EXPERIENCE REPORT

The process of language acquisition: an experimental approach from a minimalist perspective

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ABSTRACT

We present the approach to the study of language acquisition and processing developed in LAPAL (Laboratório de Psicolinguística e Aquisição da Linguagem – PUC-Rio) in the last decades, which incorporates a minimalist conception of language in a procedural model of grammar identification, and in the online computation of sentences. We refer to experimental results regarding infants' sensibility to elements of functional categories, the early acquisition of gender and number, the early parsing of recursive structures, the role of recursion in cognitive development, and the processing cost of recursive structures and long-distance dependencies. Methodological issues concerning the assessment of children's ability to process costly structures are considered, which contribute to the identification of the nature of children's difficulties in comprehension tasks. Particular attention is paid to the application of this approach to the tracking of DLD (Developmental Language Disorder).

RESUMO

Apresenta-se a abordagem para o estudo da aquisição e processamento da linguagem que vem sendo desenvolvida no LAPAL (Laboratório de Psicolinguística e Aquisição da Linguagem – PUC-Rio) nas últimas décadas, a qual se caracteriza por incorporar uma concepção minimalista de língua(gem) em um modelo procedimental para a identificação de gramáticas e computação online de sentenças. Fazemos referência a resultados experimentais relativos à

sensibilidade de bebês a elementos de categorias funcionais, à aquisição de gênero e número em tenra idade, ao parsing precoce de estrutura recursiva, ao papel da recursividade no desenvolvimento cognitivo, ao custo de processamento de estruturas recursivas e dependências de longa distância. Questões metodológicas relativas à avaliação da compreensão de estruturas de alto custo são consideradas, as quais contribuem para a identificação da natureza das dificuldades de crianças em tarefas de compreensão. Especial atenção é dada à aplicação dessa abordagem para o rastreio do TDL (Transtorno do Desenvolvimento da Linguagem).

KEYWORDS

Grammar identification. Minimalism. Infant language processing. Processing cost. DLD.

PALAVRAS-CHAVE

Identificação da gramática. Minimalismo. Processamento precoce da linguagem. Custo de processamento. TDL.

RESUMO PARA NÃO ESPECIALISTAS

Apresentamos um painel de resultados de estudos sobre a aquisição da língua materna conduzidos com crianças, de 10 meses a 12 anos, no LAPAL (Laboratório de Psicolinguística e Aquisição da Linguagem – PUC_Rio). Consideramos que o ser humano é predisposto para o desenvolvimento da linguagem, identificando, na fala à sua volta, o tipo de informação neces-sária para que uma língua se desenvolva em sua mente. O estudo da aquisição da linguagem é fundamental para entendermos o funcionamento da mente humana e com isso contribuir para que educadores ou fonoaudiólogos possam atuar diretamente em crianças com problemas de linguagem, tal como o Transtorno do Desenvolvimento da Linguagem (TDL), que afeta 7-9% de crianças em idade escolar. Neste relato, falamos do que o bebê já percebe na fala dos adultos como informação linguisticamente relevante, do modo como a criança percebe que uma língua como o português diferencia masculino e feminino, singular e plural, por exemplo, assim como da capacidade de crianças compreenderem frases com orações subordinadas e sua relação com o desenvolvimento cognitivo. Consideramos também as dificuldades que frases desse tipo, e de frases na voz passiva, podem trazer no uso da língua, e como podem servir como um sinal de alerta para o TDL.

Introduction

The study of language acquisition admits different approaches. Two main lines of investigation can be singled out regarding grammar identification since the explicit formulation of the language acquisition problem in the context of generative linguistics: (i) the characterization of the state of children's grammar, mainly based on spontaneous production data, considering what might be ascribed to Universal Grammar (UG), and the structural conditions for change of state during development, in the light of the current state of the generative (Chomskyan) theory; (ii) the identification of children's speech perception abilities and the difficulties they face mainly in comprehension tasks, with the aim of characterizing how grammatically relevant information is identified in the input data, and the processing cost associated with it, without a necessary commitment with a particular theory of UG. Let's call them linguistic and psycholinguistic approaches, respectively.

The psycholinguistic approach to language acquisition undertaken in LAPAL (*Laboratório de Psicolinguística e Aquisição da Linguagem* – PUC-Rio) stems from the belief that the minimalism turn in the principles and parameters theory of grammar in the 1990s enables a closer interaction between linguistic theory and the study of language acquisition from the perspective of the child who identifies a grammar by processing linguistic data, given the properties of the language processing apparatus (Corrêa, 2002; 2006/18; 2014).

This report starts by briefly presenting the minimalist conception of language incorporated in our approach to language acquisition and the procedural view of this process, under the assumption that all grammatically relevant information for the parsing and the acquisition of language is available at the interfaces between the internal language and the systems recruited in language processing. In the sequence, we recap some experimental results that can illustrate this approach with Brazilian Portuguese (BP) data. Some attention is then given to children's ability to deal with recursive structures and their possible role in the development of higher-order cognitive functions. Finally, we explore the role of processing cost in the tracking of the syntactic manifestation of DLD (Developmental Language Disorder) and consider possible low-cost strategies that may circumvent processing difficulty in language production.

1. A minimalist conception of language

The fundamental difference between the principles and parameter theory in the 1980s and after the minimalist turn in the 1990s (and its refinements since then) consists of what needs to be ascribed to UG -- the language-specific innate information that enables the growth of the internal language common to human beings during the identification of the grammar of a particular language by any child. While the UG theory in the 80s ascribed most of the constraints on the form and functioning of human languages to that language-specific component, the Minimalist Program (MP), more vaguely, reduces UG to the genetic endowment that interprets part of the environment as linguistic experience and

determines the general course of the development of the language faculty (Chomsky, 2005). The language faculty essentially includes a computational component with a minimum set of recursive operations and, in a broader sense, a lexicon, to be specified (parametrized) during language development, which interacts with the systems involved in language performance. All principles formerly ascribed to UG subsume under the principle of Full Interpretation of the expressions generated by the grammar (as the universal operations apply to an array of elements from the lexicon) at the (phonetic and semantic) interfaces between the internal language and the so-called performance systems. Principles not specific to the faculty of language are assumed. They guarantee that the expressions generated by the grammar can be perceived/articulated and semantically interpretable, such as those involved in efficient computation, and data analysis, which may be used in language acquisition and other domains.

The MP is then compatible with the so-called cognitivist approach to language acquisition, according to which the processing apparatus may impose constraints on the form and functioning of human grammars (Bever, 1970; Cromer, 1991), with the ethological view that language acquisition is innately guided, even though infants may rely on statistical analysis in the identification of a particular grammar (Jusczyk, 1997), and with hypotheses focusing on the bootstrapping of syntax based on phonological and semantic information (Morgan & Demuth, 1996; Christophe et al., 1997; Pinker, 1984). In other words, the current state of the theory of UG seems to be reconcilable with long-standing views of language acquisition developed in the context of psycholinguistic research.

2. A procedural view of language acquisition

Given the minimalist assumption that all grammatically relevant information for language parsing and acquisition is available at the interfaces of the internal language and performance systems (Chomsky, 1995); given the conclusion that it is the formal features of the functional elements of the lexicon that distinguishes the grammar of different languages (Borer, 1984); and the fact that the information concerning these features is expressed in morphological patterns, it can be assumed that children are innately guided to identify these patterns as grammatically relevant in the speech sound (or correlate) and to ascribe a semantic and logical interpretation to them, as they try to make sense of the world in social interaction.

The research under the phonological bootstrapping hypothesis (Morgan & Demuth, 1996; Christophe, Guasti & Nespor, 1997) demonstrated that the chunking of the speech input into prosodic units can contribute to its segmentation into syntactic units, thereby restricting the combinatorial possibilities to be analysed. These chunks constitute the processing window in which patterns can be identified (Morgan, 1986). Infants' early sensitivity to functional elements (Shady,1996; Shafer, V.; Shucard, D.; Shucard, J.; Gerken, L A., 1998) is compatible with the idea of an innate guide to the identification of the formal features that distinguish languages. However, the phonological bootstrapping hypothesis does not clarify sufficiently how syntax, and the ability to parse get started. It is necessary, in view of the research program under development in LAPAL, that a minimalist conception of language is

incorporated. Once children distinguish the set of functional elements (closed class elements) from its complement (open class elements), it can be argued that the first formal features are specified in the lexicon under construction (Corrêa, 2009). Since, according to the minimalist view, the computational system of language operates on formal features, once the lexicon contains elements that can be formally distinguished as closed and open class elements, the merging of lexical elements, which results in the construction of syntactic objects (a hierarchical structure), can start. From then on, the very parsing activity can guide the identification of syntactic properties and lexical meaning (Corrêa, 2009; Corrêa & Augusto, 2009).

The research in LAPAL in the 2000s was motivated by an enthusiasm for the possibility of bringing together such an abstract theoretical concept as "formal feature" (an unquestionably domain-specific concept) with the (domain-general) concept of patterns that can be recognized on a statistical basis, in a language development theory grounded on experimental results. The creation of a baby lab enabled the conduction of experiments in the head-turn preference procedure (HPP) (Kemler-Nelson et al., 1995) to investigate the early sensitivity to determiners and verbal affixes. The intermodal preferential-looking paradigm was used in order to verify whether homophonous words would be differently parsed by 18-month-old children (Bagetti, 2009). Later on, the HPP procedure was overpassed by the central fixation (CF) procedure (Cooper & Aslin, 1990), which was used in the study of the early sensitivity to the complementizer and to the long-distance dependency in passive sentences Object identification, picture identification and elicited production tasks have also been used with toddlers and older children to investigate morphological distinctions and syntactic processing abilities. In the next section, some of the results obtained are summarized.

3. Early knowledge and processing abilities

The distinction between closed-class and open-class elements in the constitution of the lexicon can be regarded as a fundamental step in grammar identification across languages (Morgan, Shi & Allopenna, 1996). Amongst functional elements, determiners are particularly relevant for the delimitation of nouns, adjectives and phrases, and for the marking of morphological distinctions in languages such as Portuguese. In a study conducted in LAPAL, the early sensitivity to determiners by infants (mean age 14 months) was investigated in the context of the acquisition of gender, given that the morphological information of gender (as a noun class) is only reliably expressed in the determiner (Name, 2002; Name & Corrêa, 2003; Corrêa & Name, 2003). In that investigation, by means of the HPP technique (Name & Corrêa, 2006/2018), eight short stories (mean duration 41.1 sec) were created in two versions: Normal and Modified. In the Modified condition, the phonological form of the determiners was altered, though in accordance with the phonological pattern of the language. The stories were recorded in a

female voice and presented in a fluent child-direct speech style. (1) and (1') illustrate a normal and a modified story, respectively.[1]

(1) **Um** dia, **uma** formiga andava n**o** galho de **uma** árvore quando **uma** folha caiu em seu pezinho. **A** formiga pediu a**o** passarinho que tirasse **aquela** folha de sua pata. **O** passarinho tirou, mas seu bico machucou **o** pé d**a** formiga. (...)

(1') [**ɔR**] dia, [**are**] formiga andava [**nɔne**] galho de [**are**] árvore quando [**are**] folha caiu em seu pezinho. [**ɛne**] formiga pediu a [**ɔne**] passarinho que tirasse [**ɔfɔpe**] folha de sua pata. [**ɔne**] passarinho tirou, mas seu bico machucou [**ɔn**e] pé d[**ɛne**] formiga. (...)

Even though the total number of infants who finished the activity was small, the majority of them preferred to listen to the stories in the Normal condition, and the mean listening time was significantly longer for the Normal (8, 96 sec) than for the Modified condition (6,94 sec).

According to the procedural model of language development (Corrêa, 2009; 2014), once children are sensitive to the form of the elements in the class of determiners, they have a delimited space in which they can perceive systematic alterations in the phonological form, such as gender and number alterations. Assuming that the speech data is analysed as interface information, children are innately guided to interpret these alterations as possible morphological distinctions encoded by these forms, which will lead them to search for categorical or meaningful distinctions in their social interaction. There is evidence that by the age of two years, children are sensitive to gender alteration of words. In Corrêa & Name (2003), two experiments were reported. In the first one, a word recognition task was used. Children (mean age 23;2 months) were asked to show a picture (in a set of four pictures in a book), to a puppet called Dedé. This experiment aimed to verify whether alterations in the determiner form would affect the word-picture mapping. Four conditions were created, as illustrated in Table 1. Table 2 presents the percentage of correct responses in each condition.

Condition	Sentence

[1] In that study, demonstrative pronouns were included in the class of determiners.

Gender congruent determiner (CONG)	*Mostre* ***a*** (fem.) *bola* (fem.) *pro Dedé.* Show the (fem.) ball (fem) to Dedé *Ache* ***aquele*** (masc.) *carro* (masc.) *pro Dedé.* Find that (masc.) car (masc.) to Dedé
Gender incongruent determiner (INCONG)	*Mostre* ***a*** (fem.) *carro pro Dedé.* Show the (fem.) car (masc) to Dedé) *Ache* ***aquele*** (masc.) *bola* (fem.) *pro Dedé.* Find that (masc.) ball (fem.) to Dedé
Portuguese complementizer (COMP)	*Mostra* ***se*** *bola pro Dedé.* Show if ball to Dedé. *Acha* ***que*** *carro pro Dedé.* Find which car to Dedé
Pseudo-form (PF)	*Mostre* ***biu*** *carro pro Dedé.* Show biu car to Dedé *Ache* ***gur*** *bola pro Dedé.* Find gur ball to Dedé.

Table 1 - Experimental conditions in the word-recognition task
Source: adapted from Corrêa & Name, 2003

Condition	% correct responses
CONG	92.21
INCONG	76.64
COMP	63.64
PF	66.64
Total mean	74.03

Table 2 - Percentage of correct responses in each condition
Source: adapted from Corrêa & Name, 2003

The figures in Table 2 show that even though children can depict the target word form in all the sentential contexts created, they are sensitive to gender incongruence. The difference between CONG and INCONG; and between INCONG and COMP/PF was statistically significant. These figures also show that an inadequate functional word affects children's performance similarly to a pseudo-form.

The second experiment reported by Corrêa & Name (2003) brought evidence to young children's reliance on agreement (concord) to ascribe a novel noun to a particular (intrinsic) gender class (o-N; a-N, regardless of the thematic vowel in the noun). An elicited production task was used with children younger than three years of age (1;2-2;7; mean ages 2;7) and older than three (3;0 to 5;4, mean age 4;6). They were presented to a short text focusing on pictured novel objects named by a pseudo-name (eg. *depa*). In the end, they would have to tell what had happened with one of those objects; (eg. the

(masc./fem.) *depa* disappeared). In Portuguese, definite articles, demonstrative pronouns or 3rd person referential pronouns are inflected for gender. Hence, any response, even an elliptical one, would require the encoding of the gender ascribed to the noun. The stories presented the pseudo-nouns in three conditions: the gender of the determiner (GD) and the thematic vowel (TV) of the noun were congruent (o, -o; a, -a); GD and TV were not congruent (o, –a; a, -o); the TV was neutral, regarding gender (o/a, –e). Children younger than three were not affected by the congruence between GD and TV. It is then the identification of gender patterns in the determiner and the parsing of a DP (Determiner phrase)[2] that enables the ascription of nouns to gender classes in early language acquisition. It is only later, when gender classes are already constituted, that children associate the gender of the noun with its thematic vowel, based on frequency, which contradicts the commonly held view that this associative strategy is operative in gender acquisition (Karmiloff-Smith, 1979; Pérez-Pereira, 1991) (See Table 3).

Age group (n=30)	GD = TV (o, -o; a, -a)	GD ≠ TV (o, -a; a, -o)	Neuter TV(o/a, –e)
Younger than three	2.9	2.7	2.8
Older than three	3.0	1.9	2.7
Mean	2.97	2.3	2.8

Table 3 - Mean correct ascription of gender to novel nouns (max. score = 3)
Source: adapted from Corrêa & Name, 2003

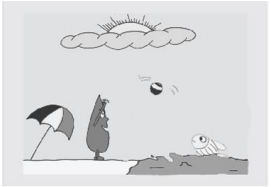
Results in a similar trend were obtained with animate nouns, whose gender may be intrinsic (as in *mulher* (fem.); *homem* (masc.); *vaca* (fem.); *boi* (masc.)) or optional (as in *menino/-a*; *gato/-a*), in which the thematic vowel –o is substituted by the feminine morpheme –a (marked gender, from a grammatical point of view). In a study conducted with children acquiring BP and European Portuguese (EP), a short story was created with novel animate characters named with novel (pseudo) nouns (which might have either intrinsic or optional gender) (Corrêa, Augusto & Castro, 2011).

In this study, the novel animate character and a known animal were presented. A Who-question, asked at the end of the story, required children to refer to the novel character. As in Corrêa & Name (2003), there were three conditions in which the gender of the determiner was correlated, non-correlated or neutral in relation to the noun ending. Figure 1 illustrates the sort of stimulus used.

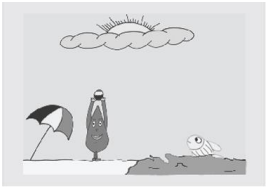
[2] The traditional NP (noun phrase) constituent was reanalysed in the generative theory as DP (determiner phrase), in the light of the arguments in Abney (1987). Hence, whenever DP appears in the text, it refers to the nominal domain.

Aqui tem um dabo; uma dabo; um/uma dabe. (Here there is a (masc./fem.) dabo/dabe)

e aqui tem um peixe. (and here there is a fish)



O/a dabo/dabe e o peixe estão jogando (BP)*/a jogar* (EP) *bola* (The (masc./fem) dabo/e and the fish are playing ball at the beach)



Quem pegou a bola? (Who has caught the ball?)

Figure 1 – Images to elicit the production of the gender of a novel noun
Source: in Corrêa, Augusto & Castro (2011)

The results suggested that, in both BP and EP, 2- and 4-year-old children rely on the gender information in the determiner when referring to the newly introduced character. They appear to make use of the same algorithmic procedure that seems to apply to inanimate nouns, even though, unlike Correa & Name's results, 2-year-olds were affected by the mismatch between determiner and noun. Animate nouns made the feminine condition more vulnerable in comparison with inanimate nouns. There were more target responses to masculine than to feminine nouns (Mean = 2.43, SD = 0.79, for masculine; Mean = 2.02, SD = 1.11, for feminine nouns). Notice that in the latter, the noun ending –a can either be a thematic vowel (when gender is intrinsic) or a feminine gender morpheme (when gender is optional). Young children seem to be sensitive to the marking of conceptual (optional) gender, as suggested by some responses in which there were alterations in the –o and in the –e noun endings with a feminine determiner. Optional gender would be predicted to impose more demands on the syntactic computation, in so far as it would require an additional functional category (Halle & Marantz, 1993; Noyer, 1997). Children's performance with animate nouns in comparison with inanimate nouns seems to reflect this additional burden.

Young children's sensitivity to systematic alterations within the determiner category, which leads to the search for an interpretable distinction at the semantic interface, can also be noticed with regard to grammatical number. In a study conducted with children acquiring BP (Corrêa, Augusto & Ferrari-Neto, 2005; Ferrari-Neto, 2008), later replicated with children acquiring EP (Castro et al., 2009), by means of a picture-identification task, 18 to 30 months old children (mean age – 25 months) had to identify the referent of a DP with a pseudo-noun in four conditions: redundant plural (the –s morpheme attached to the determiner and to the noun, eg: *os dabos*); non-redundant plural (the –s morpheme attached only in the determiner, eg: *os dabo*); pseudo-plural suffix, which may occur in the production of children acquiring Portuguese (the –s morpheme only in the noun, eg: *o dabos*); and pseudo=plural infix (the –s morpheme at the coda of the first syllable, eg. *o dasbo*). Children had to show a puppet (Dedé), the referent of the critical DP in a set of 4 pictures in a book. Figure 2 illustrates the material used. Since the noun was a pseudo-noun, it was only by means of the plural morpheme that the target referent could be identified.

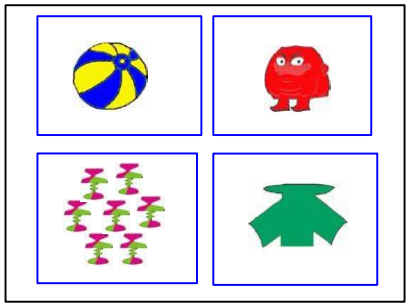


Figure 2 - Visual material to the identification of the referent of a plural DP with a novel noun
Source: Correa, Augusto & Ferrari-Neto (2005) and in Castro et al. (2009).

The results showed that BP-speaking children rely on the number information provided by the determiner both in the redundant and non-redundant plural condition, whereas EP-speaking children gave more correct responses in the redundant condition (since the marking of number in the noun is optional in the non-standard varieties of BP, but not in EP). There were, nevertheless, more correct responses in the non-standard condition than in the pseudo-plural suffix condition in both varieties, which suggests that the crucial number information is provided by the determiner. Hence, these results are compatible with the view that once alterations in the elements of the determiner classes are perceived, children are compelled to provide an interpretation to them at the semantic interface, thereby pairing the phonetic and the semantic interface information.

The early ability to rely on determiners in an agreement relation suggests that a branched DP can be parsed. What about a non-branched DP? That is, a personal pronoun whose grammatical features are maximally projected (DP) in the syntactic structure. Would children distinguish minimal and maximal projections of D? A study in the intermodal preferential looking paradigm, conducted in the context of Bagetti's thesis in LAPAL (Bagetti, 2009), investigated whether young children (17- to 23-month-olds) (mean age 21 months) differentiate homophonous words (*pinto* (noun); *pinto* (verb); *brinco* (noun); *brinco* (verb); *mato* (noun); *mato* (verb), based on the form of the determiner (Eg. **O** *brinco da boneca* vs ***Eu*** *brinco de boneca*). Fig. 3 presents the sort of visual material used and the corresponding stimuli. The visual fixation time for the visual stimulus corresponding to the noun and to the verb conditions was significantly longer than for the competing image, suggesting the early differential recognition of the minimal and maximal projections of D (See Bagetti, 2013 for the detailed analysis).

Olha! O pinto na mesa!
Look! The chick on the table!

Olha! Eu pinto a mesa!
Look! I paint the table!

Figure 3 - Visual stimuli to an intermodal preferential-looking task

Source: Bagetti (2013)

Other studies conducted in LAPAL concerning the role of D delimitation of noun and adjective lexical categories, and in the encoding of definiteness and genericity, considering the possibility of bare nouns in BP, can be found in Teixeira & Corrêa (2008), Teixeira (2009); and in Augusto & Corrêa (2005), Augusto (2007) and Augusto & Corrêa (2007), respectively.

Evidence for the more subtle early perception of grammatically relevant information at the phonetic interface stems from a study of verbal affixes (Bagetti & Corrêa, 2011). Verbal affixes in Portuguese encode grammatical distinctions pertaining to Person, Number, Tense, Aspect and Mood. The recognition of the morphophonological patterns of these elements is therefore the first step for the representation or specification of a number of functional categories. Moreover, early sensitivity to the pattern of bound morphemes would be expected to enable the processing of subject-verb agreement in the second year of life. In this study, the HPP procedure was used. Children were presented with short stories in a fluent child-direct speech style, as in Name & Corrêa, (2003). One normal and two modified versions were created. Phonological alterations not affecting the syllable pattern were made in verbal affixes. The same alterations were made in nominal roots. About 20% of the verbs (verb affixes) and nouns (nominal roots) were altered in a balanced manner. Whereas the alteration in verbal affixes resulted in unrecognizable verbal forms, the same alterations in nominal roots gave rise to possible novel nouns. (2), (2') and (2") present the three versions of a test story.

(2) Normal: O rei descobriu uma lagoa e estabeleceu uma lei: - É só minha! O plebeu
partiu e o besouro não mais se banhou. O hebreu enfureceu-se e mandou secar a lagoa. O rei se arrependeu. O hebreu mandou encher a lagoa (...)

(2') O rei desco'br[ɜy] uma lagoa e estabele['sɔR] uma lei: - É só minha! O plebeu par['tɜy] e o besouro não mais se bann['un]. O hebreu enfures['ɔR]-se e mandou secar a lagoa. O rei se arrepend[ɔR]. O hebreu mand[un] encher a lagoa (...)

(2") Root mod: : O 'rɔw descobriu uma lagoa e estabeleceu uma 'lɔw: - É só minha! O ple'bɔR partiu e o be'zurro não mais se banhou. O he'brɔR enfureceu-se e mandou secar a lagoa. O 'rɔw se arrependeu. O he'breɔR mandou encher a lagoa (...)

Infants from 9 to 12 months old (mean age: 10;0) and from 14 to 18 months old (mean age 16;0) were tested. It was expected that children would be sensitive to alterations in the closed class elements (bound morphemes) but not in the nominal roots. This prediction was confirmed. There were significantly shorter listening times to the version in which the verbal affixes were modified than in the normal version (Mean 7.03 sec (Normal) vs 5.48 sec (Affix modified) in the 10-month-old group; 6.77 sec (Normal) vs 5.02 sec (Affix modified) in the 16-month-old group). The difference between the normal version and the version modified in the nominal roots was not significant in both groups. The difference

between the two modified versions was also significant in the youngest group, but not in the oldest one. It may be due to the fact that the pseudo-nouns obtained in the condition modified in the nominal roots had stressed syllables with open diphthongs, whose frequency in the language is low. Older children may, therefore, be sensitive to this fact.

The HHP technique has been progressively surpassed by the Central fixation one. The more recent studies with infants and toddlers in LAPAL made use of the latter. These involved the early recognition of the interface information regarding the long-distance dependency held between the auxiliary verb (a functional element) and a participial form in passive sentences, and the early perception of recursive sentential structure, as part of a broader investigation on recursion and its possible role in the development of higher order cognitive functions.

Regarding passives, the sort of interface information that enables the possibility of voice to be identified as a contrasting feature of the language is the presence of patterns of AUX-participle relations (ESTAR-participle for adjectival passives, and SER-participle for verbal passives).

The literature on the acquisition of passives either presents evidence in favour of the view that it is a late achievement dependent on maturation (Borer & Wexler, 1987; Snyder & Hyams, 2015, among others) or that some conditions may prevent children from expressing their grammatical knowledge (Crain, Thornton & Murasugi, 1987/2009; O'Brien, Grolla & Lillo-Martin, 2006; Bencini & Valian, 2008). The development of the ability to parse and produce sentences in which the theme/patient occupies the subject position had not, however, been the focus of the studies on this topic.

Lima-Junior (2016) presented results of experiments with infants, children and adults that support an acquisition procedure based on the early recognition of the long-distance dependency between the auxiliary and the participial form, in which the distinction between the auxiliaries *ser* and *estar* can be detected by three-year-olds, with lower processing cost for adjectival passives in relation to the verbal ones, even in adulthood (see also Lima-Junior & Augusto, 2013; Lima-Junior et al., 2018). Felicitous discourse conditions, such as when the subject of the sentence maintains or reintroduces the discourse topic, facilitate the parsing of agentive passives with an animate subject and their production under priming by 3-year-olds (Lima-Júnior, Corrêa & Augusto, 2018). For the present purposes, the investigation concerning the early ability to detect a discontinuous dependency that can be grammatically relevant will be considered.

The experiment reported in Lima-Junior & Correa (2018) made use of the central fixation technique in order to verify whether the crucial data for the identification of passive voice in the language, namely the AUX-participle complex, would be detected at the phonetic interface by young children, as revealed by their listening times. In Santelmann & Jusczyk (1998), infants between 15 and 18 months had been exposed to sentences expressing dependency between Auxiliary (BE) and gerund (as in Grandma is singing) in contrast with an Auxiliary-gerund in an ungrammatical configuration (as in *Grandma **can** sing**ing***), and there was evidence that children are sensitivity to the ungrammaticality of the latter. The same rationale applied to the study with passives conducted in LAPAL. The auxiliary (SER) + participle dependency was contrasted with an ungrammatical sequence in which the verb following the auxiliary was inflected in the Portuguese equivalent to the Past continuous tense in English

(*Pretérito imperfeito* in Portuguese). Two types of stories were created: normal and modified. In the modified version, instead of the participial inflection –do in the main verb, the inflection –va was used. (3) and (3') below illustrate the test material.

(3) Normal: *Quando entrou em casa, a formiguinha falou: O chão do meu quarto* ***foi*** *molh****ado****. Na cozinha, o garfo* ***foi*** *bab****ado*** *pelo meu amiguinho. Em cima da pia, o queijo* ***foi*** *agu****ado*** *e o melão* ***foi*** *cort****ado****! Não dá pra acreditar! O fogão* ***foi*** *quebr****ado****... (...)*
(3') Modified: *Quando entrou em casa, a formiguinha falou: O chão do meu quarto* ***foi*** *molha****va****. Na cozinha, o garfo* ***foi*** *baba****va*** *pelo meu aminguinho. Em cima da pia, o queijo* ***foi*** *agua****va*** *e o melão* ***foi*** *corta****va****! Não dá pra acreditar! O fogão* ***foi*** *quebra****va****... (....)*

The participants were divided into two age groups (13 to 15 months; mean age 14;8; 17-20 months; mean age 18;14 months). There were significant effects of age (longer listening times in the oldest group) and type of story (longer listening times for the normal version), though it was in the oldest group that this difference reached significance. As in the case of the present continuous tense in English, the long-distance dependency between the auxiliary and the verb affix in Portuguese passives could be detected by 18 months of age.

Another early ability that has been investigated by means of the central fixation technique concerns the detection of interface information regarding recursion. It is well known that recursive operations characterize the language computational system, and it can be assumed that this system operates recursively as soon as it is bootstrapped. However, languages vary regarding the syntactic nodes that admit recursive operations and their interface expression. Longitudinal studies with production data reveal that children start producing recursive multi-clausal structures after 24 months and that it is by 30-36 months that complex syntax becomes evident in their speech (Bowerman, 1979; Diessel, 2004; see Grolla, 2009 for illustrations with BP data).

Production in the target language necessarily presupposes the identification of the grammatical means of expressing these grammatical relations. In Portuguese, the complementizer *que* introduces completive clauses and relative clauses (behaving, as a relative pronoun in the latter). The study by Teixeira & Correa (2018) does not present evidence that at the end of the first year of life (10 to 15 months) infants are sensitive to the complementizer as they are to verbal affixes, though they seem to be sensitive to the pattern of sentences with completive clauses.

The set of experiments with infants and toddlers conducted in LAPAL provides elements for a procedural theory of language acquisition that incorporates general principles of data analysis in the identification of patterns, and a domain-specific ability to ascribe grammatical relevance to these patterns. That is, the ability to interpret these patterns as interface information, giving rise to the representation of formal features in the elements in the lexicon upon which universal recursive syntactic operations apply.

4. Recursion, movement and high-cost sentences

Recursive operations and syntactic movement have been a main concern of the authors since their earliest investigations – the acquisition of relative clauses, for the first author (Correa, 1986; 1995a; 1995b); the structure of factive sentences for the second one (Augusto, 2003; 2009). In the research program developed in LAPAL, recursion, movement and its implications for processing cost in language acquisition gave rise to a number of joint works both concerning typical language development and the tracking of DLD (Developmental Language Disorder).

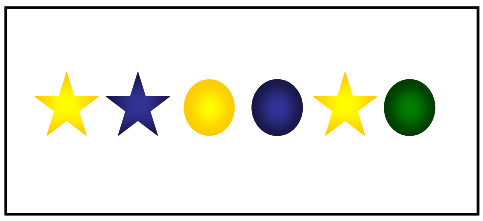
Regarding typical language development, the possible role of recursion in the development of higher-order cognitive functions was particularly considered. For the sake of space, we will only refer to Corrêa, Augusto, Marcilese & Villarinho (2015), which brings together the results of joint thesis supervisions on recursion in language and numerical systems (Marciles, 2011); and recursion in language and the development of second-order false beliefs (Villarinho, 2012). In the referred chapter, embedded nominal modifiers (the second green ball) and complement sentences of mental verbs (John thinks that there is a unicorn in the park) are explored, based on the online model of syntactic computation presented in Corrêa & Augusto (2007).

This integrated model focuses on online computation, whose operations required in the syntactic formulation of sentences in production, and in sentence parsing during comprehension, correspond to the operations of the language computational system characterised in the MP (namely, Select, Merge, Agree, Move (Merge+Copy)). Unlike a grammatical derivation, online computation assumes an interaction between the lexicon and conceptual/intentional systems. Speech intents and message plans would give rise to the lexical array, recovered from the mental lexicon, from which a linguistic computation departs in sentence production. In comprehension, it is the recognition of lexical units in an input string that would give rise to the linguistic computation. Another relevant aspect of this online model of syntactic computation is the alteration of the directionality of derivation, as a means of coping with the requirements of left-to-right incremental processing. A bidirectional assembling of syntactic objects is proposed, in which functional nodes give rise to top-down derivations of syntactic skeletons in which bottom-up derived syntactic objects stemming from lexical nodes are attached.

In Corrêa et al. (2015), an experiment on children's comprehension of recursive nominal modifiers is reported. Previous studies had shown that 3 to 6-year-old English-speaking children (mean age 5.1) parsed these embedded structures as conjoined ones when requested to show the particular referent described by a complex DP with an ordinal modifier in a row, as exemplified in Figure 4 (Matthei 1982). Moreover, it has been argued that the conjoining clauses (direct recursion) would precede "real" (indirect) recursion in language development (Roeper, 2011).

Biased: Mostra pra mim a terceira estrela azul.

Show me the third blue star (the third star blue in BP).



Unbiased: Mostra pra mim a segunda estrela amarela

Show me the second yellow star (the second star yellow in BP)

Figure 4 - Visual material in the two conditions for a recursive modifier
Source: Marcilese (2011), Corrêa et al. (2015)

We pointed out, alternatively, that children may not refrain from relying on the immediate incremental parsing of the input, thereby providing the first response that seems to match the picture, even if their grammar generates recursive structures. An eye-fixation experiment with adult speakers of BP (Marcilese 2011; Marcilese et al. 2013) suggested that immediate eye-fixations were not congruent with the pointing answer in this kind of task. Two conditions were considered: simultaneous presentation of the linguistic input and the visual input; or sequential presentation of the visual input. Results showed that the simultaneous condition led to more fixations on the critical ordinal position, suggesting that this position was searched for by the adults under incremental parsing but inhibited by the complete parsing of the sentence.

A sequential presentation of the visual input was then used in the experiment with children. Forty-seven BP-speaking children aged 4-6 participated in the experiment. Although children were affected by the visual array and their performance did improve with age, the number of correct responses was well above chance, except for the 4-year-old group in the biased condition, and the performance of 6-year-olds was almost at ceiling. It seems then that children, like adults, try to accomplish sentence-picture matching as they parse the sentence incrementally. Unlike adults, however, they seem to have an underdeveloped ability to inhibit immediate parsing. This reasoning can be made explicit in the online model of syntactic computation proposed, in so far as it allows for incremental parsing from left to right.

Regarding false beliefs, the online model of syntactic computation presented in Correa & Augusto (2007) enabled us to show that being able to keep a main clause active in working memory, while complement clauses are analysed and semantically interpreted, is crucial for a false belief judgement to be elicited.

In complex sentences, during a left-to-right scanning of a sentence, the ascription of a truth value to the main clause has to be delayed until the complement clause is processed and a truth value is attributed to it, independently (that is; the truth value of the complement clause should not interfere on the ascription of a truth value to the main clause). The fact that two truth values have to be assigned at the end of the sentence – one for the complement clause, and another for the main clause, reflects the kind of reasoning false beliefs require, which is undoubtedly costly. This cost is amplified with

second-order false beliefs (eg Maria believes that Pedro thinks that the unicorn escaped), whose expression by means of recursively generated clauses is made precise, thereby facilitating comprehension.

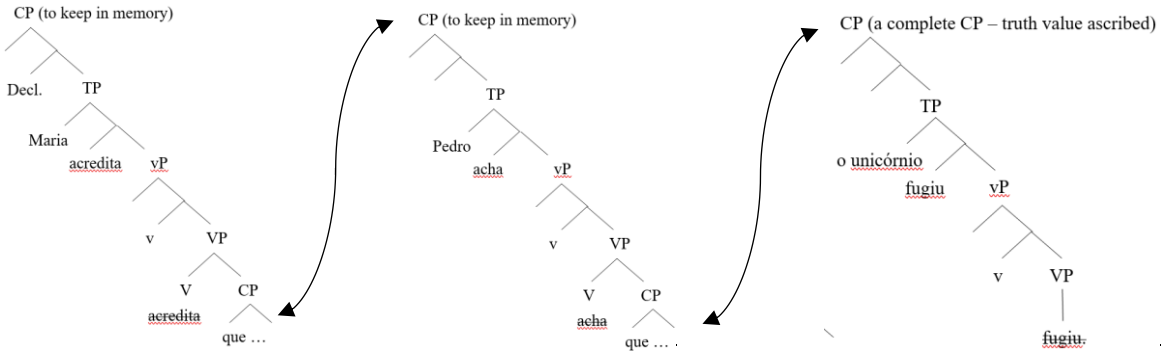


Figure 5 - Second-order belief complex sentence
Source: elaborated by the authors

Recursive operations and long-distance dependencies impose demands on the working memory system, which may require an interplay between language development and the development of abilities not specific to the language domain. Coping with these highly costly processing demands can be particularly difficult for children whose language behaviour is suggestive of DLD (Correa & Augusto, 2011). In the next section, we refer to some specific results obtained with schoolchildren in the tracking of DLD.

4. Processing cost in the tracking of DLD

DLD (Developmental Language Disorder) is identified when language development in children does not follow the usual course despite typical development in other areas, that is, these language difficulties cannot be explained by an associated biomedical condition, such as neurological deficits, cognitive delay, hearing disabilities, and emotional or behavioural problems (Leonard, 1998). The term DLD has recently been endorsed for use in the CATALISE Consortium (Bishop et al., 2017), thereby replacing the previous well-attested term SLI (Specific Language Impairment), even though the exclusion diagnosis criteria have been relaxed.

The literature refers to subtypes of DLD/SLI (Friedmann & Novogrodsky, 2008), depending on the different domains of language that are exclusively or predominantly impaired, such as word finding, phonology, morphology, syntax, semantics, and pragmatics. Syntactic DLD is one of the most studied subtypes and has been the main focus of the research conducted at LAPAL. Syntactic difficulties are usually reported for historically unrelated languages and include problems with verbal and nominal

morphology, as well as with more complex structures, such as passive sentences, WH-questions and relative clauses.

In LAPAL, the interest in DLD gave rise to the development of a battery of tests, the MABILIN (*Módulos de Avaliação de Habilidades Linguísticas*) for the tracking of language impairment in school-children (Corrêa, 2000). It has been used in a number of investigations, focusing on syntactic, morpho-syntactic abilities and on the grammar-pragmatics interface. The tracking of language impairment in schoolchildren has been achieved based on the testing of children from 7 to 13 years old in different public schools in the south, north and west zones in Rio de Janeiro, in the great Niteroi area and some in the great Brasilia area. The reference values for the identification of language impairment in the syntactic domain have been obtained with about 300 children. The battery includes three modules: 1. Syntactic (focusing on structures that have been shown to be costly across languages); 2. Morphosyntactic (focusing on gender and number grammatical marking in the DP; person/number agreement in the TP, taking into account variation in BP); 3. Grammar-pragmatics interface (focusing on intentional information expressed in the functional categories, such as definiteness and reflexiveness), still under development.

Some basis for decisions concerning the sort of grammatical contrasts that are worthy of including in the MABILIN battery and the most suitable methodology for the assessment of abilities pertaining to the grammar-pragmatics interface are discussed in Longchamps (2014), Ribeiro (2019) and Corrêa, Ribeiro and Longchamps (2022). Based on minimalist assumptions coupled with the notion of ostension from Relevance Theory (Wilson & Sperber, 2004), the research conducted at LAPAL has considered that the locus of language-specific pragmatic problems would stem from problems with formal features of functional categories pertaining to this interface, such as definiteness, verbal aspect and mood (Longchamps & Corrêa, 2014; 2016; Corrêa et al. (2022)). Some implications for the assessment of language abilities in the spectrum of autism were also explored (Corrêa, Ribeiro & Perelmuter, 2020; Corrêa et al. (2022)).

The Syntactic Module is, nevertheless, the most extensively developed and used.[3] The initial assessment of syntactic processing abilities is conducted by means of a picture-identification task, with the visual material presented on a computer screen.[4] This comprehension task includes active reversible sentences, reversible and irreversible passives, subject and object WH (who and which) questions, and subject and object right-branching and centre-embedded restrictive RCs, the latter with transitive and intransitive verbs in the main clause – a total of 13 sentence types, each of them with eight trials. Figure 6 illustrates the material used in the evaluation of the comprehension of relative clauses (e.g. Show the butterfly that the rabbit painted.) and WH and WH+N (which) questions (e.g. Which butterfly did the bee wet?):

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[3] Module 1 was extended to European Portuguese (EP) (CORRÊA et al., 2017) and adapted to Rioplatense Spanish (DOTTI et al., 2018).

[4] The syntactic module is available for researchers and speech therapists in https://mabilin.biobd.inf.puc-rio.br.

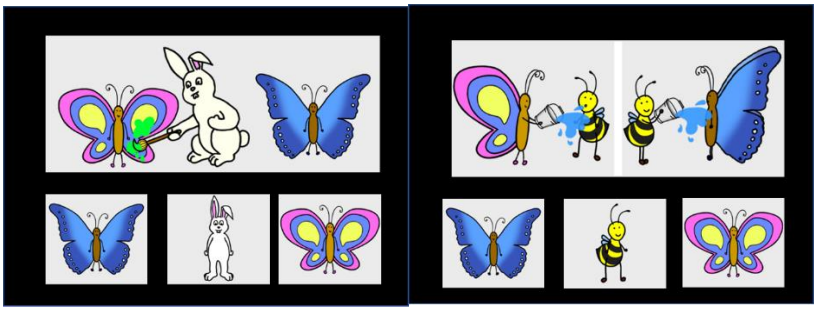

Figure 6 - Material used in MABILIN – Module 1.
Source: Correa, 2000 and https://mabilin.biobd.inf.puc-rio.br/

Assuming the procedural approach to language acquisition and the model of online computation grounded on minimalist assumptions presented here (Corrêa 2012, 2014), it is possible to identify the kind of interface information that promotes the automatic assembling of these structures, enabling comprehension (Corrêa & Augusto, 2013) and to estimate the cost related to each kind of sentence. It has been assumed that children at risk of DLD may have trouble identifying this kind of information or conducting the procedures such information triggers in an effective way. Possible causes underlying DLD in the course of language acquisition have been explored (Corrêa & Augusto, 2011; Corrêa, 2014).

The focus of these studies has been on the three kinds of structures usually impaired in DLD, as already mentioned: passives, relative clauses and Wh-interrogatives. These structures involve what has been termed *movement* of constituents in the generative approach. The online model of syntactic computation takes movement to be a cost operation in so far as elements must be retained and associated with their canonical position in comprehension.

An initial assessment of the language comprehension abilities of 289 school children (7–10 years old) provided data, which confirmed that the most demanding structures were the following: reversible passives, object WH-N questions, object right-branching relatives, and object centre-embedded relatives (Corrêa, Augusto & Bagetti, 2013). The MABILIN software indicates the sentence conditions in which the child's performance is 2 standard deviations below the mean of their age and the degree (moderate, expressive, very expressive) of the overall difficulty in the test, based on the number of conditions in which the child's performance was below the standard.

As for passives, even though children can detect the interface information that is relevant for the processing/acquisition of passives from an early age (section 3), in comprehension tasks, young children tend to assume that the subject of the sentence is the agent. They may also adopt a semantic strategy trying to establish some logical relation between the referents and the action, which may lead to a successful interpretation result for irreversible passives, but not for reversible ones. Hence, development requires that the ascription of a thematic role to the subject is delayed until the recognition of the Auxiliary+participle complex. An optional PP (Prepositional phrase) may be yet assembled, which receives the role of the agent of the passive. As for production, the encoding of a DP (nominal

constituent/argument), which does not play the role of an agent in some event, accounts for the additional cost of the passive voice. However, as it has been previously observed, children are able to produce passives when primed by the passive structure in a game that satisfies felicitous discourse conditions (Lima Junior, Correa & Augusto, 2018). DLD children may have more difficulties in overcoming the complexities related to the passive structure.

As a means of intervening in children's difficulties in the syntactic domain, Corrêa, Augusto and Bagetti (2022) presented the ProMetaS – a syntactic metalinguistic procedure. This intervention procedure focused on passives and relative clauses. For passives, the metalinguistic procedure called attention to the presence of the Aux+Part verb, as well as the necessity of relating the element in the position of the subject with the position of the object of the verb in order to interpret it adequately. That is, visual material highlights the fact that the subject DP has to be interpreted as a theme and not as the agent. An example of a slide used is given in Figure 4:

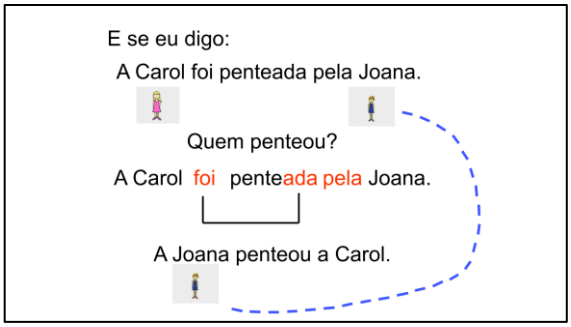

Figure 7 - Slide used in ProMetas to illustrate thematic roles in passive and corresponding active sentence
Source: Correa et al. (2022, p. 368)

Twenty-one children at risk of DLD according to the standards of MABILIN have been submitted to the ProMetaS and subsequently retested. Sixteen children out of those twenty-one showed significant improvement on the second assessment, which amounts to 76,2% of the participants, suggesting that the procedure is likely to be effective in improving the syntactic processing abilities of children at risk of DLD.

Relative clauses and WH-interrogatives are also highly demanding sentences, which also impose a considerable computational cost. Both structures involve an element in the left periphery of a clause (in bold in the examples below) that has to be associated with its canonical position (marked ___), where it is required by the verb. In this respect, object structures (5) are considered harder to acquire/process than subject ones:

(4) a. This is **the boy** that ___ called the teacher.
b. **Which boy** ___ has called the teacher?

(5) a. This is **the boy** that the teacher called ___.

b. **Which boy** did the teacher call ___?

As already mentioned, object WH-N questions, object right-branching relatives, and object center-embedded relatives were amongst the most demanding structures tested in the MABILIN in the initial assessment of the language comprehension abilities of 289 school children (7–10 years old) (Corrêa, Augusto & Bagetti, 2013). Children identified as at risk of DLD usually resort to a number of cost-reducing strategies in the production of these structures (Corrêa, Augusto, Bagetti & Longchamps, 2015; Corrêa & Augusto, 2021).

Correa and Augusto (2021) showed that cost-reducing strategies for relative clauses include, for example, the use of passive subject relatives (the boy that was pushed by the girl) instead of direct object relative clauses (the boy that the girl pushed), the use of chopped and resumptive strategies (the girl I gave the book (to her) A *garota que eu dei o livro (pra ela)*[5]) instead of standard indirect object relative clauses (the girl to whom I gave the book A *garota para que meu dei o livro*[6]) and simpler clauses (the girl with the book). These strategies are used both by typically developing children and DLD children. Although the use of these strategies may largely bring groups together, children at risk of DLD produce more truncated/inappropriate responses, showing that the overall quality of the responses can distinguish language-impaired children.

Correa et al. (2015) showed that cost-reducing strategies are also resorted to when WH+N questions are elicited as, for example, the use of pronouns as subjects (Which book does he prefer? *Que livro ele prefere*? [7]) instead of full DPs (Which book does the boy prefer? *Que livro o menino prefere*?) in object WH+N questions, the use of WH in situ (He prefers which book? *Ele prefere que livro*?), simpler yes-no interrogatives (Does he prefer this book? *Ele prefere este livro*?). As referred to for relative clauses, the difference between typically developing children and children at risk of DLD is in the use of inadequate and ungrammatical sentences in these tasks.

From a methodological point of view, the specific task demands must be considered when the nature of children's difficulty is characterised. In Correa (1986; 1995a/b), it was shown that by altering the demands of the acting-out task, by presenting two possible referents to the head noun (a correct and an incorrect one), 3-year-old children demonstrated to treat relative clauses differently from co-ordinated clauses, in so far as they distinguished the main clause in sentences with subject centre-embedded relatives (6) from sentences with subject right-branching relatives (7).

(6) The horse that kicked the cow jumped over the fence.
(7) The horse kicked the cow that jumped over the fence.

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[5] In Portuguese, the relative marker/pronoun *que* cannot be deleted.

[6] In Portuguese, preposition stranding would not be allowed.

[7] Unlike English, Portuguese does not require an auxiliary and its movement in interrogative sentences.

By the same token, the picture-identification task can be made more felicitous by presenting two possible referents to the head noun, as it is conducted in MABILIN (Figure 6), unlike the widely used picture-identification tasks, in which children have to choose one of two pictures of the same characters in reverse thematic roles. In any case, in a picture identification task, the image itself can impose an additional burden on the task (Correa; Rodrigues; Augusto, 2022; Correa & Augusto, 2019; Rodrigues et al., in press). In Rodrigues et al. (2023), the comprehension of right-branching relative clauses and WH+N questions in MABILIN was analysed as a function of image complexity. Two inhibitory control (IC) tasks (child`s versions of the Flanker and Go/no-Go tests) were applied, in so far as the sentence-image mapping requires inhibiting an immediate response until the images are fully analysed, which can be harder when the two images have two characters in reverse thematic roles (Figure 6). A positive correlation between children's overall performance in the language test and the IC tests was obtained. Moreover, children`s performance in the analysis of complex images was positively correlated with IC abilities. These results suggest that demands of the sentence-mapping process in linguistic tasks can be crucially dependent on IC and, regarding language assessment, children's difficulties in the simple image conditions would be more likely to directly reflect a specific language impairment. These results contribute to the discussion concerning the nature of the difficulty that the costly structures considered here impose on children – difficulties restricted to the processing of syntactic movement in the presence of an intervening element (Friedmann, Belleti & Rizzi, 2009), difficulties that stem from the sentence-mapping process or from the interactions of syntactic and visual analyses. The theoretical issues regarding domain-specific effects can be found in Correa, 2020; Augusto & Correa (2023).

5. For the sake of conclusion

In sum, bringing together a psycholinguist approach to language acquisition and a minimalist conception of language seems to contribute to characterising how grammatically relevant information is identified in the language input (understood as interface information) and represented as formal features of lexical items. The sort of approach to language processing and acquisition pursued in LAPAL also seems to have contributed to clarifying how recursion in language may affect and be constrained by cognitive development. Finally, distinguishing the nature of the demands that processing tasks may impose in the course of language acquisition and in the assessment of children's performance can contribute to characterising domain-specific and non-specific requirements for the full achievement of language processing abilities.

Additional Information

Evaluation and author's answer

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EVALUATOR 1

O presente trabalho precisa de revisão.

Revisar o resumo, contemplando: objetivo, relevância do tema, metodologia e resultados finais.

Verifique o objetivo do resumo com objetivo da introdução.

Conflict of Interest

The authors have no conflicts of interest to declare.

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