hypothesis IPh, 0 < 0, 0 would be more likely to be confirmed than the prediction 0, 0 < ip, ip of the absolute boundary hypothesis. We also anticipated that children with CIs would be slower than children with NH in responses to the ambiguous sentences due to their previously reported prosodic (e.g., Chin, Bergeson, & Phan, 2012), syntactic (e.g., Tobey et al., 2013), and working memory deficits (e.g., Pisoni & Cleary, 2003).

Method

Participants

Thirteen children (seven girls and six boys) with CIs and 15 children (seven girls and eight boys) with NH between 8 and 12 years (*M* = 10.2, *SD = 1.4*) participated in this study. All children were monolingual speakers of Brazilian Portuguese who have not lived in a different country for any period during their lives. All children had vocabulary scores on the ABFW Child Language Test (Andrade, Befi-Lopes, Fernandes, & Wetzner, 2004) and nonverbal IQs measured by the Test of Nonverbal Intelligence–Fourth Edition (Brown, Sherbenou, & Johnson, 2010) with normal limits to ensure that none of the children had general lexical or cognitive delays (see Table 2). Children with NH had no history of language impairment as reported by their parents and school-based speech-language pathologist and passed a hearing screening at 25 dB HL (American Speech-Language-Hearing Association, 1997). The families of children with NH and CI were middle class on the basis of the Brazilian Economic Classification Criterion questionnaire (ABEP, 2008). Table 2 includes demographic information. Prior to the prosody task, all children underwent a two-alternative, forced-choice lexical decision task containing all the animals (16) and colors (five) necessary to the comprehension of the target sentences. All children from both groups correctly identified all animals and colors, exhibiting 100% accuracy.

All children with CIs were prelingually deafened. Their preimplant audiograms demonstrated severe-to-profound bilateral hearing loss. The CI group included both unilateral and bilateral CI users. All received their implant(s) before 4 years of age. These children had no other associated impairments and are participants of rehabilitation programs with an emphasis on residual hearing training and an auditory–oral approach. One of the children, Subject 9, used a hearing aid contralateral to the CI (the hearing aid was not switched off during the experiment). Demographic data of children with CIs and details on implants are displayed in Table 3.

Stimuli

Prosody

The target stimuli consisted of eight base sentences, each containing a prepositional phrase attachment ambiguity (see Appendix). All sentences contained a noun phrase followed by a prepositional phrase and a verb phrase. Each, prepositional phrase and verb phrase had the same number of syllables in all eight sentences. Prosodic boundaries were placed at A and B (see example in sentence (a) below), respectively, high and low boundaries. The sentences were recorded in each of the eight prosodic boundary pairs: 0, 0; 0, ip; 0, IPh; ip, 0; ip, ip; ip, IPh; IPh, 0; IPh, ip.

a) *Tucanos*$_{\boldsymbol{A}}$ *e galinhas*$_{\boldsymbol{B}}$ *com maçãs verdes estão na gaiola.*
Toucans$_{\boldsymbol{A}}$ and chickens$_{\boldsymbol{B}}$ with green apples are in the cage.

Sixteen unambiguous filler sentences were mixed with the experimental sentences to create two contrasting prosodies and decrease awareness of the target manipulation. Eight filler sentences contained a predicate attachment, as in (b), and eight contained a reflexive assignment, as in (c).

b) *O coelho na frente do cachorro é cinza.*
The rabbit in front of the dog is grey.
c) *O pai na frente do avô está se lavando.*
The dad in front of the grandpa is washing himself.

Table 2. Mean (standard deviation) and range of age, nonverbal IQ, expressive vocabulary, gap detection, and frequency discrimination threshold information according to group (NH and CI).

Demographics	NH (*n* = 15)	CI (*n* = 13)	*t* test
Age	9;9 (1;3) [8;8–12;7]	10;5 (1;6) [8;0–12;3]	$t(26) = -0.986$, $p = .333$, $r = .19$
IQ[a]	106.1 (7.7) [94–120]	99.5 (5.5) [92–107]	$t(26) = 2.536$, $p = .018$*, $r = .45$
Vocabulary[b]	93 (2.5) [88.8–96.9]	91.7 (1.6) [88.8–93.8]	$t(26) = 1.604$, $p = .121$, $r = .30$
Gap detection (ms)	2.3 (1.9) [1–8]	31.8 (28.7) [12–100]	$t(26) = 3.980$, $p < .001$*, $r = .62$
Frequency Discrimination (Hz)[c]	12.9 (11.7) [2–41]	73.3 (65.4) [10–194]	$t(26) = 3.518$, $p = .002$*, $r = .57$

Note. Between-group comparisons are indicated by independent-sample *t* tests. NH = children with normal hearing; CI = children with cochlear implants.

[a]Test of Nonverbal Intelligence–Fourth Edition. [b]ABFW Child Language Test. [c]Mean frequency discrimination threshold (500, 1000, and 2000 Hz).

*Significant difference.

These filler sentences were previously used in studies that did not investigate prosody (Fortunato-Tavares et al., 2012, 2015; Fortunato-Tavares, Howell, Schwartz, & de Andrade, 2017). New recordings of the original sentences were made, focusing on stress manipulations. For example, in sentences, such as (b), stress was alternately placed on noun 1 (*rabbit*) or noun 2 (*dog*), and in sentences, such as (c), stress was alternately placed on noun 1 (*dad*) or noun 2 (*grandpa*). Stress was placed on the two possible antecedents to investigate whether stress placement would interfere with the selection of antecedents (i.e., Is the stressed antecedent selected more often?). There were no pauses after either noun. The task was the same as for target sentences. Target and filler sentences were randomly presented by E-Prime 2.0 software (Psychology Software Tools, 2012).

All sentence stimuli were naturally produced by one female native speaker of Brazilian Portuguese and recorded and analyzed using the Praat software (Boersma & Weenink, 2013). The speaker was a linguist and produced each utterance in the most natural manner possible. Recordings focused on natural changes of phonetic properties of boundaries, where prosodic boundaries were characterized by changes in acoustic parameters, more specifically duration and F_0 changes, immediately before the boundary, and pauses, immediately after the boundary.

The parameters related to prosodic boundaries (F_0, duration of nouns, and duration of vowels preceding boundaries, and pauses after boundaries) were statistically analyzed to ensure that consistent prosody was created across items in the same condition and that there was a contrast across different conditions. Intonational phrase boundaries were accompanied by pauses of approximately 300 ms, intermediate phrase boundary contained pauses of approximately 100 ms, and word boundary had no pauses. The vowels of nouns had longer duration at intonational phrase boundaries than at intermediate phrase boundaries. No words in Brazilian Portuguese end in stop consonants, which do not allow a clear measure of the duration of the pauses in sentences. For this reason, we

Table 3. Demographic information and implant details for children with cochlear implants.

Subject	Gender	Age (years;months)	Cause of deafness	Ear implanted	Implant	Processing strategy
1	F	12;0	Unknown	L	Nucleus 24	ACE
2	F	10;6	Unknown	R	Nucleus 24	ACE
3	M	12;0	Unknown	L	Nucleus 24	ACE
4	M	8;8	Unknown	R L	Nucleus 5	ACE
5	M	8;0	Unknown	R L	Nucleus 5	ACE
6	F	10;8	CMV	R L	Nucleus 24	ACE
7	F	12;2	Unknown	R	Nucleus 24	ACE
8	F	10;6	Unknown	R L	Nucleus 24	ACE
9	M	12;1	Unknown	L	Nucleus 24	ACE
10	F	12;3	CMV	L	Sonata	FSP
11	M	8;1	Unknown	R L	Nucleus 5	ACE
12	F	9;2	CMV	L	Sonata	FSP
13	M	9;3	Genetic	R L	Nucleus 24	ACE

Note. F = female; ACE = advanced combination encoder; M = male; L = left; R = right; CMV = cytomegalovirus; FSP = fine structure processing.

calculated the duration of the noun and pause together. The mean sum of pause and words differed significantly according to boundary type, $F(2, 125) = 339.610$, $p < .001$, $r = .92$. Longer duration was observed for intonational phrase boundaries (M = 1908 ms, SD = 222 ms) than intermediate phrase boundaries (M = 1557 ms, SD = 165 ms) and word boundaries (M = 858 ms, SD = 180 ms). Post hoc tests with Bonferroni corrections showed that the difference occurred for each comparison (all $p < .001$). F_0 on the word preceding the boundary differed significantly according to prosody type, $F(2, 125) = 46.411$, $p < .001$, $r = .65$, and was higher for intonational phrase boundaries (M = 295 Hz, SD = 44 Hz) than for intermediate phrase boundaries (M = 255 Hz, SD = 28 Hz) and word boundaries (M = 229 Hz, SD = 21 Hz). Post hoc tests with Bonferroni corrections confirmed differences for each comparison (all $p < .001$). Preboundary vowel duration also significantly differed according to boundary type, $F(2, 125) = 187.352$, $p < .001$, $r = .87$. Longer preboundary vowels were observed for intonational phrase boundaries (M = 357 ms, SD = 40 ms) than for intermediate phrase boundaries (M = 301 ms, SD = 44 ms) and word boundaries (M = 179 ms, SD = 43 ms). Post hoc tests with Bonferroni corrections also confirmed differences for each comparison (all $p < .001$).

Figure 2 illustrates spectrograms of the recordings of the target sentence *Aranhas e camelos com copos azuis estão no deserto* (Spiders and camels with blue cups are in the desert) in two different prosodic forms (IPh, 0 and 0, IPh, respectively). A pair of pictures was created for each sentence. For the target sentences, one picture reflected the low attachment and another represented the high attachment interpretation of the sentence. Figure 3 includes the visual stimuli for the target sentence *Tucanos e galinhas com maçãs verdes estão na gaiola* (*Toucans and chickens with green apples are in the cage*). The picture on the right reflects a high attachment response, whereas the picture on the left reflects a low attachment response. The location of the low and high attachment pictures was randomized. Filler sentences and their visual stimuli were selected from a previous experiment on predicate attachment and reflexive assignment (Fortunato-Tavares et al., 2012, 2015, 2017).

Procedure

E-Prime 2.0 software (Psychology Software Tools, 2012) was used for stimulus presentation and data collection. Participants were individually tested in a quiet room where they were seated in front of the computer with a serial response box and high-definition speakers. The total duration of the task was approximately 35 min. All stimuli were presented at the most comfortable loudness level on an individual basis according to participants' feedback.

Figure 2. Spectrograms of the target sentence *Aranhas e camelos com copos azuis estão no deserto* (Spiders and camels with blue cups are in the desert) recorded in the prosodic forms IPh, 0 (upper) 0, IPh (lower), illustrating word, F_0, and duration tiers. IPh = intonational phrase boundary; 0 = word boundary.

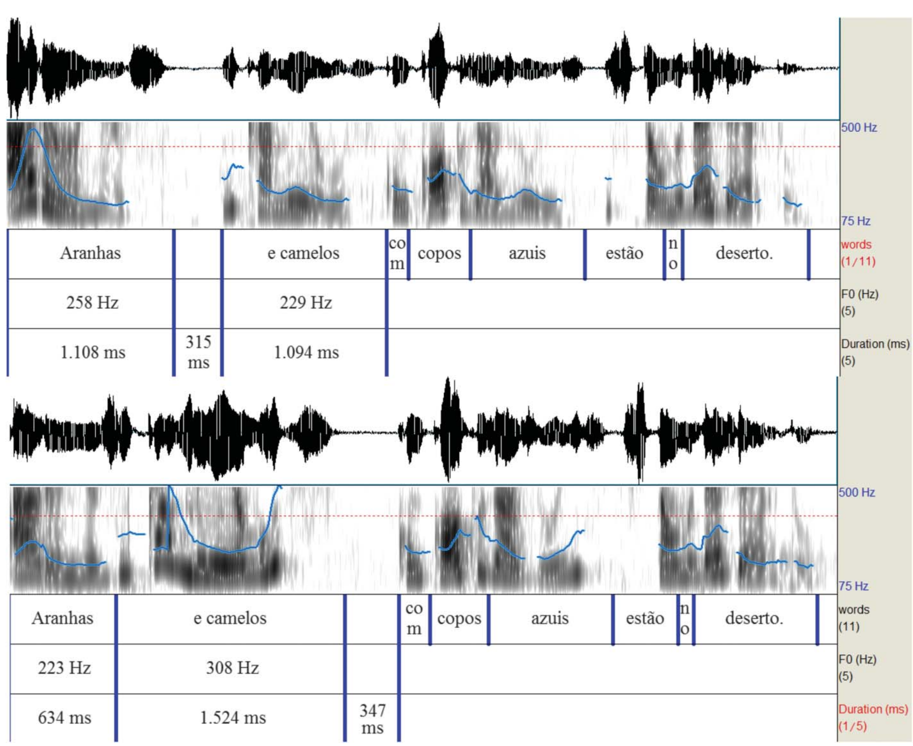
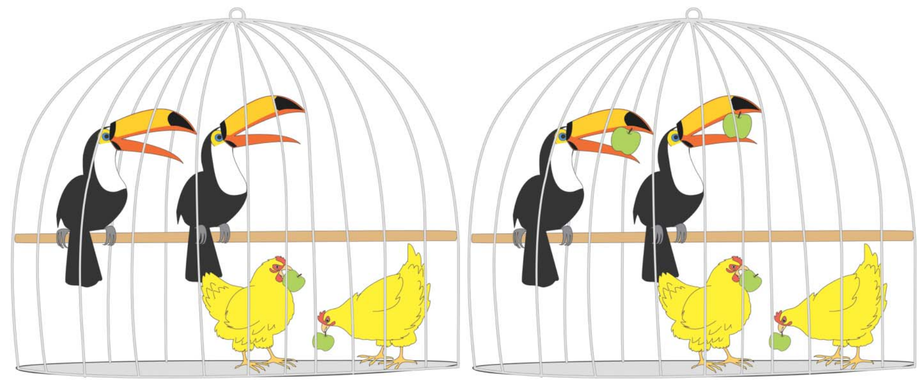


Figure 3. Visual stimuli for the target sentence *Tucanos e galinhas com maçãs verdes estão na gaiola* (Toucans and chickens with green apples are in the cage).



In all trials, participants heard each sentence once. Immediately following the offset of a sentence, two figures with the two possible interpretations appeared on the screen. With the pictures still visible, after a 200-ms interstimulus interval, the sentence was repeated. Participants had to press a button to indicate their selection. Responses were accepted no earlier than the offset of the second sentence stimulus. The intertrial interval was 1,000 ms. Ten practice trials preceded the experiment.

Each participant heard 64 target and 32 filler sentences. The stimuli were presented to participants in four blocks: block (a) included strong prosody contrasts, containing trials with one intonational phrase and one word boundary (IPh, 0 and 0, IPh); block (b) consisted of trials reflecting neutral prosody with identical high and low prosodic boundaries (0, 0 and ip, ip); block (c) included trials with weak prosody contrast—intermediate phrase and word boundaries (ip, 0 and 0, ip); and block (d) contained trials with two prosodic boundaries (IPh, ip and ip, IPh). Within the block, the stimuli were presented in a random order to avoid length, order, or familiarization effects. Blocks were also presented in a random order to avoid those effects.

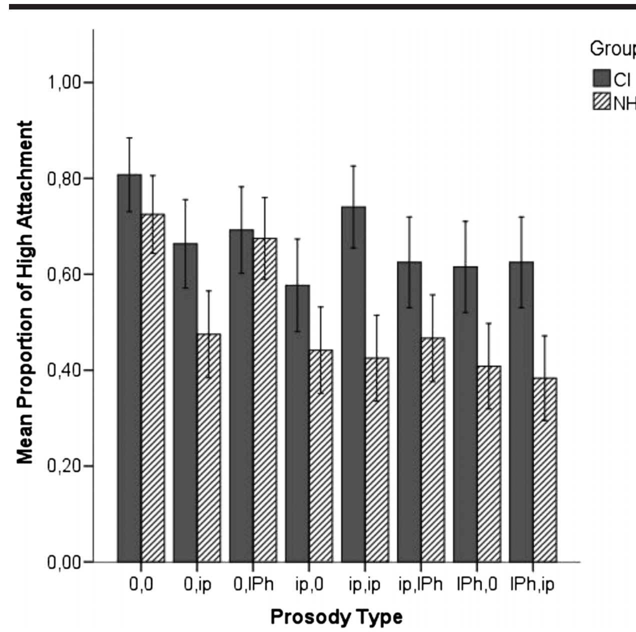
Results

Attachment results are presented according to the eight prosodic forms and the specific predictions of the absolute boundary hypothesis and the relative boundary hypothesis. As the experiment contained a binary variable (participants selected either high or low attachment interpretation), high attachment responses were selected for statistical analysis. The analyses of response times for high attachment responses and each of the eight prosodic forms are presented.

Attachment

Children with CIs exhibited an overall stronger preference for high attachment than children with NH regardless of prosody (see Figure 4). A mixed-model analysis of variance (ANOVA) conducted on the proportions of high attachment responses by item revealed a significant effect for prosodic type, $F(7, 182) = 7.765$, $p < .001$, $\eta^2 = .230$, indicating that, overall, interpretation of the target sentences varied according to their prosodic forms. There was a significant interaction between prosodic type and group, $F(7, 182) = 2.375$, $p = .024$, $\eta^2 = .084$. This indicates that children with NH and children with CIs differed in how they used prosodic forms to disambiguate sentences. There was a strong tendency to group effect, $F(1, 26) = 4.131$, $p = .052$, $\eta^2 = .137$, indicating that proportions of high attachment responses of children with NH and children

Figure 4. Mean proportion of high attachment responses according to prosody type and group. Error bars denote 95% confidence interval. NH = normal hearing; CI = cochlear implant; IPh = intonational phrase boundary; ip = intermediate phrase boundary; 0 = word boundary.



with CIs differed. Planned independent-sample t tests with Bonferroni corrections for proportion of high attachment interpretations indicated that children with NH and children with CIs differed in the proportion of high attachment interpretations in three prosodic types: ip, ip, $t(26) = -2.984$, $p = .024$, $r = .51$; IPh, 0, $t(26) = -1.826$, $p = .032$, $r = .34$; and IPh, ip, $t(26) = -2.043$, $p = .016$, $r = .37$.

Children With NH

A follow-up repeated-measures one-way ANOVA revealed that the proportion of high attachment responses of children with NH was significantly influenced by the prosodic type, $F(7, 98) = 8.703$, $p < .001$, $\eta^2 = .383$. To investigate the specific predictions of absolute boundary hypothesis and relative boundary hypothesis, planned pairwise comparisons were conducted (see Table 4). For children with NH, two predictions of the relative boundary hypothesis (IPh, 0 < 0, 0; ip, 0 < 0, 0) were confirmed, whereas only one absolute boundary hypothesis prediction (0, ip < 0, IPh) was confirmed for these children.

Children With CIs

A follow-up, repeated-measures one-way ANOVA revealed that the proportion of high attachment responses was not significantly influenced by the prosodic type, $F(7, 84) = 1.444$, $p = .199$, $\eta^2 = .107$. Planned pairwise comparisons were conducted to investigate the specific predictions of absolute boundary hypothesis and relative boundary hypothesis. The same two relative boundary hypothesis predictions (IPh, 0 < 0, 0; ip, 0 < 0, 0) confirmed for children with NH were also confirmed for children with CIs. In contrast, no absolute boundary hypothesis prediction was confirmed for children with CIs (see Table 4).

Response Time

Response times were calculated from the offset of the second time the target sentence was played to the pressing of the response button on the serial response box. Following the same pattern of attachment analyses, response times were analyzed for high attachment responses. Outliers were identified as response times that were more than 1.5 interquartile range (distance between the first and third quartiles) below the first quartile (minor outliers) or above the third quartile (major outliers). No minor outliers were identified. A total of 14 major outliers (0.67% of all responses) were identified (eight in the group of children with NH and six in the group of children with CIs). Figure 5 illustrates the mean response times (in ms) according to prosodic form and group. The high response time of the children with NH in the 0, 0 condition could be explained by the data of one participant. Even though response times from this child were not all in the range of outliers, they still elevated the mean. Kolmogorov–Smirnov tests indicated that the data were normally distributed in both groups on all prosodic types (all $p > .05$) after log (natural logarithm of 10) transformation.

A mixed-model ANOVA conducted on response times for high attachment responses showed a strong tendency to a significant effect for prosodic type, $F(7, 133) = 2.066$, $p = .051$, $\eta^2 = .098$, revealing that response times varied according to prosodic types. There was no significant interaction between prosodic type and group, $F(7, 133) = 1.659$, $p = .125$, $\eta^2 = .080$, indicating that children with CIs and children with NH exhibited similar speed in providing high attachment responses according to prosodic type. There was no significant effect of group, $F(1, 19) = 1.540$, $p = .230$, $\eta^2 = .075$, indicating that response times of children with CIs and children with NH were in general the same.

Summary of Main Results

Children with NH and children with CIs differed in how they used prosodic forms to disambiguate sentences. For children with NH, the results confirmed two predictions of the relative boundary hypothesis (IPh, 0 < 0, 0;

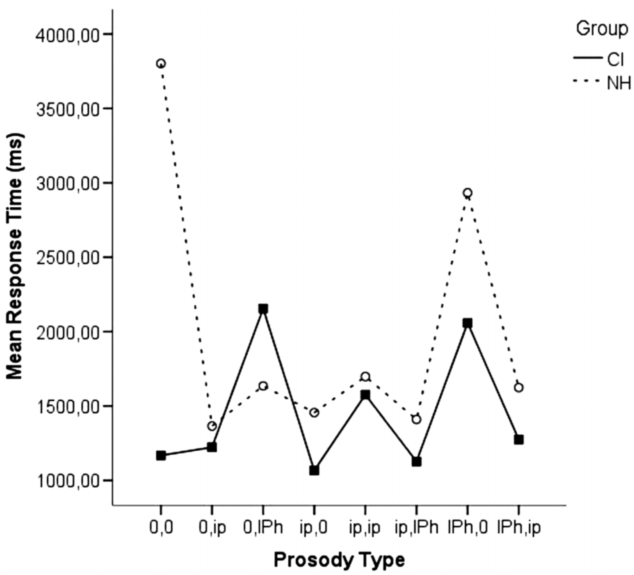
Table 4. Unique predictions of relative boundary hypothesis (RBH) and absolute boundary hypothesis (ABH) by prosodic form according to group (NH and CI).

			NH		CI	
Hypothesis	**Prosody**	**Prediction**	***t*(14)**	***p***	***t*(12)**	***p***
RBH	No low boundary	IPh, 0 < 0, 0	−7.400	< .001*	−2.175	.025*
		ip, 0 < 0, 0	−5.563	< .001*	−2.299	.020*
	Low ip boundary	IPh, ip < 0, ip	−0.731	.238	−0.536	.301
		ip, ip < 0, ip	−0.437	.334	0.775	.227
		IPh, ip < ip, ip	−0.857	.203	−1.287	.111
ABH	Equal boundaries	0, 0 < ip, ip	6.082	< .001*, **	0.719	.243
	Larger high boundary	IPh, 0 < IPh, ip	0.349	.366	−0.078	.528
		ip, 0 < IPh, ip	0.771	.226	−1.162	.134
	Larger low boundary	0, ip < 0, IPh	−2.195	.023*	−0.474	.322
		0, ip < ip, IPh	0.125	.451	0.369	.359

Note. NH = normal hearing; CI = cochlear implant; IPh = intonational boundary; 0 = null boundary; ip = intermediate boundary.

*Significant difference. **Significant difference with inverse relationship of prediction (ip, ip < 0, 0).

Figure 5. Mean response times (in ms) according to prosody type and group (CI and NH). NH = normal hearing; CI = cochlear implant; IPh = intonational phrase boundary; ip = intermediate phrase boundary; 0 = word boundary.



ip, 0 < 0, 0) but only one of the absolute boundary hypothesis (0, ip < 0, IPh). The two relative boundary hypothesis predictions confirmed for children with NH were also confirmed for children with CIs. In contrast, no absolute boundary hypothesis prediction was confirmed for children with CIs. Response times varied according to prosodic types and were, in general, the same for children with CIs and children with NH.

Discussion

This study examined how children with CIs and NH benefit from prosodic boundaries when disambiguating syntactically ambiguous sentences. The informative/relative boundary hypothesis (Carlson et al., 2001; Clifton et al., 2002) and the absolute boundary hypothesis (Watson & Gibson, 2005) were contrasted. No previous studies have examined such hypotheses in children with CIs. This is surprising giving the known prosodic processing (e.g., Chin et al., 2012; Meister et al., 2009; Straatman et al., 2010) and sentence comprehension (Caselli et al., 2012; Tobey et al., 2013) deficits in children with CIs. A better understanding of the factors underlying sentence comprehension deficits in these children is critical for intervention planning. In this study, prosodic boundaries aided syntactic disambiguation in children with NH but not in the same way as for children with CIs.

The analyses of specific predictions by absolute boundary hypothesis and relative boundary hypothesis revealed that neither of these models could completely explain how Brazilian Portuguese–speaking children with CIs use prosody to disambiguate sentences. Despite the fact that some of the specific predictions of the two models were confirmed, neither model alone was sufficient to explain the relationship between prosody and syntactic ambiguity attachment in English-speaking adults as well (Snedeker & Casserly, 2010). Considering the proposed by the two hypotheses and the findings of previous and the current study, the only consistency is that the relative size of the boundaries (as proposed by the relative boundary hypothesis) seems to explain the relation between prosody and ambiguity attachment when there is either one intermediate phrase or one intonational phrase (but not both) on a sentence. In general, these two hypotheses lack consistency within and cross-linguistically when there are two boundaries on a sentence. Moreover, further empirical evidence is necessary regarding the relationship between lexical stress, possible processing factors, and prosodic boundary relations.

Relative Boundary Hypothesis

Two predictions of the relative boundary hypothesis (IPh, 0 < 0, 0; ip, 0 < 0, 0) were confirmed for children with NH and for children with CIs, suggesting that they perceive and use the relative size of the boundaries in the same manner. When there was no low boundary, the relative size of the high boundary affected attachment; the presence of a more salient high boundary discouraged high attachment. The same effect has been found for English-speaking adults (Schafer, 1997; Snedeker & Casserly, 2010). Therefore, as predicted by the relative boundary hypothesis, it is likely that the relative size of the high boundary has an effect on syntactic disambiguation regardless of age, language, or hearing status; however, this is only true when there is no low boundary.

The relative boundary hypothesis did not hold true when the low boundary was an intermediate phrase boundary. The presence of a low intermediate phrase precluded the influence of the high boundary on attachment as predicted by the relative boundary hypothesis in the comprehension of Brazilian Portuguese speakers, regardless of hearing status. Snedeker and Casserly (2010) also did not find robust support for this claim; the effect was reliable in the subject analyses but not significant in the item analyses. Clifton et al. (2002) tested several different syntactic structures (e.g., relative clauses, conjunctions, adverbial adjuncts, prepositional phrase modifiers, *-ly* adverbs), and although they found evidence providing overall support for relative boundary hypothesis, these predictions (ip, ip > IPh, ip; 0, ip > IPh, ip) were not confirmed for all syntactic structures under investigation. Therefore, the relative size of the high boundary alone does not consistently determine attachment when there is a low intermediate phrase boundary.

Stress patterns may explain the absence of intermediate phrase effects. Schafer et al. (2000) speculated that stress patterns could provide information to resolve ambiguity. A boundary can increase the salience of the preceding word, increasing the likelihood of attachment to that word. In the current study, the presence of an intonational phrase in the prosody boundary pair IPh, ip increased stress on the first noun (as shown by F_0 and duration analyses in Tables 2 and 3, respectively), which might have forced attachment to a higher position. Children with CIs could have learned to follow this pattern, ignoring other prosodic cues and exhibiting a high attachment bias. The same effect could have occurred in the study by Snedeker and Casserly (2010). That study also included sentences with a high attachment preference (more high than low attachment responses were given in the prosodic uninformative sentence: 0, 0). Stress may overcome the effects of prosodic boundaries—at least in sentences with a high attachment preference and a low intermediate phrase boundary.

Absolute Boundary Hypothesis

None of the absolute boundary hypothesis predictions were confirmed in children with CIs, indicating that the absolute boundary hypothesis does not explain how prosodic boundaries govern attachment of syntactically ambiguous sentences in these children. For children with CIs, there was no difference among the different prosodic versions of the sentences testing the absolute boundary hypothesis. Only one of the five absolute boundary hypothesis predictions (0, ip < 0, IPh) was confirmed for children with NH, providing little support to the absolute boundary hypothesis in general. For children with NH, the absolute value of the low boundary affected interpretation as predicted by the absolute boundary hypothesis only when the low boundary was more salient than the high boundary and when there was only one boundary on both sentences involved. This contrasts with previous findings for English-speaking adults (Carlson et al., 2001; Clifton et al., 2002; Snedeker & Casserly, 2010) that did not to confirm this prediction. Factors outside the scope of the absolute boundary hypothesis, such as working memory and, certainly, cross-linguistic variations, might have influenced these outcomes.

In contrast to the absolute boundary hypothesis predictions, children with NH gave fewer high attachment responses for ip, ip sentences than for 0, 0 sentences. The presence of a high boundary on ip, ip sentences discouraged high attachment regardless of the low boundary (the reverse of the absolute boundary hypothesis). Alternatively, in sentences with two identical boundaries, the high boundary may be more relevant: 0, 0 sentences had more high attachment responses than ip, ip sentences because the absence of a high boundary joined the two constituents favoring high attachment. However, this apparently more important role for the high boundary did not hold true for sentences with two different boundaries. Sentences with 0, ip would have had more high attachment responses than sentences with ip, 0 or ip, ip, which was not the case. The more frequent high attachment responses for the 0, 0 version could also be attributed to the possibility that our sentences had a high attachment bias in Brazilian Portuguese despite the potential syntactic ambiguity.

When there was a larger (more acoustically salient) high boundary, the size of the low boundary did not influence attachment in the way predicted by the absolute boundary hypothesis in Brazilian Portuguese–speaking children with CIs and children with NH. For English-speaking adults in previous studies, the results were inconsistent. The absolute size of a low boundary guided the attachment when there was a larger high boundary in the study by Snedeker and Casserly (2010), but this was not true in the study by Carlson et al. (2001). Several factors could explain these conflicting findings. Although the sentences tested in the three studies were globally ambiguous, a manipulated version is being compared to a "baseline" sentence. For sentences that have a low attachment preference, there should be few low attachment responses on the 0, 0 conditions—the reverse is also true for sentences that have a high attachment preference. The study by Snedeker and Casserly (2010) and the current study found that sentences with a preference for high attachment—the 0, 0 condition—led to more high than low attachment. In Carlson et al.'s (2001) study, there was a preference for low attachment. Although this alone does not explain the cross-linguistically contrasting findings, it might explain the differences observed between the two studies with English-speaking individuals. The proportion of high attachment in the study by Carlson et al. (2001) on the two prosodic forms (IPh, 0, IPh, ip) were both .15, whereas in the study by Snedeker and Casserly (2010), they were around .45 and .70, respectively. The low attachment preference for the sentences in the study by Carlson et al. created a floor effect that concealed differences.

Acoustic Salience

The acoustic salience of prosodic boundaries was expected to override the patterns predicted by the relative and the absolute boundary hypothesis in children with CIs. Although children with CIs did not exhibit an overall prosody effect, two predictions of the relative boundary hypothesis were confirmed; one that was *very likely* (IPh, 0 < 0, 0) and one that was *unlikely* (ip, 0 < 0, 0) based on acoustic salience. In the first case, a straightforward explanation arises from prosodic strength, as the contrast between an intonation phrase boundary and a word boundary is more acoustically salient and, therefore, more likely to differ from other forms and confirm predictions. However, the second contrast (ip, 0 < 0, 0) warrants more consideration for two reasons. Predictions involving the contrast between intermediate phrase and word boundaries seemed unlikely to be confirmed because of acoustic salience. There were no attachment response differences in other conditions that involved this contrast for children with CIs. Therefore, boundary salience alone was a not the determining factor in how prosodic boundaries influenced attachment in children with CIs.

A different interpretation of acoustic salience arises when considering the absolute boundary hypothesis findings. No prediction involved contrasts that were more likely to be confirmed because of boundary salience (see Table 1).

There were only two possible acoustic salience conditions: less likely to be confirmed (medium acoustic contrasts between intonational phrase and intermediate phrase) and unlikely to be confirmed (the weak acoustic contrast between intermediate phrase and a word boundary). Possibly because there was no highly salient contrast, no absolute boundary hypothesis predictions were confirmed for children with CIs. Although the findings of the absolute boundary hypothesis suggest an influence of boundary salience, the acoustic salience findings for the relative boundary hypothesis predictions do not support this view. The interaction of acoustic salience and the hypotheses that aimed to explain how prosodic boundaries govern syntactic disambiguation is not straightforward, perhaps because discrimination of acoustic stimuli is only one part of this and children also have to attend to such differences in spoken language and recognize their significance. Therefore, for the group of children with CIs, comprehension could have been impacted by either not integrating or not perceiving the prosodic changes. Studies with an acoustic science perspective that titrate parametrically the acoustic cues to prosodic boundaries for sentence parsing are needed to understand the acoustic particulars of prosody perception by children and adults with CIs.

Processing Time

Hearing status did not influence the response time for the sentences. Although the children with NH and the children with CIs differed in the influence of prosody on attachment responses, the two groups had similar response times on trials where they selected a high attachment response. Children with CIs may have had no global limitations in comprehension speed for this task. Alternatively, they had a strong preference for high attachment and, therefore, responded quickly.

Only those predictions of a unique boundary in the sentence (a word and either an intonational phrase or intermediate phrase boundary) were confirmed for children with NH and with CIs. Thus, neither group benefited from multiple sources of prosodic boundary information. Working memory may contribute to these outcomes because of the demands of retaining information for two different boundaries and comparing these boundaries compared with the demands of a single boundary. The process of binding (between boundaries and phrase structure) and release from binding, as described in recent working memory models (Lewandowsky & Oberauer, 2009; Oberauer, 2010) and interference between cues, may well be involved in these tasks. There is a strong association between working memory, as measured by digit span tasks, and speech and language performance of children with CIs (Pisoni & Cleary, 2003; Pisoni & Geers, 1998). Children with NH may have faced some of the same challenges as children with CIs in working memory demands (Fry & Hale, 2000). Other cognitive abilities may also play a role for children with CIs. The impact of a period of sensory deprivation caused by severe hearing impairment in children with CIs affects executive functioning, which includes processes, such as working memory, cognitive flexibility, attentional control, cognitive inhibition, and inhibitory control (Pisoni et al., 2010). The poorer executive functions of children with CIs (e.g., Beer et al., 2014) may have affected their performance. A more direct examination of specific executive functions could address the role of executive function demands on prosody and syntax interface.

In the current study, we applied a binary experiment similar to previous research on the subject (e.g., Snedeker & Casserly, 2010). This is a consistent approach considering that the attachment ambiguities studied have only two possible interpretations. Overall, chance played a minimal role on the findings for four reasons. First, some boundary pairs were not expected to favor neither high or low attachment under the absolute or the relative boundary hypotheses (e.g., sentences with two equal boundaries under the relative boundary hypothesis). Thus, response patterns near chance would be expected for those conditions. Second, different high attachment percentages were observed for different conditions even though the trials were randomized. Third, children with CIs had a strong preference for high attachment (for some conditions near 80%). Fourth, children with NH were more near chance but reached near 70% in two (out of eight) conditions.

Conclusion

This study revealed that neither the absolute boundary hypothesis nor the relative boundary hypothesis explains how prosodic boundaries influence attachment in Brazilian Portuguese–speaking children with CIs and in children with NH. The relationship between the position and the size of boundaries and the resolution of syntactic ambiguities is not as straightforward and cannot be explained by the predictions of these two hypotheses. Exclusively prosodic explanations of attachment are inadequate. The current study also demonstrated that children with CIs have deficient acoustic input for prosody that affects their linguistic comprehension. Alternatively, they could have an efficient input for prosody but may not attend to it. Overall, children with CIs did not use prosodic information to disambiguate sentences or to facilitate comprehension of unambiguous sentences similarly to the children with NH. Children with CIs exhibited a strong preference for high attachment (regardless of prosodic cues to the contrary). It may be important to assess the recognition of prosodic contrasts that affect sentence comprehension directly in intervention of children with CIs, focusing on the interaction between syntax and prosody.

Instead of characterizing listeners' location of phrase boundaries in sentence comprehension as purely prosodic (as the generally unsuccessful absolute and relative boundary hypotheses), the interactions among prosody, attachment preferences, lexical cues, and other factors that influence sentence processing could be examined. The use of methods that provide continuous information, such as eye tracking, may also help determine parsing strategies in children with

CIs. Finally, the role of working memory and executive functions in sentence comprehension by children with CIs and their peers with NH is critical to a complete picture of language comprehension in these children.

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Appendix

Target Sentences in Brazilian Portuguese and its Corresponding English Translations

1	Tucanos e galinhas com maçãs verdes estão na gaiola. *Toucans and chickens with green apples are in the cage*.
2	Corujas e morcegos com chapéus marrons estão na caverna. *Owls and bats with brown hats are in the cavern*.
3	Aranhas e camelos com copos azuis estão no deserto. *Spiders and camels with blue glasses are in the desert*.
4	Formigas e abelhas com flores roxas estão na árvore. *Ants and bees with purple flowers are on the tree*.
5	Coelhos e cachorros com bolas azuis estão no cercado. *Rabbits and dogs with blue balls are inside the fence*.
6	Gorilas e girafas com galhos marrons estão na floresta. *Gorillas and giraffes with brown branches are in the forest*.
7	Ovelhas e cavalos com capins verdes estão na fazenda. *Sheep and horses with green grass are on the farm*.
8	Baleias e jacarés com laços rosas estão no aquário. *Whales and alligators with pink ribbons are in the aquarium*.