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Priming Prepositional-Phrase attachment ambiguities in English- and Spanish-speaking children and adults during language comprehension

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Abstract

To better understand language acquisition, researchers have explored the nature and development of children's mental representations of language. However, to this day, children's language development is still unclear. Thus, this thesis is aimed at answering the research question: what is the development and nature of children's syntactic representations and – given that language experience plays an important role in language acquisition (Matthews, Lieven, Theankston, & Tomasello, 2005; Abbot-Smith, Lieven, & Tomasello, 2001) – how are they affected by language experience? To address this question, we used a structural priming paradigm, an experimental method that has been informative about the development and nature of children's language representations (including specific syntactic structures), and the role of language experience. Structural priming occurs when processing a prime sentence facilitates processing a subsequent target sentence with the same structure. Priming effects in the absence of verb repetition between prime and target (i.e., lexically-independent) have been interpreted as evidence of abstract syntactic representations. Priming effects may be enhanced in the presence of verb repetition (i.e., lexically-dependent; the lexical boost) (Pickering & Branigan, 1998), which has been interpreted as evidence for a lexically-specific component in syntactic representations.

Until now, most developmental structural priming research has focussed on studying a limited number of structures during language production in English-speaking children. This is not ideal, as researchers need to understand: (1) whether current theories of language development, and specifically the role of language experience in development, hold across languages (2) if the mechanisms involved in structural priming in language production are the same as in language comprehension; and (3) cross-linguistic differences in how particular syntactic structures are acquired.

This thesis therefore uses a structural priming paradigm to study the influence of recent language experience on the high-attached (HA) and low-attached (LA) analyses of prepositional phrases (PPs) in globally ambiguous sentences during language comprehension (e.g., *The girl is touching the dog with the banana*) in 4- to 6-year-old (Younger group) and 8- to 10-year-old (Older group) English- and Spanish-speaking children and adults. PP attachment ambiguities have been successfully used to understand language comprehension in children

and adults (e.g., Snedeker & Trueswell, 2004), and have been shown to have different cross-linguistic preferences in adults (e.g., Carreiras & Clifton Jr., 1999), therefore allowing direct cross-linguistic comparisons of PP attachment preferences in the absence and presence of a prime in children at earlier and later stages of development, and adults.

Thus, to answer our main research questions about the nature and development of children's syntactic representations we investigate: (a) How does PP attachment develop over time during language comprehension? (b) How does recent experience of syntactic repetition with and without verb repetition affect PP attachment preferences in children and adults? and (c) Do children and adults show effects of cumulative experience?

Studies 1 and 2 used a child-appropriate web-based sentence-picture matching task to investigate the comprehension of PP preferences. We measured whether children chose a picture corresponding to the LA versus HA analysis when they heard a sentence with an ambiguous PP attachment, in the absence of a prime (i.e., baseline condition) or after hearing/matching a prime sentence that forced either an LA or HA analysis and that had the same or a different verb as the target sentence. We investigated whether English- and Spanish-speaking children showed existing and stable abstract representations of the HA and LA analyses when processing globally ambiguous PP sentences. We compared PP attachment preferences during language comprehension between 4- to 6-year-olds and 8- to 10-year-olds, as well as between 4- to 10-year-old children and adults. To better understand how children's language representations were strengthened by experience, we also examined whether the individual language experiences with the HA and LA analyses accumulated within one session in children and adults.

In the baseline condition, English-speaking participants showed an overall preference for HA, however, children showed a stronger HA preference than adults. The Older group showed cumulative effects of experience, by showing an increase in their HA responses as the experiment progressed.

In the presence of a prime, English-speaking participants showed reliable sensitivity to recent language experience. At a session level, they showed a decrease in their overall HA preferences when they were exposed to HA and LA primes, compared to when they were not (i.e., baseline). At a trial level, they also showed reliable lexically-dependent priming effects, but not lexically-independent priming effects. This suggested that English-speaking children's

abstract representations may be more fragile than the adults' and that more power may be needed to detect reliable lexically-independent priming effects. Although participants did not show evidence of a lexical boost, verb repetition between prime and target pairs facilitated the processing of the HA and LA analyses, as suggested by previous studies (Pickering & Branigan, 1998). Participants did not show significant cumulative effects of experience.

In the baseline condition, Spanish-speaking participants showed an overall preference for HA, however, children showed a stronger HA preference than adults. In the presence of a prime, Spanish-speaking children and adults showed sensitivity to recent language experience at a session level by showing an overall decrease in their HA responses when they were exposed to HA and LA primes, compared to when they were not (i.e., baseline). At a trial level, and surprisingly, they showed reliable priming effects when there was no verb repetition between prime and target pairs, but not when prime and target pairs involved the same verb (hence, there was no lexical boost). The Older group showed cumulative effects of experience only when the verb was repeated between prime and target sentences, by showing a decrease in their HA responses as the experiment progressed.

Overall, our findings with English- and Spanish- speaking children are more compatible with early abstraction accounts of syntactic development, which argue that lexically-dependent priming effects should not differ between children and adults.

Study 3 investigated cross-linguistic differences in the representations of the HA and LA analyses between English- and Spanish- speaking participants. In the baseline condition, English- and Spanish-speaking children and adults processed globally ambiguous PP sentences in a similar way. However, in the presence of a prime, only the Older children showed a significant difference in the overall PP preferences by language. This developmentally mediated cross-linguistic difference suggested that, when exposed to LA and HA structures within a session, by the age of 8, it is easier for the English-speaking children to access the LA interpretation for globally ambiguous PP sentences than their Spanish-speaking counterparts. However, by the time English- and Spanish-speaking children reach adulthood, their interpretation of globally ambiguous PP sentences is influenced by recent language experience to the same extent.

Study 4 focussed on answering the question about whether syntactic repetition affected the processing of temporarily ambiguous sentences during language comprehension. We specifically examined whether the processing of an unambiguous prime sentence could eliminate the garden-path effect or facilitate revision mechanisms in temporarily ambiguous target sentences (e.g., *Put the duck on the sock on the star*) in English-speaking adults. Our findings showed that prior processing of an unambiguous prime facilitated garden-path recovery in the ambiguous target sentences.

Taken together, our findings provide novel insight into the nature and development of the language representations of English- and Spanish-speaking children and adults. We have provided evidence that English- and Spanish-speaking children and adults showed reliable sensitivity to recent language experience during language comprehension and that their representations of the LA analysis were not entirely bound to lexically specific items but showed some level of abstraction. However, we did not find the same patterns of structural priming effects in English- and Spanish-speaking children. This suggests that, to better understand language development, future research should continue to study cross-linguistic differences in structural priming paradigms in children.

We also found that when exposed to LA and HA structures within a session, the overall PP preferences may differ between English- and Spanish-speaking 8- to 10-year-olds, However, when native speakers of English and Spanish reach adulthood, recent language experience influences their interpretation of globally ambiguous PP sentences to the same extent.

Lay summary

To better understand language acquisition, researchers have explored the nature and development of children's mental representations of language. However, to this day, children's language development is still unclear. This thesis investigated how recent language experience influenced the way English- and Spanish-speaking children and adults comprehended ambiguous sentences. By better understanding the role of recent language experience in language comprehension, we could learn more about how and when children acquired a particular language structure. To do this, in a language comprehension task, we manipulated the language environment to which children were exposed. In particular, we investigated how the repetition of a sentence influenced the comprehension of a subsequent sentence (i.e., structural priming).

In Studies 1 and 2, we found that English- and Spanish-speaking children and adults were sensitive to the linguistic environment to which they were exposed reflecting changes in the way they interpreted ambiguous sentences.

In study 3, we found that when we did not manipulate the linguistic environment, English- and Spanish-speaking children and adults interpreted ambiguous sentences in a similar way. However, when participants were exposed to our manipulations, we found that the 8- to 10-year-old English-speaking children differed in the way they interpreted ambiguous sentences in comparison to their 8- to 10-year-old Spanish-speaking counterparts. However, these differences disappeared once English- and Spanish-speaking children became adults.

In study 4 we found how the repetition of an unambiguous sentence affected the processing of an ambiguous sentence during language comprehension, reflecting facilitated sentence processes mechanisms.

Our findings provided evidence that English- and Spanish-speaking children and adults were sensitive to recent language experience during language comprehension and that it influenced the way they understood ambiguous sentences.

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1 Priming syntactic ambiguities in children and adults during language comprehension: A review

1.1 Introduction

Understanding language is a task that almost everyone can do quickly, effortlessly and successfully. From a very young age, the language faculty is acquired and mastered, and we rarely fail to comprehend language despite its complexity and ambiguity. Understanding what people say requires using the acoustic input and changing it into a phonological representation that helps us recognise and integrate the spoken words in a sentence. This results in a syntactic and semantic representation that helps us work out the speaker's intention. However, how are we able to process the structure of a sentence and interpret its meaning at a very rapid pace? Moreover, what are the linguistic and non-linguistic factors that influence our syntactic choices during language comprehension?

Research into sentence processing examines how the human processor builds linguistic representations incrementally as a sentence unfolds, and how we arrive at a final interpretation. Understanding a sentence involves integrating multiple sources of information efficiently and on a moment-to-moment basis. Unfortunately, rapid language processing comes with its costs resulting in comprehenders sometimes misanalysing a sentence. Consider the following example:

(1) The man sent the letter was surprised.

If you had difficulties understanding the previous sentence, you have experienced the *garden-path* effect. The garden-path phenomenon refers to when the human parser has reached a point where the interpretation of a sentence no longer makes sense and it therefore needs to employ other mechanisms so a new analysis can disambiguate the structure. The incremental nature of how humans process language, that is, on a word-by-word basis, leads us to occasionally encounter local ambiguities such as (1), and cope with their resolution. For example, when we read (1), we tend to process '*sent*' as the main verb of the sentence and '*the*

letter' as the direct object of '*sent'*. However, as soon as we encounter '*was surprised'* we experience difficulty in understanding the sentence. This results in other processes coming into play leading us to arrive at the final analysis with the correct interpretation. This happens because '*sent'* is considered to be ambiguous since it can be processed as a past participle or a simple past tense verb. Thus, '*was surprised'* should be understood as the main verb of the sentence and '*sent the letter'* as a reduced relative clause (RC) (cf. *The man who was sent the letter was surprised*) (Garrod & Pickering, 1999).

The rapid integration of various sources of information while we process language has been taken as evidence of how interactive the language processor can be. This has led to the development of non-modular accounts that state that the human parser considers all levels of representations in parallel. Serial accounts, on the other hand, propose that sentence comprehension is a two-stage process, in which a modular processor makes initial parsing commitments based solely on syntactic information whereby access to other sources of information (e.g., semantic, contextual) only takes place at a subsequent stage.

The garden-path phenomenon has been extensively examined to inform the field of language processing about how children and adults comprehend sentences. By studying the garden-path effect, we can learn about the different strategies individuals employ to cope with linguistic ambiguities and about the factors that may influence sentence processing.

Factors such as plausibility (Kidd, Stewart & Serratrice, 2010), prosody (Snedeker & Trueswell, 2003; Contemori, Pozzan, Galinsky, & Dussias, 2018), referential context and lexical information (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Trueswell, Tanenhaus, & Kello, 1993; Trueswell, Sekerina, Hill, Logrip, 1999; Snedeker and Trueswell's (2004) have been found to affect ambiguity resolution. However, most of the sentence processing research has focussed on studying the adult parsing architecture, while children's parsing is still an area that is not yet fully understood. For example, we know that by the age of 5, children already have a good command of their native language, and they appear to understand a great deal of information. However, do children represent language and interpret it in the same way as adults? What is the development and nature of children's syntactic representations and how are they affected by recent language experience? Does recent language experience affect children's syntactic choices in language comprehension in the same way across languages?

In this thesis, we address these questions by focussing on how syntactic ambiguities are interpreted by English-speaking and Spanish-speaking 4- to 6- and 8- to 10-year-old children and adults and how their interpretations are affected by syntactic repetition. In particular, we used a structural priming technique to investigate the influence of recent language experience on the high-attached (HA) and low-attached (LA) analyses of prepositional phrases (PPs) in globally ambiguous sentences (e.g., *The girl is touching the dog with the banana*) during language comprehension.

Structural priming refers to when the processing of a sentence affects the production or comprehension of a subsequent sentence. That is, structural priming can increase the likelihood of producing a particular sentence structure or adopting a particular analysis during comprehension (i.e., *target sentence*) as a result of the prior processing of a sentence (i.e., *prime sentence*) (e.g., Bock, 1986; Branigan & Pickering, 2017). For example, after hearing or reading a double object prime sentence (e.g., *The boy gave the girl the apple)*, it will be more likely for an individual to produce another double object structure (e.g., *The boy gave the lady the ball*) than a prepositional object structure (e.g., *The boy gave the ball to the lady*).

By following a structural priming paradigm, in this thesis, we aim to examine the role of recent language experience in children's syntactic choices during language comprehension and to further our understanding about the nature and development of children's mental representations of language.

The present chapter reviews some of the most relevant accounts of syntactic ambiguity resolution and structural priming. We also present a review of the main developmental studies that have cast light on the factors that influence ambiguity resolution in children with a special focus on the role of language experience.

1.2 Ambiguity resolution: Serial vs. Parallel theoretical models

What are the mechanisms that the language processor uses to resolve ambiguity? When two or more analyses are compatible with the interpretation of a sentence fragment, does the processor consider them in parallel or serially? If in parallel, are they all equally important or

are they ranked? These are among some of the questions that psycholinguistic research has tried to address in the field of language processing.

In serial and restricted accounts, also known as syntax-first models, the parser constructs a single structure, usually the main clause analysis (e.g., *The man sent the letter*). It is only when sentence comprehension is unsuccessful that the parser abandons the initial syntactic structure and reanalyses the sentence until it arrives at its final interpretation (e.g., reduced relative ambiguity: *The man (who was) sent the letter was surprised*) (Frazier & Fodor, 1978; Frazier, & Rayner, 1982).

Parallel models, on the other hand, propose that multiple interpretations are activated and evaluated simultaneously. In pure unrestricted parallelism, the parser activates all possible syntactic analyses simultaneously and considers them all to have the same importance (Forster, 1979). For instance, in sentence (1) *The man sent the letter was surprised*, the parser would drop the main clause analysis easily and consider the reduced relative clause analysis instead, without experiencing any effort, since both analyses would be available and assessed in parallel. However, given the difficulty that the parser experiences when processing such reduced relative structures, we know that this account is unlikely to be correct.

Unlike pure unrestricted parallelism, ranked-parallel accounts allow multiple analyses to compete simultaneously and dynamically with each other. Each competing analysis is weighted and ranked based on its level of activation. For example, going back to sentence (1) *The man sent the letter was surprised*, the reduced relative analysis would be backgrounded, and the main clause analysis foregrounded since it is the most natural and frequent one. Once the parser encounters *was surprised*, and realises that the preferred analysis is impossible, then the parser would change the ranking of analyses and shift to the less frequent but ultimately correct activated interpretation. Parallel accounts vary depending on the number of analyses that the parser can maintain, the length of time each analysis lasts, the different mechanisms that the parser employs during ranking, or whether parallelism can be applied under certain circumstances and with certain types of structures. However, to this day, the constraint-based model (explained in the next section) (MacDonald, Pearlmutter & Seidenberg, 1994; Trueswell, Tanenhaus, & Garnsey, 1994) has been the most influential parallel account in the field of sentence processing. In this account, multiple analyses get activated and weighted depending on the compatibility they have with different constraints e.g., plausibility, frequency, prosodic information, contextual information. This compatibility with constraints

is what determines how analyses will get ranked and which ones will become either foregrounded or backgrounded.

1.3 Ambiguity resolution: Theoretical accounts

1.3.1 The Garden-Path Model

In restricted accounts, where parsing is considered serial (a two-stage process), initial decisions are made on the basis of syntactic heuristics that pursue a single analysis at a time. It is only during a subsequent stage that the parser considers and integrates other sources of information and, if necessary, triggers reanalysis processes to arrive at the final interpretation.

The so-called Garden-Path model (Frazier & Fodor, 1978; Frazier & Rayner, 1982; Frazier & Clifton, 1996) is by far the best-known parsing account that assumes serial processing and has been intensely studied over the years. Numerous studies have found evidence of slow language processing when analysing syntactic ambiguities and have taken this as evidence to support this model (e.g., Frazier & Rayner, 1982; Ferreira & Clifton, 1986) This theory was developed based on Fodor's (1983) theory of modularity, which stipulates that the parsing architecture is composed of informationally encapsulated modules. Each of these modules is responsible for manipulating a specific type of information independently. Thus, in the garden-path model, during the initial stage of processing, an autonomous modular parser constructs a structure by taking into account only syntactic information favouring the simplest analysis while ignoring contextual, semantic or frequency-based information. If the first syntactic analysis happens to be incorrect, non-structural information will be considered and recovery mechanisms will come into play to replace the initial analysis.

In the Garden-Path model, the choice of analysis is constructed on the basis of two universal principles for the purpose of reducing memory demands: *Minimal Attachment* and *Late Closure*. In general terms, the Minimal Attachment parsing strategy refers to when the processor attaches new incoming material into the analysis using as few tree structure nodes as possible in order for the parser to build the least complex syntactic analysis. Consider the following sentences (Garrod & Pickering, 1999):

(2a) The student forgot the solution immediately. (direct object analysis)

(2b) The student forgot the solution was in the book. (complement clause analysis)

In (2a) and (2b), after (*the student forgot the solution)*, the sentence can be temporarily ambiguous since (*the solution)* can be interpreted as the object of the verb (*forgot)* or as the subject of a subsequent complement clause. The Minimal attachment principle predicts that the parser will initially adopt the object analysis since it requires fewer tree structure nodes than the complement clause analysis. Once (*was)* is encountered in (2b), the parser will soon notice that the direct object analysis is impossible and that it must reanalyse the sentence.

In contrast, Late closure is applied when both analyses of an ambiguous sentence have the same number of nodes. In this case, the new material must be attached into the structure or clause that is currently being processed, that is, new-arriving information is associated with the most recent clause or phrase. To exemplify this principle, consider the sentences below (Garrod & Pickering, 1999):

(3) As the woman edited the magazine amused all the reporters.

(4) The steak with the sauce that was tasty didn't win a prize.

Sentence (3) causes the parser to misanalyse the noun phrase (NP) (*the magazine) a*s soon as it reaches the verb (*amused)*. The NP (*the magazine)* could be considered either as the object of the verb (*edited)* or as the subject of another subsequent clause. However, based on the Late Closure strategy, the processor chooses (*the magazine)* to be attached to (*edited)* because it is the clause that is currently being parsed. Late Closure is also predicted for sentence (4); however, the parser does not misanalyse this structure. According to the Late Closure principle, in sentence (4), the RC (*that was tasty*) is predicted to be attached to the most recent part of the phrase (*the sauce)*, rather than the NP (*the steak*), as would be predicted by the Minimal Attachment strategy (Traxler, Pickering & Clifton, 1998).

However, in the late 80s, the universality of the Late closure principle started to be questioned when Cuetos and Mitchell (1988) found evidence that the syntactic preferences from more complex NP in Spanish were not the same as in English. Consider (5):

(5)

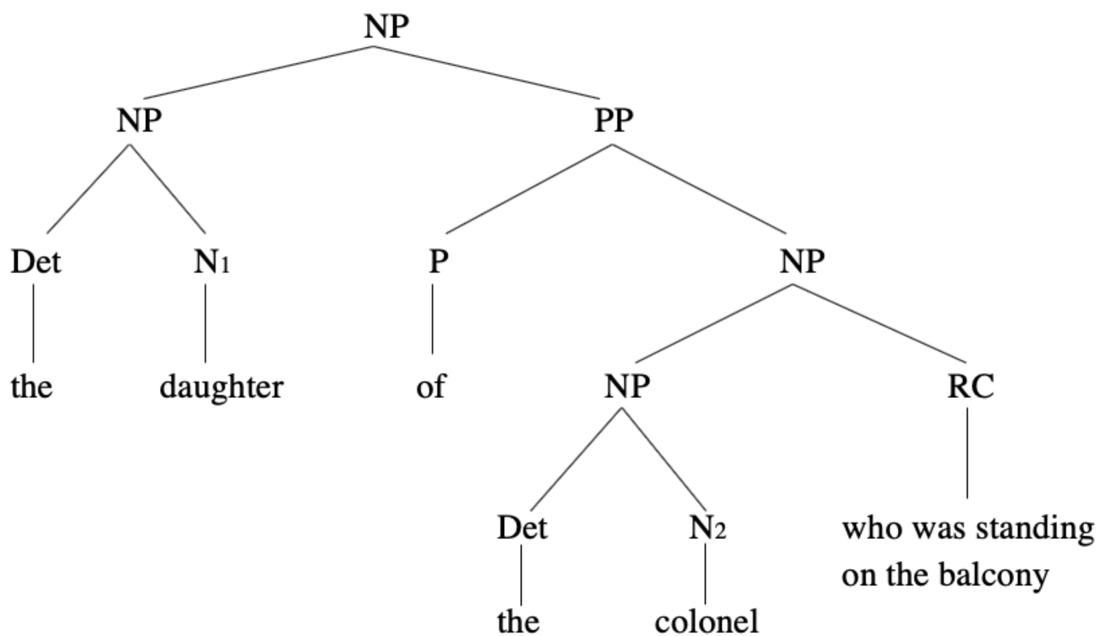

Figure 1. Example taken from Frazier & Clifton, (1996):
(5) 'The spy shot the daughter of the colonel who was standing on the balcony'

In sentence (5), the parser faces the difficult decision as to which of the two host nouns (i.e., *daughter* or *colonel*) to attach the RC (*who was standing on the balcony*). Late closure, also known as a low-attachment (LA) structural preference, predicts attachment to the second NP *(the colonel)* i.e., interpreted as *the colonel was the one standing on the balcony*. Minimal Attachment, on the other hand, predicts a high-attachment (HA) preference, that is, attachment to the first NP (*the daughter)* i.e., interpreted as *the daughter was the one standing on the balcony*. We refer to these attachment preferences as high- and low-attachment because for Minimal Attachment the RC attaches to the first NP (*the daughter*), which is 'high' in the syntax tree, whereas for Late Closure the RC attaches to the second NP (*the colonel*), which is 'low' in the syntax tree.

According to the Garden-Path model, the parser would opt for an LA interpretation for sentence (5). However, as mentioned above, Cuetos and Mitchell (1988) found cross-linguistic differences when native speakers of Spanish showed an HA preference in the majority of cases for these sentences (For a complete review see Cuetos, Mitchell & Corley,1996). These results contradicted the universality of the Late Closure principle leading to numerous studies in Spanish and across other languages e.g., Galician, French, German, Dutch (Dussias, 2003; Fraga, García-Orza & Acuña, 2005; Cuetos & Mitchell, 1988; Carreiras & Clifton Jr., 1999; Aranciba-Gutiérrez, Bizama Muñoz, Sáez Carrillo, 2015; Hemforth et al., 1998; Brysbaert & Mitchell, 1996; Mitchell, Cuetos & Zagar, 1990). Consequently, the Garden-Path model was reviewed (Frazier & Clifton, 1996) and *Construal* was proposed, a new parsing strategy, which accounts for the behaviour of certain non-primary phrases such as RCs (e.g., a constituent sequence of an NP, prepositional phrase (PP) and an RC (NP-PP-RC), as in (5)). (Also see (Grillo & Costa, 2014), who later identified that in some languages such as Italian and Spanish, but not English, such NP-PP-RC constructions could be parsed with an ing-construction rather than an RC to express meaning (e.g., *Vi a la asistenta de la señora que bajaba la escalera.* I saw the maid of the lady that went downstairs *vs*. I saw the maid of the lady going downstairs). That is, sentences that contain genuine RCs can either attach high or low; however, sentences that contain a pseudo-relative only allow for HA because there is no RC but a small clause (SC) (i.e., la asistenta de la señora que bajaba la escalera) that is the complement of the verbal phrase (VP). This could explain why in some languages (e.g., Spanish) a strong preference for HA has been reported (Alonso-Pascua, 2020)).

1.3.2 Construal theory

Construal refers to a syntactic operation where adjuncts *associate* with a thematic domain. Association is not the same as attachment, in the sense that attachment occurs with primary relations, which are found between verbs and their main arguments and are driven by general parsing principles such as Minimal Attachment and Late Closure. Non-primary relations, on the other hand, rather than being attached to a specific site in the phrase marker, are *construed* i.e., associated, with the current thematic processing domain i.e., the most recent constituent that introduced a thematic role. In simpler terms, Frazier and Clifton proposed that for non-primary phrases, such as the NP-PP-RC sentences, the processor is no longer modular, and standard parsing principles do not play any role at all in their resolution; instead,

attachment preferences are governed by a thematic or discourse processor. To illustrate this, consider the following clause (Garrod & Pickering, 1999).:

(6) The girl with the hat that looked funny...

In (6), the preposition *with* is the theta assigner since it introduces a thematic role to the NP (*the hat)*, therefore the current thematic domain is (*with the hat)*. When the following RC (*that looked funny)* is associated with the current thematic domain (*with the hat)*, then only the NP (*the hat)*, will be available to head the subsequent RC, hence, LA is predicted.

In sentence (5) (*The spy shot the daughter of the colonel who was standing on the balcony*), by contrast, *the daughter of the colonel* is considered to be the current thematic domain since the preposition *of* only transmits but does not assign any theta role. Therefore, *colonel* will not be the only available nominal in the current thematic processing domain. Instead (*the daughter of the colonel)* will be taken as a whole and considered to be the current thematic domain resulting in the subsequent relative clause being construed in relation to it. Up until this point, no commitments regarding the two nominals are made. Later on, after taking into consideration discourse information and Gricean principles, LA to the second NP (*the colonel*), will be favoured in the English language, and HA to the first NP (*the daughter*) in other languages such as Spanish (Cuetos, Mitchell & Corley, 1996). The preference for LA for this type of ambiguity in English is assumed to occur as a result of the speaker/writer's intention to be clear following the Gricean Maxim of Clarity. Otherwise, if the speaker had opted for HA, then s/he would have employed the unambiguous pre-nominal form (*the colonel's daughter)* (Frazier & Clifton, 1996).

1.3.3 The Late Closure principle: Explanations for mixed results

As a result of the inconsistent attachment preferences in other languages, Mitchell and Cuetos (1988) proposed the Modifier Straddling strategy to account for cross-linguistic NP-PP-RC ambiguity resolution processing. They suggested that for languages in which attribute adjectives follow a noun (post-modifying e.g., Spanish, French, Italian, etc), the modifier straddling strategy is switched on, and switched off for pre-modifying languages (e.g., English, Dutch) (e.g., Spanish: *la puerta verde* vs. English: *the green door*). The logic behind this account was that in post-modifying languages there is a resulting mechanism that prevails and

operates by associating the noun with the RC when there is an adjective between these two leading to HA preferences, while the opposite pattern occurs in pre-modifying languages such as English, German etc.

Gibson, Pearlmutter, Canseco-Gonzales, and Hickok (1996) proposed a two-factor model characterised by two main competing strategies: *Recency* and *Predicate Proximity*. The former is considered to be universal and favours recent attachment preference, just like the Late Closure principle in the Garden-Path model. Predicate Proximity, on the other hand, favours HA, due to a tendency to attach a modifier as close as possible to the predicate root. According to this account, in structures such as the NP-PP-RC ambiguity, attachment preferences would depend entirely upon cross-linguistic variation and the strength of each of these two competing strategies. Thus, the parser would favour Predicate Proximity over Recency in languages such as French or Italian, simply because the effects of Predicate Proximity are stronger in these languages, while a reversed pattern would be found in languages such as English or Dutch. Although these accounts help us further our understanding of early and late closure interpretations, they cannot fully explain why some attachment preferences appear to be preposition-specific.

Previous research has found that attachment biases can be affected when different prepositions are used in the PP (De Vincenzi & Job, 1993; Baccino et al., 2000; Hemforth, Fernandez, Clifton, Frazier, Konieczny & Walter, 2015). De Vincenzi and Job (1993) conducted research in Italian (a post-modifying language) and found a first noun attachment preference in NP complexes that contained the preposition *of*; however, when the preposition was changed to *with*, participants would opt for LA interpretations (e.g., Italian: *L'avvocato diffida del padre della ragazza che si e tradito al processo* (The lawyer suspects of the father of the girl who betrayed himself at the trial); Italian: *Tutti ammirano il signore con la filgia che si e messa a cantare un'opera* (Everybody admires the man with the daughter who started herself to sing opera)).

In English and Spanish, different types of complex NP resulted in different high or low attachment patterns within the same language as well as when manipulating the semantic relations of the two nouns of the NP complexes (Gilboy, Sopena, Clifton & Frazier, 1995). This led to the belief that, a language cannot be considered to be HA or LA since comprehenders do not always treat noun modification preferences in the same fashion.

The Tuning hypothesis (Mitchell & Cuetos, 1991a), an experience-based model of language processing, proposes that cross-linguistic ambiguity resolution is determined by input distributions (experience) that the comprehender may have had on past encounters with the same type of structures. This account stipulates that there are no universal parsing principles, as in the Garden-Path model. Instead, the human processor will base its initial attachment preferences on frequency-driven strategies governed by the individual's prior experience with the language under consideration. The main proposal of the Tuning hypothesis is that there is a modular statistically-based parsing mechanism that resolves ambiguities based on purely structural considerations and that it adjusts to incremental change depending on cumulative frequencies. Therefore, if the comprehender started to encounter different statistical properties at a structural level that led to a different interpretation of a syntactic ambiguity, then parsing preferences would begin to change over time and the ambiguity-resolving mechanism would start to tune in to the new input distributions. This would increase the chances of choosing that resolution in subsequent encounters with the ambiguity under consideration. Therefore, if a particular syntactic ambiguity (e.g., NP-PP-RC) is mostly resolved with an HA interpretation in a language, then the speakers of that language will be affected by that experience and will be more likely to disambiguate that type of ambiguity with an HA analysis in the future.

1.3.4 Interactive accounts

There has been much debate about the role that non-structural information plays in sentence processing. Nevertheless, to this day, and even with the use of sophisticated online measures such as eye-tracking methods, it is not clear whether a delayed non-syntactic stage during language comprehension exists. This has given rise to constraint-based theories based on earlier interactive accounts (e.g., Tyler & Marslen-Wilson, 1977) or connectionist models (e.g., McClelland, John, & Taraban, 1989). Interactive models propose that the parser has access and can manipulate all potential sources of information during early language processing. Such sources of information can be syntactic, prosodic, semantic, discourse context or frequency of syntactic preferences. As a result of a non-modular parser, the favoured analysis is determined by the parser's prior experience with the statistical properties of particular structures.

The best-known unrestricted account is the constraint-based theory (MacDonald et al., 1994), which suggests that, within a competitive architecture, a parsing mechanism immediately takes into account all kinds of information (constraints) by activating all the syntactic alternatives in parallel. Based on the level of activation, the analyses compete with each other and get ranked. An increased activation for one analysis will result in less activation for the other competing analyses. This means that the analysis that is the most compatible with the constraints will have a higher activation than its counterparts leading to easy language processing. However, when two or more analyses have similar levels of activation, the alternatives start competing with one another and processing takes longer. It is during this competitive process that garden-path effects take place in language comprehension.

For instance, when the constraints fully support one analysis during early processing, this analysis gets highly activated. However, when the parser encounters ambiguous information later in the sentence, another alternative analysis would also get activated, and both analyses would start competing. At this point both alternatives have similar levels of activation, so the settling process takes longer. This competition can cause either small, medium or large-sized slow-downs (garden-path effects) until the parser finally arrives at the correct interpretation and inhibits the incorrect (but previously activated) analysis. It is worth noting that constraint-based accounts argue for activation of structures rather than structure-building or reanalysis, as in syntax-first models e.g., The Garden Path Model. Therefore, reanalysis mechanisms do not feature in constraint-based models, instead, it is assumed that at the onset of ambiguity the two potential alternative analyses have already been activated.

1.3.5 Ambiguity resolution in children

Syntactic ambiguity resolution in the developing parser has been less studied than in adults. One of the main factors that has been shown to affect the interpretation of ambiguous sentences is verb biases. For example, in a language comprehension study, Snedeker and Trueswell (2004) examined the extent to which the interpretations for globally ambiguous sentences (e.g., Choose the cow with the stick) were influenced by lexical information in 4- to 6-year-old children and adults.

Using the visual world paradigm, children and adults were sat in front of an inclined podium and were asked to use toys to follow spoken instructions. As participants performed the actions, their eye-movements were recorded by a hidden camera that was in the centre of the podium. Verb biases (modifier-biased (LA), instrument-biased (HA) and equi-biased) were manipulated and both children's and adults' interpretations of globally ambiguous sentences were strongly influenced by the type of verb used in the phrases. For example, sentences with instrument-biased verbs (e.g., *Tickle the pig with the fan*) resulted in more looks to the instrument (*the fan*) and more HA responses (i.e., participants used the fan to tickle the pig); sentences with modifier-biased verbs (e.g., *Choose the cow with the stick*) resulted in more looks to the animal (*the cow*) and more LA responses (i.e., participants moved the animal that was holding a small stick) and equi-biased verbs fell somewhere in between instrument-biased and modifier-biased verbs.

The referential scene was also manipulated to know whether children showed sensitivity to the referential context to resolve PP ambiguities. For example, for the sentence *Feel the frog with the feather*, in 1-referent contexts, participants would see a large feather (instrument), a frog holding a little feather (target animal), a large candle (distractor instrument) and another animal different from the target animal (e.g., leopard holding a little feather) (distractor animal). In a 2-referent context, participants could see the same scene as in 1-referent contexts, except for the fact that the distractor animal was the same as the target animal but holding the distractor instrument (e.g., a frog holding a little candle). If children were able to use referential context information during sentence processing, this would support the idea that their parsing architecture may be interactive since it can use multiple sources of information to resolve ambiguities.

Snedeker and Trueswell (2004) found that referential information was a reliable cue to disambiguate the sentences for adults, but not for children. In a 2-referent context, adults were more likely to use referential context cues to resolve the ambiguities and tended to have fewer looks to the instrument and perform more modifier actions than in 1-referent contexts. Children, on the other hand, were less sensitive to the referential context and tended to perform their actions based solely on verb type.

Snedeker and Trueswell's (2004) findings showed how adults were more likely to employ linguistic and non-linguistic factors into their language processing system than children. However, although young children did not show evidence of using referential

information during language comprehension, they showed great sensitivity to verb-specific patterns. In fact, they seemed to mostly rely on verb statistics to guide their parsing commitments to resolve ambiguities. These findings showed evidence that children are strongly guided by frequency-based information of verbs and structures, and they use it to anticipate upcoming constructions and sentence interpretations. Moreover, the fact that the developing parser was able to use lexical information to resolve ambiguities may also suggest that the parser is not modular, as suggested by serial accounts e.g., interactive accounts.

Similar effects with children were found in follow-up studies using the same ambiguities as in Snedeker and Trueswell (2004). Kidd and Bavin (2005) tested whether 3- to 5-year-old children were able to use implausible information as a cue to overcome verb biases when interpreting globally ambiguous sentences during an off-line task. By using a within-participants design, children used toys to act out sentences that were either instrument biased (HA), modifier biased (LA) or conflicting sentences. Conflicting sentences were comprised of action verbs and implausible objects (e.g., *Chop the tree with the leaves).* On an inclined podium, children could see a tree with leaves, a tree without leaves, an axe and a bunch of leaves. If children were able to adopt the LA interpretation for conflicting sentences (i.e., choosing the axe to chop the tree that had leaves), then this would be evidence that young children were sensitive to referential information and used it to disambiguate sentences during language comprehension. Kidd and Bavin found that for the conflicting sentences the 5-year-olds were more likely to override instrument biased interpretations (HA interpretations: 27%) than the 3-year-olds (HA interpretations: 59%). The authors suggested that by the age of 5, children are more likely to use referential information to interpret ambiguous sentences than are 3-year-olds, who tend to rely more on lexical biases.

However, in a follow-up study, Kidd, Stewart and Serratrice (2011) used the visual world paradigm to test the same claim as in Kidd and Bavin's (2005) study, but this time, 5-year-olds' responses were compared against the adults'. Responses to conflicting sentences revealed that adults were sensitive to the referential context and were able to override instrument-biased interpretations and adopt more modifier-biased interpretations. By contrast, 5-year-olds were more likely to adopt instrumental interpretations than the adults. The findings in Kidd and Bavin (2005) and in Kidd, Stewart and Serratrice (2011), suggest that, during sentence comprehension, young children may rely more on verb statistics and their

distributional patterns found in the input than on top-down cues such as referential context information, as suggested by Snedeker and Trueswell (2004).

Another factor that has been shown to affect ambiguity resolution in children is animacy. In an offline study, Aranciba-Gutiérrez et al. (2015) tested the extent to which animacy, gender and memory were associated with HA and LA preferences for ambiguous RCs in Spanish-speaking children and adults. Throughout one school semester, 7-, 10-, and 13-year-old children and adults answered two memory tests and three different reading attachment questionnaires with NP-PP-RC ambiguous structures. The first questionnaire included sentences with two animate nouns of different genders, the second questionnaire had sentences in which the first noun was inanimate and the second noun was animate, and the third questionnaire had sentences with two animate nouns of the same gender.

When the two nouns were animate and of different genders, only the 7-year-old children showed a significant preference for LA, while the other older children and adults showed a preference for HA. No significant age group differences were found when the first noun was inanimate, and the second noun was animate. Aranciba-Gutiérrez et al. suggested that participants may have shown an increase in their LA responses and a decrease in their HA responses due to the animacy of the second noun, however, such an increase in the participants' LA responses was not strong enough to cause an overall LA preference for the NP-PP-RC ambiguous structures. A relationship between the memory measures and the participants' answers to the questionnaires was not found. This study shows more evidence for the overall HA preference in Spanish-speaking populations, as reported in previous studies (e.g., Mitchell & Cuetos, 1988) and the influence of the role of animacy during ambiguity resolution. What is more, it shows developmental patterns in Spanish-speaking children's preferences for HA and LA for ambiguous RCs.

Another interesting factor that has received less attention in ambiguity resolution research in children is the influence of frequency and language experience. The Tuning hypothesis (Mitchell & Cuetos, 1991a) predicts that in the absence of frequency-based information relevant to the resolution of a particular syntactic ambiguity, the parser will have unbiased attachment preferences. This means that there is no reason for the parser to choose either an HA or LA interpretation, so both preferences have a 50% chance of being selected. However, once a particular attachment preference starts to be adopted, the parser will gradually start adjusting its attachment preferences following corpus statistics in the language in

question. To test this hypothesis, in an off-line experiment, Cuetos et al. (1996) tested 7, 8 and 9-year-old Spanish-speaking children. All the children answered questionnaires that involved the NP-PP-RC ambiguity. The authors found an interaction between age and the proportion of their HA responses, that is, the older the children were, the more inclined they were to adopt an HA interpretation (7-year-olds = 59.1%; 8-year-olds = 72.7%; 9-year-olds = 74.9%).

In a later three-stage experiment, Cuetos et al. investigated whether children's syntactic interpretations of syntactic ambiguities could be altered by controlling the frequency of exposure to the HA and LA analyses in Spanish. In the first stage, children answered a questionnaire that involved NP-PP-RC ambiguities, then children were divided into two groups, one that corresponded to the HA condition and the other to the LA condition. In the following 10 school days, the children in each group read three stories, each of which included two NP-PP-RC ambiguous sentences (each child was exposed to 60 NP-PP-RC ambiguities in total). The children who were allocated to the HA condition read sentences that were only disambiguated towards the HA interpretation, while the children who were in the LA condition read sentences that were only disambiguated towards the LA interpretation. After a week without any research-related tasks, children answered another attachment questionnaire. The children who were allocated to the HA condition were more likely to select more HA interpretations in the last attachment questionnaire (Pre-test: 71.44%; Post-test: 92.17%). However, the children who were in the LA condition did not show the same pattern (Pre-test: 29.20%; Post-test: 27.81%), if anything they showed a slight decrease in their LA responses in the post-test. The results from the HA condition were predicted by the Tuning hypothesis, however, the results from the LA condition were unexpected. Cuetos et al. explained the LA results by suggesting that children may have been exposed to external HA biases during the two weeks of the experiment, therefore, this may have reduced the effect on their LA interpretations. Although Cuetos et al.'s results may not be entirely explained by the Tuning hypothesis, they do show how language experience is an important factor that influences our syntactic preferences during language comprehension.

In another study following a within-participants design, Qi, Yuan and Fisher (2011) followed a train-test design and manipulated the language input to test whether 5-year-old children's structural biases for familiar verbs were influenced by linguistic distributional information. During the training phase, 60 children watched eight dialogues that involved two

women describing unseen events using the ambiguous sentences with equi-biased verbs from Snedeker and Trueswell (2004) (e.g., *Feel the frog with the feather*).

Qi et al. (2011) manipulated verb biases (instrument- and modifier-trained verbs) and the referential scene (1-referent and 2-referent contexts). Half of the videos disambiguated the sentences with the instrumental interpretation, and the other half with the modifier interpretation. Each child was exposed to 4 instrument-training dialogues and 4 modifier-training dialogues. During the test phase, on an inclined podium, children used toys to act out spoken instructions that involved ambiguous sentences (e.g., *Point at the pig with the flower*) while their eye-movements and actions were recorded. The researchers tested each child on the verbs they heard, in both the instrument- or modifier-training dialogue conditions and examined whether children could retrieve the new encoded verb-bias information from the dialogues when they encountered follow-up ambiguous *with-* phrases. Children did not show any significant effects on their offline data. However, children's eye-movements showed early training effects. For example, in the sentence *Point at the pig with the flower,* during the first-noun window (i.e., the pig) children fixated more on the animal rather than on the instrument (i.e., the flower) for modifier-trained verbs, whereas, for instrument-trained verbs, children had more fixations on the instruments (i.e., the flower) than on the animals (i.e., the pig).

Qi et al. interpreted their results as evidence of linguistic distributional learning and suggested that children's verb biases were modified as a result of the brief exposure to the HA or the LA analyses that they received during the training phase. Therefore, Qi et al.'s findings provide evidence of how brief linguistic experience of familiar verbs may modify children's structural biases during language comprehension, as suggested by Cuetos et al. (1996).

1.4 Structural priming in children: A review of the theoretical accounts

As discussed in the previous section, syntactic ambiguity resolution has been reported to be affected by various factors. Another factor that we will now discuss and that we will focus on in this thesis is syntactic repetition. When the processing of a sentence (i.e., the prime sentence) affects the comprehension and production of a subsequent sentence (i.e., the target sentence) with the same structure (Bock, 1986), this phenomenon is referred to as structural priming. Priming effects occur because the processing of a prime sentence activates the underlying representation of that syntactic structure resulting in processing mechanisms that

make it more likely to be reused or more easily comprehended in a subsequent sentence (e.g., Pickering & Ferreira, 2008; Bock, 1986). For example, it will be more likely for an individual to use a passive sentence after being exposed to a passive structure than to an active structure. Similarly, the comprehension of a passive sentence will be facilitated after being exposed to a passive construction rather than an active construction. By manipulating aspects of the prime and target sentences, we can demonstrate the existence of mental language representations, determine their nature, and have a better understanding of the mechanisms involved that give rise to priming effects, which are widely linked to language acquisition.

Priming effects have been tested in different languages and between languages. They also have been shown in different populations e.g., bilinguals, children with typical and atypical language development, second language learners, people with amnesia, etc (see Pickering & Branigan, 2019; Pickering & Ferreira 2008; Kootstra & Muysken, 2017). Priming effects have been found in comprehension (e.g., children: Thothathiri & Senedeker, 2008; Havron, Scaff, Carbajal, Linzen, Barrault & Christophe, 2020; adults: Branigan, Pickering & McLean, 2005; Traxler, 2008), from comprehension to production (e.g., Huttenlocher et al., 2004; Branigan & McLean, 2016; Branigan et al., 2005), from production to comprehension (e.g., Arai, van Gompel, & Scheepers, 2007), in dialogue (e.g., Branigan, Pickering & Cleland, 2000), but particularly, they have been extensively studied in language production (studies with children: e.g., Branigan & McLean, 2016; Bencini & Valian, 2008; Messenger 2021, Branigan & Messenger, 2016; Peter, Chang, Pine, Blything, & Rowland, 2015; Rowland, Chang, Ambridge, Pine, & Lieven, 2012; Messenger, Branigan & McLean, 2011; Savage, Lieven, Theakston, & Tomasello, 2003; Huttenlocher, Vasilyeva, & Shimpi, 2004).

The fact that priming effects can still occur in the absence of lexical repetition between the prime and the target sentences (i.e., lexically-independent priming effects) has been interpreted as evidence for the existence of abstract representations (Bock, 1986). Moreover, enhanced priming effects can arise when content words (usually verbs or nouns) are shared between the prime and target sentences, this is usually referred to as the *lexical boost,* which is thought to reflect links between abstract and lexical representations (Pickering & Branigan, 1998). However, developmental structural priming studies have reported mixed results about the lexical boost and its development in children (see Thothathiri & Snedeker, 2008, for priming effects in comprehension). While some studies have found enhanced priming effects when prime and target share the verb as well as lexically-independent priming effects from

comprehension to production in children (e.g., Branigan & McLean, 2016), others have found a lexical boost only in older children, but not in young children (e.g., Rowland et al., 2012) or no evidence of the lexical boost in children (e.g., Peter et al., 2015; Brandt, Nitschke & Kidd, 2017). Such mixed results may be the result from methodological differences, for example, different designs and implemented procedures (e.g., in blocks of primes and target sentences, alternated order of primes, between- or within-participants designs, with or without fillers, the need to repeat the prime sentences), presentation of stimuli (e.g., videos vs. pictures vs. pre-recorded sentences), online vs. offline tasks, different coding schemes, a reduced number vs. a more robust number of primes, etc.

Research into language development has used structural priming as a technique to investigate the nature of children's representations of language, the age at which children start showing abstract representations and how these develop over time (e.g., Huttenlocher et al., 2004; Rowland et al., 2012). Usage-based lexicalist accounts propose that, during the early stages of language development, children's linguistic knowledge is lexically-specific to some degree, and as children grow and are exposed to linguistic input distributions, their representations of language slowly and gradually become abstract (i.e., lexically-independent) (Tomasello, 2000; Savage et al., 2003; Ninio, 2006; Rowland et al., 2012). By contrast, early abstraction accounts suggest that children's language representations do not go through a strict lexically-based stage, instead they are abstract from the early stages of language development (Pinker, 1989; Fisher, 2000).

Structural priming paradigms have been widely used to determine whether children go through a developmental stage at which their representations of language are entirely lexically-specific or abstract but with a lexically specific component. Therefore, usage-based lexicalist accounts predict that young children will show priming effects only when the verb is repeated between prime and target pairs. Thus, if young children's language representations have a strong lexically specific component, as suggested by the usage-based lexicalist accounts, then they are also predicted to show a stronger lexical boost than the adults. In contrast, early abstraction accounts predict that young children will show priming effects regardless of the lexical content between prime and target sentences since they also have abstract syntactic representations like adults.

Two main models explain structural priming effects. The residual activation model (Pickering & Branigan, 1998), based on the lexical access model by Levelt, Roelofs and Meyer

(1999), proposes that priming effects result from a single short-term mechanism within the lemma stratum. That is, when processing a structure, priming effects arise because of the residual activation of the lemma (e.g., *give*), combinatorial nodes, and the links between these two. For example, the lemma *give* is associated with combinatorial nodes that get activated when a particular structure is used. So, the NP,NP combinatorial node will get activated when we produce a double object construction (e.g., *The child gave the lady the apple),* likewise, the NP,PP combinatorial node will get activated when we utter a prepositional-object construction (e.g., *The child gave the apple to the lady*). Thus, under this account, it is suggested that lexically-independent priming effects result from the residual activation of combinatorial nodes (e.g., NP,NP). If, however, the target sentence involves the same verb as the previous sentence (e.g., *The girl gave the princess the ball*), then priming effects will result from the residual activation of the pre-activated lemma (*give*), the NP,NP combinatorial node, and the strengthened link between the lemma and combinatorial nodes that will give rise to accentuated priming effects (i.e., lexical boost). If subsequent prime and target pairs no longer share the same verb, there will still be a priming effect, but this will be weaker since it will originate only from the residual activation of the combinatorial node. Therefore, the residual activation model suggests that both the lexical boost and lexically-independent priming effects can be attributed to language mechanisms within one system. Moreover, the model also predicts that when there is verb overlap between the prime and target sentences, enhanced priming effects will arise irrespective of age.

Based on the residual activation model, in the globally ambiguous sentence, *The girl is pushing the teacher with the ball*, the verb will be linked to two combinatorial nodes that specify the presence (Subject [Agent] + Object [Patient] + instrument phrase [Instrument]) or absence (Subject [Agent]+ Object [Patient]) of an instrument phrase. In the HA interpretation the combinatorial node that specifies the presence of the instrument phrase is also linked to other combinatorial nodes that represent Subject node, Object node and Instrument node each of which is linked to a NP node (girl), NP node (teacher) and a PP node (with the ball) respectively. Therefore, for the HA interpretation, the information linked to the ambiguous PP would correspond to the instrument.

In the LA interpretation the verb is linked to the combinatorial node that specifies the absence of an instrument (Subject [Agent]+ Object [Patient]). This combinatorial node will be linked to another combinatorial node that represents the Subject and another that represents the Object, each of these nodes are linked to a NP: Subject node linked to the NP (girl) and Object

node linked to the NP (teacher). In the LA interpretation, the PP node (with the ball) that is linked to an Instrument node in the HA interpretation, is also linked to a combinatorial node that specifies a modifying function; whilst also being connected to the NP node (teacher). This NP node is in turn linked to the Object node. Thus, in the LA interpretation, the PP attachment ambiguity is modifying the Object NP (the teacher).

The error-based learning account (e.g., Chang, Dell & Bock, 2006) explains structural priming effects and language acquisition with an error-driven implicit learning mechanism. Chang et al. suggest that when the parser encounters a structure that does not match the predicted or expected structure (i.e., prediction error), the parser will then have to adjust its weights on the structures to better predict the input. This, in turn, will result in priming effects and long-term implicit learning. The amount of the adjustment will depend on the probability of the actual input, that is, the greater the prediction error, the greater the adjustment for less probable input (i.e., high prime surprisal) giving rise to larger priming effects for structures with high surprisal (Jaeger & Snider, 2006). Thus, stronger priming effects will result from structures with high surprisal, and such priming effects will accumulate throughout the experiment, making participants more likely to use the less probable input. However, the authors also argue that individuals' personal features, such as their prior language experience will determine what the weights are to start with and the accuracy of the predictions. Moreover, the degree of the adjustments will also depend on the individuals' different learning rates. In other words, the individual's propensity to learn a language will affect the size of the priming effects, and such learning rates will vary at an individual and group level. Usually, learning rates will decrease with age, as the individual acquires more language experience and develops an adult-like language processing system. Thus, under this account, young children are predicted to experience stronger lexically-independent priming effects and cumulative effects than older children and adults because of their high prediction error and high learning rates (Chang et al., 2006), or it may also be because they experience reduced competition when selecting a structural alternative due to their limited knowledge of structures (Pickering & Branigan, 1999). Similarly, older child are predicted to experience stronger lexically-independent priming effects and cumulative effects than adults.

Chang et al. argue that the lexical boost cannot be explained by the same error-driven implicit learning mechanism, instead they suggest that it originates in the explicit memory, and that it decays quickly. As a result of already developed memory and cognitive skills and better attention and motivation adults are able to generate, store, and retrieve information, which is

why a lexical boost effect is usually reported in this population. Children, on the other hand, due to their underdeveloped memory and cognitive control skills, may or may not be able to form and retrieve an explicit memory when processing a verb, resulting in the lexical boost effect being absent or weak. However, previous research has reported mixed results about the lexical boost in children. While some studies have found no evidence of the lexical boost in children (e.g., Prepositional object datives and Double object datives: Peter et al., 2015; Object-relative clauses: Brandt, Nitschke & Kidd, 2017), others have found a lexical boost and lexically-independent priming effects in children as young as three (Passive and Active: Branigan & McLean, 2016), and other studies have only found a lexical boost in 5- to 6-year-olds, but not in 3- to 4-year-olds (e.g., Prepositional object datives and Double object datives: Rowland et al., 2012).

1.5 Priming syntactic ambiguity resolution in children and adults

Over the years, structural priming studies of adults have shown largely consistent patterns of priming effects and enhanced priming effects when lexical content is shared between the prime and target sentences. However, this has not been the case with children. In fact, developmental priming studies are limited, especially in language comprehension, so there are still questions about the nature and development of children's language representations and the mechanisms that give rise to priming effects in children.

For example, in a language comprehension study, Thothathiri and Snedeker (2008) used the visual world paradigm to prime 3- to 4-year-olds with temporarily ambiguous datives (double-object: *Bring the monkey the hat*; prepositional-object: *Bring the money to the bear*) and examined how they represented argument structure. Children followed spoken instructions and used toys to perform their actions on an inclined podium while their eye-movements were being recorded. The authors found that under the double-object prime condition, children were more likely to fixate on the recipient (e.g., monkey) than children who were exposed to the prepositional-object prime condition. That is, Thothathiri and Snedeker manipulated the primes so under the double-object prime condition, children were expected to see the first noun as the recipient (e.g., monkey), and under the prepositional-object prime condition, children were expected to see the first noun as the theme (e.g., money). Both 4- and 3-year-olds showed priming effects in the absence and presence of verb overlap between the prime and target

sentences. Moreover, 3-year-olds did not show evidence of enhanced priming effects when the prime and target pairs shared lexical content. Thothathiri and Snedeker's findings suggested that children as young as 3 showed abstract linguistic representations during language comprehension and that such effects were not necessarily fully dependent on a lexically-specific component, as suggested by the strict early abstraction accounts.

In another language comprehension study, Brandt et al. (2017) investigated structural priming in globally ambiguous relative clauses in 6- and 9-year-old German-speaking children. In particular, they examined whether the proportion of agent-first relative clauses (preferred analysis) could be decreased by exposing children to an increased proportion of patient-first relative clauses (dispreferred analysis) (e.g., *Wo ist die Krankenschwester, die die Malerin umarmt* (where is the nurse that is hugging the painter - where is the nurse that the painter is hugging*))*. The authors used a sentence-picture matching task and followed a three-phase methodology (baseline, prime, post-test). Brandt et al. found that only the 9-year-old children, but not the 6-year-olds, showed reliable priming effects that were also long-lasting. However, they did not find evidence for a lexical boost, that is, 9-year-old children showed equivalent priming effects irrespective of whether there was noun repetition between the prime and target sentences. The authors suggested that 6-year-old children may not have shown priming effects because they may not have a fully developed abstract representation of the object relative clause construction yet.

These results would be consistent with the error-based learning account that suggests that for priming effects to occur, the parser must have acquired and have some knowledge of the primed structure to be able to predict it. Although it is not clear whether these results show support for either usage-based lexicalist accounts or early-abstraction accounts, what they do suggest is that priming dispreferred and low-frequency structures may be possible during language comprehension. However, this will depend to a greater extent on the individuals' prior language experience with the structure to be primed, as suggested by the error-based learning account (Chang et al., 2006).

In another developmental priming study, Havron et al. (2020) used a picture-matching task, similarly to Branigan et al. (2005) and Pickering, McLean and Branigan (2012) to examine the likelihood of choosing an LA analysis after an LA prime in 5- to 6-year-old French-speaking children and adults. Since the studies reported in chapters 2, 3, and 4 of the

current thesis followed the same methodology as in Havron et al. (2020) and Branigan et al. (2005), we provide a more detailed description of these studies in this section.

Following a between-participants design, Havron et al. investigated PP attachment ambiguities in children and adults. They used pre-recorded globally ambiguous sentences and exposed participants to three priming conditions: an alternating condition (exposure to both HA and LA primes, n = 40 children, 40 adults), an only HA condition (n = 22 children, 20 adults), and an only LA condition (n = 19 children, 20 adults). On prime trials, participants saw on a tablet two pictures, one that corresponded to either the HA or LA analysis (depending on the condition) and another that did not correspond to either analysis. For example, for the LA prime sentence (e.g., *La fille chatouille la bébé avec le pinceau* (The girl is tickling the baby with the brush)), one picture depicted a child with a brush being tickled by a girl (LA, correct picture), and the other picture depicted a different action i.e., a child using a brush to paint while being watched by a girl (incorrect picture). This way, participants would be forced to choose the picture with the LA interpretation. On target trials, children would see two pictures, one that would correspond to the HA analysis and the other one to the LA analysis, that is, both pictures could match the spoken sentence. In the alternating condition, participants were expected to choose an HA response on target trials after being exposed to an HA prime, and an LA response on target trials after being exposed to an LA prime. Participants were exposed to 11 prime-target pairs and 6 fillers.

Both children and adults showed a main effect of priming with no interactions of age group when prime and target pairs shared lexical content, that is, participants were more likely to choose a LA target response after being primed with a LA prime than with a HA prime in the alternating condition. Participants were also more likely to select a LA response over a HA response in the LA only condition than in the alternating condition. However, no significant effects were found when comparing the likelihood of selecting a HA response over a LA response in the HA only condition in comparison with the alternating condition. Children also showed a reliable effect of cumulative priming, that is, as the experiment progressed, children became increasingly likely to choose interpretations that they had chosen previously.

Havron et al.'s findings showed evidence that during language comprehension, 5- to 6-year-old French-speaking children showed lexically-dependent priming effects and that they were able to adopt the two attachment analyses (HA, LA) in the same experimental session

after receiving mixed exposure to HA and LA primes. Moreover, the fact that children also showed an effect of cumulative priming is suggestive that the children's representations may be abstract to some degree, since the influence of earlier responses on later responses operates across items that contain different verbs. This finding would be consistent with the error-based learning account that suggests cumulative effects may reflect implicit learning (Chang et al., 2006), although future research will still have to look for evidence for priming effects in the absence of verb repetition between prime and target pairs for this type of ambiguity and during language comprehension.

Thothathiri and Snedeker (2008), Brandt et al. (2017) and Havron et al. (2020) have shown, in their studies of English-, German-, and French-native speakers, that children between the ages of 3 and 9, are sensitive to the input distributions and are able to use recent language experience as a cue to interpret language, especially when prime and target sentences share lexical content. Moreover, although there is some evidence that children as young as 3 may employ abstract representations of language during language comprehension, this may not be the case for all the syntactic structures, especially for those that may be more complex, dispreferred and/or low-frequency. Finally, these studies also suggest that priming effects also accumulate during language comprehension and may reflect implicit learning.

Priming syntactic ambiguities during language comprehension has also been demonstrated in adults. In fact, as mentioned in the previous section, Havron et al. (2020) followed the same methodology as Branigan et al. (2005) and Pickering et al. (2012), who also tested structural priming of attachment ambiguities but in adult native speakers of English.

Following a within-participants design, Branigan et al. (2005) used a forced-choice picture selection task (as described in Havron et al., 2020) to test whether adults' syntactic choices during language comprehension were influenced by mixed exposure to HA and LA primes in the absence and presence of verb repetition between prime and target pairs during language comprehension. The Branigan et al. and Havron et al. studies were similar in most respects. However, in Branigan et al. (2005), the adult participants were exposed to 24 primes, 24 targets and 72 fillers, and they read each expression silently, rather than listening to pre-recorded sentences. Also, for the prime trials, the incorrect prime picture involved a different object rather than a different action. For example, for the LA prime sentence *The policeman is prodding the doctor with the gun,* participants would see two pictures on the screen, one picture

that was interpreted as *The doctor with the gun is prodded by the policeman* (LA, correct picture) and another picture interpreted as *The doctor with the baseball bat is prodded by the policeman* (incorrect picture). Branigan et al. (2005) found that participants only showed priming effects in the presence, but not in the absence of verb repetition between prime and target sentences. However, in Pickering et al. (2013), the authors ran the same experiment as in Branigan et al. (2005), but this time they also examined whether priming effects would persist when the prime and target were separated by intervening filler sentences rather than adjacent. This time, adult participants showed priming effects in the absence and presence of verb overlap between prime and target sentences as well as a lexical boost. Furthermore, priming effects were also found in adults irrespective of whether prime and target sentences were adjacent or separated by fillers. The authors suggested that in Branigan et al. (2005) a Type II error may have been the reason why participants did not show priming effects in the absence of verb repetition.

Branigan et al.'s (2005) findings are very relevant for the current thesis. They provided evidence that English-speaking adults are sensitive to recent language experience during language comprehension and that they show existing and abstract syntactic representations of the HA and LA analyses of PP attachment ambiguities. Moreover, the fact that verb repetition between prime and target pairs facilitated the processing of the HA and LA analyses in English-speaking adults (i.e., they showed a lexical boost), is also consistent with the residual activation account (Pickering & Branigan, 1998).

1.6 The current thesis

To better understand how children acquire language, we need to understand the nature and development of children's mental representations of language. Thus, this thesis is aimed at answering the research question: what is the development and nature of children's syntactic representations and how are they affected by language experience? To address this question, we used a structural priming paradigm in language comprehension, an experimental method that has been informative about the development and nature of children's language representations by exploring the role of language experience.

Until now, most developmental structural priming research has focussed on studying a limited number of structures (e.g., active vs. passive; double object construction vs. prepositional object construction) during language production in English-speaking children. Therefore, the mechanisms involved in structural priming during language comprehension in children remain understudied. What is more, developmental structural priming studies in language comprehension and with children whose first language is not English are very limited. This is not ideal, as it is important to understand cross-linguistic differences in how particular syntactic structures are acquired and whether current theories of language development, and specifically the role of language experience in development, hold across languages.

This thesis therefore used a structural priming paradigm to investigate the development and nature of syntactic representations and the influence of language experience in English- and Spanish-speaking children and adults. In particular, we studied the effects of recent language experience on the high-attached (HA) and low-attached (LA) analyses of prepositional phrases (PPs) in globally ambiguous sentences during language comprehension (e.g., *The girl is touching the dog with the banana*) in 4- to 6-year-old (Younger group) and 8- to 10-year-old (Older group) English- and Spanish-speaking children and adults.

To answer our main research question, we investigated: (a) How does PP attachment develop over time during language comprehension? (b) How does recent experience of syntactic repetition with and without verb repetition affect PP attachment preferences in children and adults? and (c) Do children and adults show effects of cumulative experience?

In the current thesis, we based our studies from chapters 2, 3 and 4 on the work by Branigan et al. (2005) but with a focus on the nature and development of children's language representations. Specifically, the studies reported in chapters 2 and 3 were aimed at investigating structural priming of globally ambiguous sentences involving PP attachment ambiguities in the absence and presence of verb overlap between prime and target pairs in 4- to 6- and 8- to 10-year-old English- (Chapter 2) and Spanish- (Chapter 3) speaking children and adults. In these two chapters we were interested in learning more about the underlying mental representations of language in children, how they develop and the mechanisms involved in structural priming during language comprehension. By studying structural priming in child native speakers of English and Spanish, we also learnt more about the stages at which children develop ambiguity resolution mechanisms and whether the developing parser behaves similarly with the influence of recent language experience in these two languages.

Chapter 4 was aimed at directly investigating whether there were cross-linguistic differences between the findings of the English- and Spanish speaking children and adults from chapters 2 and 3.

Chapter 5 focussed on answering the question about whether syntactic repetition affected the processing of temporarily ambiguous sentences during language comprehension. In particular, we examined whether an unambiguous prime sentence (e.g., '*Put the duck that is on the jacket on the blanket)* could eliminate the garden-path effect or facilitate garden-path recovery of a temporarily ambiguous target sentence (e.g., *Put the duck on the sock on the star)* in the presence of lexical repetition between the prime and target sentences. This chapter reports the findings of a preliminary experiment with adults using the visual-world paradigm and eye-tracking methods to investigate online language comprehension. The intention had been to also run this experiment with children. However, due to the COVID-19 pandemic, this line of research was not feasible and had to be suspended.

Chapter 6 aimed to discuss the findings and implications of the studies from chapters 2 to 5 and suggested future research directions to continue furthering our knowledge of how sentence processing may be influenced by language experience during language comprehension in children.

2 Priming Prepositional-Phrase attachment ambiguities in English-speaking children and adults during language comprehension

2.1 Introduction

Language comprehension is an efficient process that involves integrating multiple sources of linguistic and non-linguistic information with great speed. As a sentence unfolds, listeners and readers automatically make partial parsing commitments that usually lead to the correct interpretation. Unfortunately, rapid language processing comes with its costs resulting in comprehenders sometimes choosing the wrong interpretation of a sentence. Syntactic ambiguity resolution has been widely investigated and considerable psycholinguistic research has focussed on answering the question of how the parser arrives at its final interpretation. Factors such as plausibility (Kidd, Stewart & Serratrice, 2010), prosody (Snedeker & Trueswell, 2003; Contemori, Pozzan, Galinsky, & Dussias, 2018), referential context and lexical information (e.g., Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Trueswell, Tanenhaus, & Kello, 1993; Trueswell, Sekerina, Hill, Logrip, 1999) have been found to affect the resolution of syntactic ambiguities in children and adults. However, less is known about how previous exposure to syntactic structures influences the comprehension of syntactic ambiguities in children and what this tells us about the development of children's syntactic representations. To address these issues, in the present study we use a structural priming paradigm to examine the way English-speaking children represent language and how priming effects can lead to representational change.

In language production, structural priming is the tendency to repeat the structure of a sentence that has just been heard or read. In language comprehension, the way a sentence is interpreted can also prime a subsequent sentence interpretation. Thus, by using the priming technique in the laboratory, we can increase the likelihood of interpreting a phrase (i.e., *target sentence*) as a result of the prior processing of a sentence involving the same interpretation (i.e., *prime sentence*). When priming effects occur in the absence of lexical repetition between the prime and target sentences (i.e., lexically-independent priming effects), this is generally interpreted as evidence for an existing abstract representation of the syntactic structure in

question (e.g., Bock, 1986; Branigan, Pickering & Cleland, 2000). Moreover, if the priming effect is accentuated in the presence of lexical repetition between the prime and target pairs (i.e., lexically-dependent priming effects), this is usually referred to as the *lexical boost*, which reflects a relationship between abstract and lexical representations (Pickering & Branigan, 1998). A link between children's early language production and exposure to the linguistic input they receive has been suggested by previous studies (Matthews, Lieven, Theakston, & Tomasello, 2005; Abbot-Smith, Lieven, & Tomasello, 2001). As a result of this, the development of abstract representations in young children has been argued to emerge due to increased language exposure and the accumulation of individual language experiences involving different structures and word combinations. This suggests that children are susceptible to the linguistic patterns in the input on a turn-by-turn basis and that these effects do not dissipate, instead they persist and accumulate. Hence, in structural priming paradigms, such linguistic influences have been referred to as cumulative priming effects (e.g., Kaschak, Kutta & Jones, 2011).

Developmental structural priming studies have focussed on finding evidence that supports either usage-based lexicalist or early abstraction accounts by exploring how children represent language and the age at which they start showing priming effects. Usage-based accounts propose that during the early stages of language acquisition, children's linguistic knowledge is governed by lexically-dependent representations, and as children get older, their representations become abstract (i.e., lexically-independent) as a result of the linguistic experience they have with verb-specific patterns found in the input (Tomasello, 2000; Savage, Lieven, Theakston, & Tomasello, 2003; Ninio, 2006; Rowland et al., 2012; Peter, Chang, Pine, Blything, & Rowland, 2015). Early abstraction accounts, on the other hand, suggest that in the early stages of development, children do not go through a stage of lexically-dependent representations, instead, they start with higher-level linguistic categories (i.e., abstract representations) from the beginning (Pinker, 1989; Fisher, 2001). Structural priming paradigms have shown to be a powerful way to test these two theories of syntactic development. Testing whether young children show lexically-dependent or lexically-independent priming effects can help us determine whether they do or do not go through an early stage in which their linguistic representations are bound to lexically-specific information.

Evidence of priming effects in children during language comprehension and production is limited and has shown mixed results regarding the nature and development of children's

mental representations of language, as we discuss below. Thus, by using the structural priming technique the aim of the present study is to examine how 4- to 6 and 8- to 10-year-old English-speaking children represent language, how their linguistic representations develop over time and whether the accumulation of individual experiences of a particular structure influences syntactic choices during language comprehension in children and adults. In particular, we use the globally ambiguous structure e.g., '*The girl is touching the dog with the banana',* in which individuals may adopt either the high-attached (HA) analysis (VP-attachment or instrumental interpretation), where the ambiguous prepositional phrase (PP) *with the banana* modifies the verb (i.e., the girl uses the banana to touch the dog); or the low-attached (LA) analysis (NP-attachment or modifier interpretation) where the PP modifies the noun *dog* (i.e., the dog with the banana is touched by the girl). We refer to these preferences as high- and low-attachment because in the former the PP attaches to the VP, which is 'high' in the syntax tree, whereas in the latter, the PP attaches to the NP, which is 'low' in the syntax tree. We used such PP ambiguities in the current study because children as young as 3 have been reported to accept both interpretations (Zimmer, 2017) and also because such structures have been widely used to investigate syntactic ambiguity resolution in children and in adults (e.g., Snedeker & Trueswell (2004); Kidd & Bavin, 2005; Kidd, 2007; Kidd, Stewart & Serratrice, 2011). This gives us the opportunity to study language development and compare children's behaviour against what we know about adults.

Therefore, to answer our main research question about the nature and development of children's syntactic representations we focus on addressing: (a) How does PP attachment develop over time during language comprehension? (b) How does recent experience of syntactic repetition with and without verb overlap affect PP attachment preferences in children and adults? and (c) Do children and adults show effects of cumulative experience?

2.2 Ambiguity resolution

Serial models of language comprehension (e.g., Garden Path model) in adults have explained ambiguity resolution by proposing an initial syntactic stage where a modular parser selects the simplest construction with the least number of nodes (i.e., Minimal Attachment principle). The integration of lexical and discourse information occurs later, in a second stage

where the parser evaluates and revises, if necessary, the final interpretation (Frazier & Fodor, 1978). In contrast to serial models, parallel accounts claim that the activation of multiple analyses occurs simultaneously, resulting in linguistic and non-linguistic input being rapidly processed by making probabilistic use of several sources of information (e.g., MacDonald, Pearlmutter, & Seidenberg,1994; Trueswell et al., 1999). Irrespective of whether language processing follows a two-stage or a constraint-based approach, researchers working within models agree on the fact that the final analysis will depend on the integration of all sources of information (cf. Good-Enough models; Ferreira, Bailey & Ferraro, 2002). Good-Enough models do not assume that all sources of information necessarily contribute to the final analysis (e.g., Ferreira & Patson, 2007).

Ambiguity resolution in children has been less studied than in adults. For example, in a language comprehension experiment using the eye-gaze paradigm and toys to perform spoken instructions, Snedeker and Trueswell (2004) explored whether adults and 4- to 6-year-olds would use verb biases and referential context cues to resolve globally ambiguous sentences (e.g., *Feel the frog with the feather)*. For this type of ambiguity, participants may adopt the HA analysis (i.e., using a feather to feel the frog) or the LA analysis (i.e., feeling the frog that is holding a feather).

Snedeker and Trueswell found that instrument-biased verbs (e.g., *Tickle the pig with the fan*) resulted in participants looking and ultimately choosing an instrument more often to perform their actions. Modifier-biased verbs (e.g., *Choose the cow with the stick*) resulted in participants performing the action on the target animal more often without the use of an instrument. Unbiased verbs (e.g., *Feel the frog with the feather*) fell somewhere in between instrument-biased and modifier-biased verbs. Referential context was a reliable cue to disambiguate the sentences only for adults, but not for children.

These findings provide evidence that children are strongly guided by bottom-up information such as frequency-based information of verbs and structures, and that they mostly rely on it to anticipate upcoming constructions and sentence interpretations. By contrast, adults are able to employ both bottom-up as well as top-down information such as verb-biases and referential context cues to guide their parsing commitments. (See Chapter 1, section 1.3.5 for a detailed description of this study).

Similar results were found in follow-up studies that involved PP ambiguities that triggered recovery mechanisms due to implausible information in English-speaking 3- to 5-

year-old children and adults (Kidd & Bavin, 2005; Kidd, Stewart & Serratrice, 2010). For example, when participants listened to the sentence *Chop the tree with the leaves,* children could see on an inclined podium a tree with leaves, a tree without leaves, an axe and a bunch of leaves (similar methodology as in Snedeker & Trueswell, 2004). Participants needed to override the strong verb bias for the HA interpretation and identify that the instrument (the bunch of leaves) was implausible to perform the action. If participants were able to use implausible information as a cue to overcome verb biases, then they would interpret the sentence with a LA analysis (i.e., they would use the axe to chop the tree that has leaves). 5-year-olds were more likely to override the HA interpretation than the 3-year-olds, but less likely to adopt a LA interpretation than the adults. (See Chapter 1, section 1.3.5 for a detailed description of this study).

These studies provided evidence that young children tend to heavily rely on bottom-up lexical cues during sentence comprehension and that it takes them some time to develop the integration of other sources of information such as referential cues to guide their parsing commitments (Kidd, 2007); Although see Qi, Love, Fisher and Brown-Schmidt (2020), who in a visual-world paradigm task found evidence that during language comprehension 5-year-olds, just like adults, were able to use referential context information to resolve temporary syntactic ambiguities such as (*Put the frog on the pond into the tent*), however, their sensitivity to the referential context was delayed rather than non-existent, as it had been previously suggested (e.g., Trueswell et al., 1999).

A growing body of language acquisition research has found evidence that individuals are sensitive to the distributional patterns of the input. Learners can track verb-specific and verb-general statistics and rely on these sources of information so when they encounter the same verb, they are able to determine its future behaviour. Therefore, if lexically specific and lexically independent frequency information is a strong guide that can shape our sentence-structural biases in sentence comprehension, we would expect that by encountering a number of new linguistic experiences involving different structural biases of familiar verbs our parsing preferences in sentence comprehension may gradually change.

This claim has been tested in a train-test paradigm by Qi, Yuan and Fisher (2011). Using the equi-biased verbs from Snedeker and Trueswell (2004), (e.g., *Feel the frog with the feather*), 5-year-old children were exposed to videos of dialogues that involved descriptions of

events using PP attachment ambiguities during the training phase. Half of the videos supported the modifier interpretation and the other half the instrumental interpretation. During the test phase, children acted out PP ambiguities by moving toys displayed on a tabletop while their eye-movements were recorded. (See Chapter 1, section 1.3.5 for a detailed description of this study).

The authors did not find statistically significant differences with respect to the behavioural data; however, eye-movement measures showed evidence of reliable early training effects. That is, for the modifier-trained verbs, children tended to look more at the animals, whereas for the instrument-trained verbs, children were likely to look more at the instruments.

Qi et al. interpreted their results as evidence of linguistic distributional learning and suggested that children's verb biases were modified as a result of the brief exposure to structures supporting either the HA or the LA analyses they received during the training phase.

Qi et al.'s findings as well as the previous studies discussed in this section provide evidence that young children are able to incorporate other sources of information (e.g., lexical information, recent language experience) into their parsing strategies, as suggested by interactive accounts of language comprehension. Moreover, Qi et al.'s findings also suggest that children are sensitive to the distributional patterns of the input and that even brief language experience may shape children's structural biases.

2.3 Structural priming

So far studies investigating syntactic ambiguity resolution have reported that sentence comprehension is influenced by various factors, one of them also being syntactic repetition. Structural priming occurs when the processing of a sentence is affected by the processing of a previous sentence with that same structure (e.g., Branigan & Pickering, 2017). This occurs because the prime activates the abstract representation of that syntactic construction resulting in processing mechanisms that facilitate either the comprehension or the production of the same structure in a subsequent sentence (e.g., Bock, 1986). When priming effects occur in the absence of shared content words between the prime and the target sentences, this has been taken as evidence for existing abstract representations. Priming effects may be stronger if prime

and the target pairs share the same verb (lexical boost*)* (Pickering & Branigan, 1998). This paradigm has been used to explore the nature of mental representations of language and the interactions that syntactic representations may have with lexical items. Priming effects have been demonstrated in language comprehension studies (e.g., adults: Branigan, Pickering & McLean, 2005; Pickering, McLean & Branigan, 2012; eye-tracking reading comprehension: Traxler, 2008; in children: Havron, Scaff, Carbajal, Linzen, Barrault & Christophe, 2020; visual-world paradigm in spoken comprehension: Thothathiri & Snedeker, 2008,) in dialogue (e.g., Branigan et al., 2000), but especially, they have been studied in language production extensively (e.g., children: Huttenlocher, Vasilyeva, & Shimpi, 2003; Messenger, Branigan & McLean, 2011; Peter et al., 2015; Branigan & McLean, 2016; Messenger, 2021).

Structural priming effects and the lexical boost have been explained by two main different accounts. The residual activation model (Pickering & Branigan, 1998) attributes these effects to a single short-term mechanism within the lemma stratum. That is, prime processing activates the links between verbs and structural nodes, resulting in residual activation that gives rise to either abstract or lexical priming. For example, in a double object construction such as *The girl gave the boy the toy* the lemma node *give* and the NP,NP combinatorial node are activated resulting in lexically-independent priming effects due to the residual activation of the NP,NP combinatorial node. If, however, the subsequent sentence contains the same verb as the prime sentence (i.e., give), then residual activation of the already activated lemma node *give*, the NP,NP combinatorial node and the strengthened link between the lemma and the combinatorial nodes, will result in stronger priming effects i.e., lexical boost. (See Chapter 1, section 1.4 for a detailed description of this account).

The error-based learning model explains structural priming and language acquisition with an error-driven implicit learning mechanism (e.g., Chang, Dell & Bock, 2006), whereby learning is the consequence of a parser encountering a structure that does not match the predicted or expected construction. When there is a mismatch between the actual input and the expected input (i.e., *prediction error*), the parser adjusts the weights on the structures in order to make more accurate predictions that better match the input, leading to priming and long-term implicit learning. The amount of the adjustment depends on the probability of the actual input, with a greater prediction error, greater adjustment for less probable input (i.e., *high prime surprisal*), giving rise to larger priming effects for structures with high surprisal (e.g., Jaeger & Snider, 2006).

The lexical boost is explained by a different mechanism from implicit learning, which originates in the explicit memory and whose effects decay quickly. Children's explicit memory skills are not as developed as adults'. Thus, under this account, the lexical boost in the developing parser may or may not arise. Such variation between speakers is predicted to occur not only in the lexical boost, but also in the abstract priming effects themselves. That is, the learner's language experience and their language learning propensity will determine their learning rate and therefore the priming effects. (See Chapter 1, section 1.4 for a detailed description of this account).

Although studies of adults have shown largely consistent patterns over the years, there is still mixed evidence about the nature and the development of the syntactic representations in children. While some studies have reported structural priming effects in the presence and absence of lexical repetition (Thothathiri & Snedeker, 2008; Bencini & Valian, 2008; Huttenlocher, Vasilyeva, & Shimpi, 2003; Rowland et al., 2012; Branigan & McLean, 2016), others have not (Savage et al., 2003; Goldwater, Tomlinson, Echols, & Love, 2011). Such mixed evidence might result from differences in the age of children or in the methodology such as the way primes and target sentences are presented (e.g., videos vs. pre-recorded sentences), different coding schemes and tasks, between- or within-participants designs, presentation of multiple primes without intervening fillers, etc. Moreover, the majority of the structural priming studies in children have tested the effects during language production with structures that involve no syntactic ambiguity, while very few studies have explored priming effects on syntactically ambiguous sentences during language comprehension.

For example, by using the eye-gaze paradigm and toys on an inclined podium, Thothathiri and Snedeker (2008) investigated how children represented argument structure by priming 3- to 4-year-olds with temporarily ambiguous datives (double-object: *Bring the monkey the hat*; or prepositional-object: *Bring the money to the bear*) and testing whether they would show abstract priming effects during language comprehension. The authors found that under the double-object prime condition, children were more likely to look at the recipient (e.g., monkey) than children who had been exposed to the prepositional-object prime and who interpreted the first noun as the theme (e.g., money). Moreover, lexically-independent priming effects were reported with no difference of the priming effect in the absence and presence of verb overlap in 3-year-old children. (See Chapter 1, section 1.5 for a detailed description of this study).

These findings highlighted the importance of abstract representations in children as young as 3 and suggested that in language comprehension, priming effects may not be lexically-dependent in the early stages of development.

Brandt, Nitschke and Kidd (2017) also tested priming effects during language comprehension in 6- and 9-year-old German-speaking children. Following a baseline-, prime, and a post-test-phase methodology, the authors tested whether the strong preference for the agent-first relative clause could be altered by exposing children to an increased number of patient-first relative clauses (e.g., *where is the nurse that is hugging the painter* - *where is the nurse that the painter is hugging).* Brandt, Nitschke and Kidd found that only the 9-year-old children showed a priming effect that was also long lasting. However, this effect was not accentuated when lexical content was repeated between the prime and target sentences. Thus, it was suggested that 6-year-old children had not shown priming effects because they were unable to accept the dispreferred interpretation of the relative clause or because they may not have a fully developed abstract representation of the object relative clause.

The results of Thothathiri and Snedeker (2008) and Brandt et al. (2017) are compatible with the error-based learning account that argues that for priming effects to occur, individuals must already have an existing abstract representation of the structure being primed. Additionally, Brandt et al.'s findings also provide evidence that priming a dispreferred structure may be possible during language comprehension, however, the effects will greatly depend on the individuals' prior experience with the structure, with younger children being less likely to show priming effects for less frequent structures than older children.

The current study followed the same methodology as in Branigan et al. (2005) and Havron et al. (2020). Therefore, we provide a more detailed description of these studies.

In a language comprehension study with adults, Branigan et al. (2005) examined the effects of structural priming on globally ambiguous sentences such as (1) *The policeman is prodding the doctor with the gun*. The ambiguous PP *with the gun* can attach high and modify the verb (prodding) and thus be interpreted as *The policeman uses the gun to prod the doctor*; or it can attach low and modify the noun (doctor), and thus be interpreted as *The doctor with the gun is prodded by the policeman*. By using a description-picture matching task, and following a within-participants design, Branigan et al. exposed adult participants to two prime conditions (HA- and -LA primes). On prime trials, adults read a sentence such as (1) and chose

one of the two pictures shown on the screen. One of the two pictures matched either the HA or LA interpretation (depending on the condition) and the other picture matched neither of the analyses. Thus, participants were forced to adopt either the HA or LA analysis on prime trials. Prime trials would always be followed by target sentences such as (1). On each target trial, participants saw two pictures, but this time both pictures could match the sentence interpretation. That is, one of the pictures would correspond to the HA interpretation and the other one to the LA interpretation. Thus, on target trials, participants were expected to choose the same interpretation they had chosen on the previous prime sentence. Two experiments were run to examine priming effects in the absence and presence of verb overlap between the prime and target sentences. The authors found that adults were more likely to choose a HA response after a HA prime than after a LA prime in both experiments, however, the priming effect was only statistically significant when the prime and target sentences shared the same verb.

In Pickering et al. (2012), the authors followed the same paradigm and used the same materials as in Branigan et al. (2005) to investigate how globally ambiguous sentences such as (1) were affected by structural priming in the absence and presence of verb overlap. However, this time they also examined whether such effects would persist when prime and target sentences were adjacent or separated by one or two intervening fillers. Participants tended to select the same attachment in the target sentence as in the prime, even when two fillers intervened between the prime and target sentence, and when the prime and target sentence did not share the same verb. Further, priming effects were enhanced when the verb was repeated between the prime and target sentence (the lexical boost). The authors explained that in Branigan et al. (2005) they may not have found immediate priming effects in the absence of lexical repetition in adults due to a Type II error. Additionally, they also proposed an account in which frequency-based preferences reflect the same underlying mechanism in comprehension as lexically-dependent and lexically-independent structural priming.

Following the same methodology as in Branigan et al.'s (2005) and Pickering et al.'s (2012), but using a between-participants design, Havron et al. (2020) investigated lexically-dependent and cumulative priming effects of globally ambiguous sentences (e.g., *The girl is tickling the baby with the brush*) in 5- to 6-year-old children and adults. There were three conditions, one in which participants were primed only with the HA analysis, another in which they were primed only with the LA analysis and an alternating condition, in which participants were primed with both the HA and LA analyses. In the alternating condition, after every two

LA prime trials, a HA prime trial and possibly a filler trial would always follow. By using an application on a tablet, participants were exposed to fixed lists of 11 prime-target pairs and 6 unambiguous filler sentences. Havron et al. measured the likelihood of selecting a LA interpretation after a LA prime when prime and target sentences shared the same verb.

A main effect of prime in the alternating condition with no interaction with age group was found. This finding may be compatible with the residual activation account (Pickering & Branigan, 1998), that predicts facilitated processing when prime and target pairs share the same verb. However, future studies should look for evidence of lexically-independent priming effects as well to provide evidence of the lexical boost across age groups.

The authors also compared the LA target responses from the LA only condition against the alternating condition as well as the HA target responses of the HA only condition against the alternating condition. Participants were only more likely to choose a LA response in the LA condition than when they had received equal exposure to the two primes i.e., alternating condition. The authors also found an effect of cumulative priming with no significant interactions with age group in the alternating condition. That is, as the experiment progressed, participants were more likely to choose a LA response.

The fact that children showed cumulative effects when there was lexical repetition in the alternating condition, is suggestive that the children's representations may be abstract to some degree, since the influence of earlier responses on later responses operates across items that contain different verbs. This finding may be compatible with the error-based learning account that suggests cumulative effects may reflect implicit learning (Chang et al., 2006).

Havron et al.'s findings provided evidence that children as young as 5 years of age were sensitive to the distributional patterns of the input and that their strong preferences could be altered to some extent. Moreover, Havron et al. also provided evidence that children and adults whose first language was other than English i.e., French, also showed lexically-dependent and cumulative priming effects for this type of ambiguity during language comprehension. However, the question as to whether 5- to 6-year-old French-speaking children may show immediate lexically-independent priming effects and cumulative effects in the absence of verb overlap, still needs further investigation. What is more, future research is needed to track the development of children's syntactic representations of PP ambiguities across different age groups and answer the question about when children start showing adult-like PP attachment preferences in the absence and presence of HA and LA primes. These findings will help us

draw more inferences about children's syntactic development and the nature of their syntactic representations. The present study addressed these questions.

The current study

By following the same paradigm as Branigan et al. (2005) and Pickering et al. (2012), but with different pictures and pre-recorded spoken sentences, this study examined both lexically-dependent and lexically-independent priming effects in 4- to 6- and -8- to 10-year old English-speaking children and adults. Our aim was to study the nature and development of children's mental representations of language during language comprehension by analysing structural priming in PP ambiguities. To do this, we focussed on comparing the syntactic choices of 4- to 6-year-old children against 8- to 10-year-old children as well as 4- to 10-year-old children against adults. We also examined cumulative effects of experience by analysing how individual language experiences accumulated within one session and whether such effects accumulated in 4- to 10-year-old children to the same extent as in adults.

Usage-based lexicalist accounts suggest that during the early stages of language development, children's syntactic constructions may be bound to lexically-specific information such as verbs. Therefore, these accounts predict that 4- to 6-year-old children will not show lexically-independent priming effects. That is, they will not be more likely to choose LA after comprehending a LA prime with a different verb (lexically-independent), but will be more likely to choose LA after comprehending a LA prime with the same verb (lexically-dependent). Thus, this account predicts that 4- to 6-year-old children will be more likely to show a stronger lexical boost than the 8- to 10-year-old children and adults.

Showing enhanced priming effects when there is verb repetition between the prime and target sentences would also be consistent with the residual activation account (Pickering & Branigan, 1998), which attributes the lexical boost as a result of the co-activation of the lemma and combinatorial nodes and the strengthened association between these two.

Early abstraction accounts predict that 4- to 6-year-old children will show lexically-independent priming effects and that the lexical boost should not differ between 4- to 6- and -8- to 10-year old children as well as adults, since children's linguistic representations are not bound to lexical items, but to lexically-independent information.

The error-based learning account predicts that exposure to the less frequent and thus more surprising structure (LA) will cause high prediction error (i.e., a strong discrepancy between what is expected and what is actually encountered) that will result in participants readjusting their structural preferences leading to long-term implicit learning effects. This readjustment will cause immediate and cumulative lexically-independent priming effects. Lexically-dependent priming effects are expected to be only short-lived because they do not rely on an implicit learning mechanism but rather on explicit memory. Thus, we expect that lexically-independent priming effects will be more accentuated in 4- to 6-year-old children than 8- to 10-year-old children due to their limited experience with the language and higher learning rate; therefore lexically-independent priming effects will also be more accentuated in 8- to -10year-old children than in adults. Moreover, due to the nature of the lexical boost under this account, the 8- to 10-year-old children and adults will show a lexical boost but not 4- to 6-year-old children, as their explicit memory skills are not as developed as older children and adults (Rowland et al., 2012; Schneider & Pressley, 1997).

Cumulative effects should also be consistent with an implicit error-based learning mechanism, that is, individual experiences of structural readjustment will accumulate when processing a less frequent structure making it more likely to be re-used. Therefore, participants are expected to show an increase in the overall number of their LA interpretations as the experiment goes on. Larger cumulative effects might be shown in 4- to 6-year-old children than in the other two age groups due to their limited experience with the language that may cause higher prediction errors than the other two age groups resulting in greater implicit learning (Chang et al., 2006).

The current study examined English-speaking children's and adults' overall preferences for interpreting ambiguous PPs (experiment 1); priming effects and cumulative effects in the absence of verb overlap between prime and target pairs (experiment 2); and priming effects and cumulative effects in the presence of verb overlap between prime and target pairs (experiment 3).

2.4 Experiment 1: Baseline PP attachment preferences in English-speaking children and adults

In this experiment, we set out to establish English-speaking children and adults' preferences for interpreting ambiguous PPs (coined as the 'baseline' experiment/condition). To do this, in a language comprehension web-based sentence-picture matching task, 4- to 6 and 8- to 10-year-old children and adults listened to globally ambiguous sentences e.g., '*The girl is touching the dog with the banana'* and chose one of the two pictures shown on a computer/tablet screen. Both pictures were potential matches to the sentence; however, one matched the HA interpretation, and the other one the LA interpretation. We analysed children's and adults' responses and compared the children's performance with that of adults, who served as the control group. We also examined the effect of age in children and cumulative effects within a session in children and adults.

We expected adults to show a strong preference for the HA than for the LA interpretation, as it has been reported in previous studies (Branigan et al., 2005). However, due to children's strong sensitivity to verb biases, we predicted that children's preference for the LA interpretation would be weaker than the one of adults', especially because the verbs used in this study were instrument-biased. This would be compatible with previous research that found that 5-year-olds generally rely on lexical information to process PP attachment ambiguities (Snedeker & Trueswell, 2004). Therefore, we expected to see a larger difference between the 4- to 6-year-olds and adults than between the 8- to 10-year-olds and adults; 4- to 6 and 8- to 10-year-olds were also expected to show a difference, given their wide age range and their significantly different language experience. If, on the other hand, the language experience that has accumulated throughout the years in an individual plays no role in the processing of globally ambiguous sentences, then children's and adults' performance should not differ.

In a different analysis, we also tested whether Age in Months within 4- to 6 and 8- to 10-year-old children predicted developmental changes in the processing of PP attachment preferences. This allowed more fine-grained investigation of developmental changes, given that in other analyses we compared different age groups. If children did not show developmental changes in their PP attachment preferences, this would mean that more language experience (in months or years) was required so that a change in the processing of PP

ambiguities would start to show. Additionally, we examined whether children and adults showed cumulative effects within a session when no prime was presented. Since participants were not forced to process the LA interpretation due to the absence of the LA prime, then the three groups were expected to self-prime with their preferred interpretation (i.e., HA). Thus, we expected an overall increase in the number of HA responses by the end of the task in all the participants. The results from this experiment also served as a baseline for the following two experiments.

2.4.1 Methods

Participants

A total number of 47 native English-speaking children and 20 adult native speakers of English (15 female, 5 male) took part in this online experiment in their homes using a computer or tablet. We recruited twenty-seven 4- to 6-year-olds (mean age 5;8, 16 female, 11 male), we refer to them as the Younger Group; twenty 8- to 10-year-old children (mean age 9;4, 8 female, 12 male), we refer to them as the Older Group; and twenty adult students from the University of Edinburgh ranging in age from 18 to 27 (mean age 20). Children were recruited through social media groups for parents in the UK and through the Developmental Lab Facebook webpage from the University of Edinburgh. None of the participants had a history of language disorders or learning disabilities and had little or no knowledge of a second language. All adult participants and children's parents/caregivers provided written consent before the experiment and received an electronic £4 Amazon gift card after the experiment. Children also received an electronic certificate of participation. We used Qualtrics to present the stimuli and collect the data.

Design

We used a mixed design with Age Group as a between-participants factor (Adults vs. Older vs. Younger) within items.

Materials

To investigate Younger and Older children's PP attachment preferences, we developed an experiment investigating their comprehension preferences in contexts without an immediately preceding prime, which also served as the baseline for the following experiments.

We followed the same sentence-picture matching task methodology as Branigan et al. (2005) and Pickering et al. (2012), but with different sentences, pictures, and pre-recorded spoken sentences that were more appropriate for children. We created 24 globally ambiguous sentences (target sentences) such as '*The girl is touching the dog with the banana',* each depicted two pictures (see Figure 1), one that would match the HA interpretation and the other one the LA interpretation. We used the following six verbs for the target sentences (*pat, push, poke, move, touch and tickle*) and made sure that the age of acquisition of these verbs corresponded to the age of the child-participants. All these verbs were instrument-biased verbs. Additionally, we constructed 24 unambiguous filler sentences, each accompanied by a pair of pictures which only one of them would match the sentence (see Figure 1, and appendix for materials). The 24 unambiguous fillers were divided into four sets of six sentences. One of the sets used intransitive verbs and had a different agent in the mismatching picture (e.g., The king is sleeping vs. The queen is sleeping). The other three sets used transitive verbs; in one set the agent was different in the mismatching picture (e.g., The boy is hugging the teacher vs. The girl is hugging the teacher); in the second set the patient was different (e.g., The dog is chasing the cat vs. The dog is chasing the sheep); and for the remaining set the agent and the patient were reversed (e.g., The queen is kissing the teacher vs. The teacher is kissing the queen). Therefore, each participant listened to a total of 48 sentences with an individually randomised order but always with an intervening filler sentence before every target sentence. The position of the pictures of the target and filler sentences was randomised and counterbalanced, that is, pictures appeared either on the right or left side of the screen. Likewise, the position of the agent in the target and filler pictures was also right-to-left oriented for half the trials and left-to-right oriented for the other half. All the pictures were designed by a professional illustrator. A native speaker of English trained in the field of psycholinguistics recorded the audios. To make sure that there was no bias between the modifier and instrument interpretations, we measured the prosodic breaks of each sentence between the NP (e.g., the dog) and the PP (e.g., with the banana) for the instrumental interpretation, and between the verb (e.g., touching) and the NP (e.g., the dog) for the modifier interpretation. Then we ran a two-sample t-test to make sure that there was no statistically significant difference between the prosodic breaks ($p > .05$)

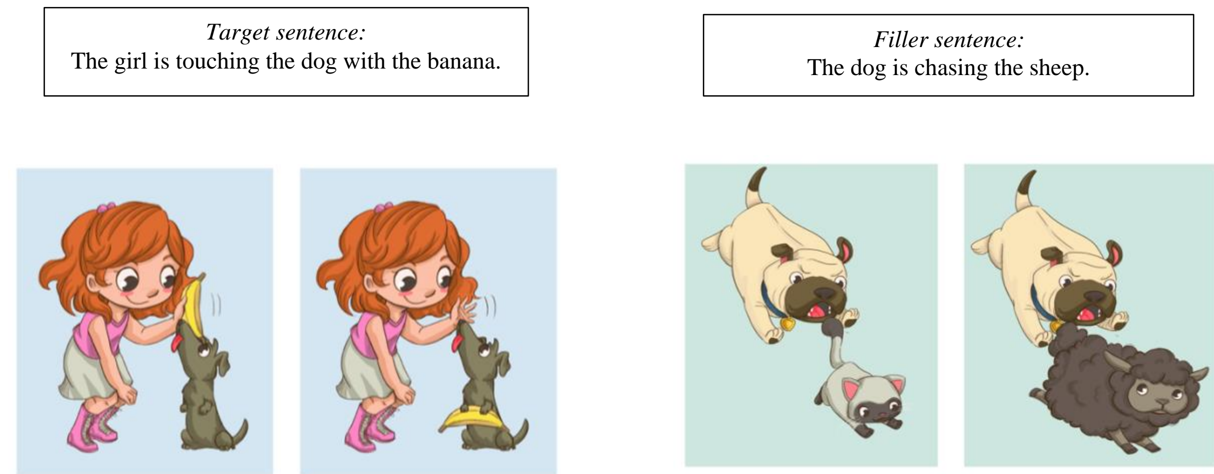

Figure 1. Example of a Target sentence and a Filler sentence.

Procedure

The experiment began with a Zoom session where participants were shown a picture of a minion (Bob) and were told that they would be helping him find treasure. They were told that in order to help Bob move forward and get closer to the treasure they would have to listen to sentences and match them with pictures. Adults were told they were going to do a children's experiment. An adult was always present with the children during the Zoom session and the researcher always made sure that participants/parents had understood the instructions. After the Zoom session participants were emailed the appropriate link and password to have access to the task. The researcher did not observe the participants while they were doing the experiment.

Before starting the task, participants were able to watch a video of how to answer a filler trial targeting an unrelated structure to the experimental task. For each trial, participants would see a slide with two pictures and the play button of the audio above them. Participants were able to listen to the sentences more than once if they needed it by clicking on the play button on each slide. Once participants had clicked on their chosen picture, the slide would automatically change showing the following slide without allowing participants to go back to the previous trial and change their answers (see Figure 2). Qualtrics was used to present and collect the data and we recorded participants' responses to the fillers and target sentences.

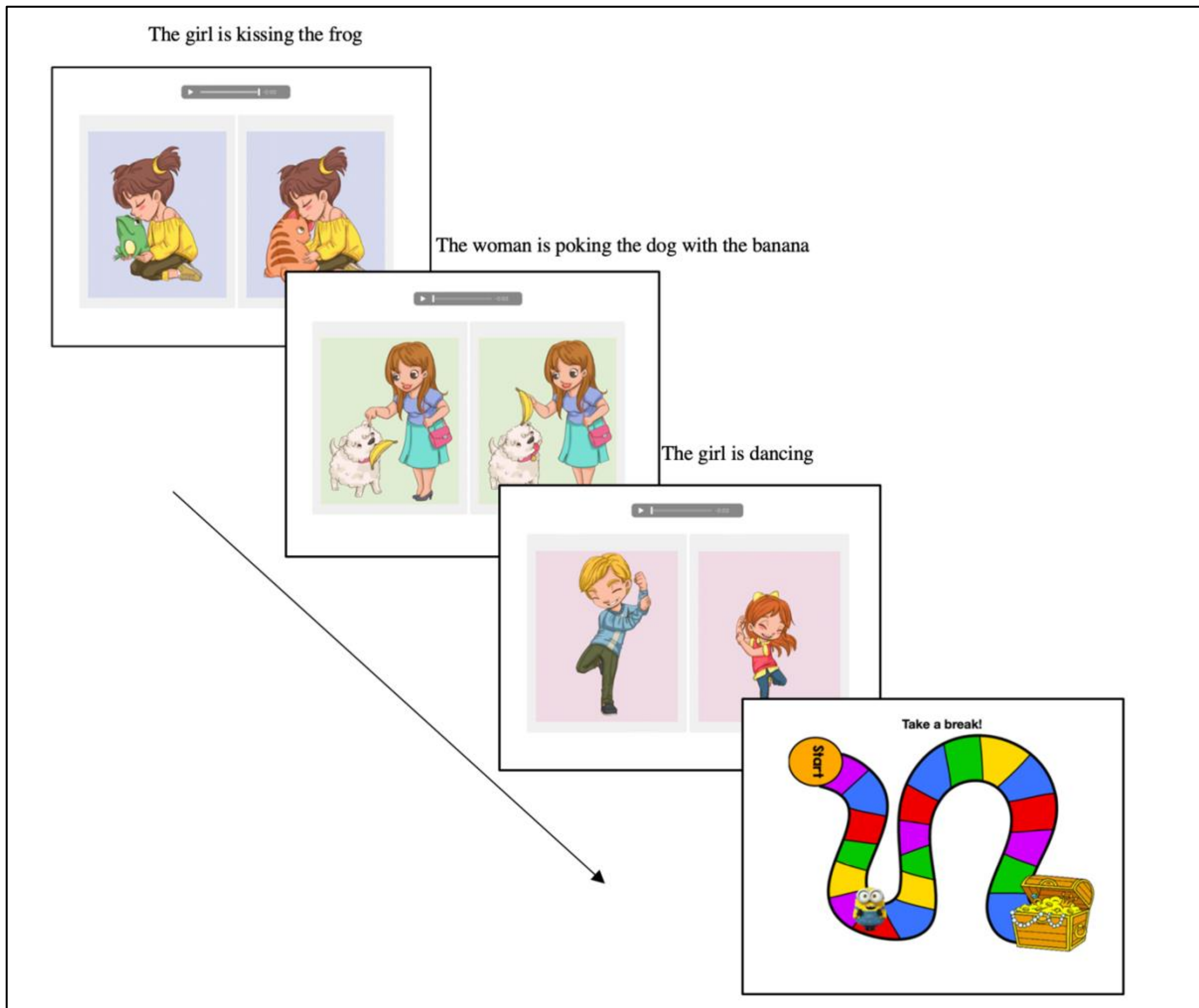

Figure 2. Example of one of the sequences: Filler – Target sentence – Filler –Take-a-break slides.

The task lasted 7 minutes in total without breaks (mean of task completion time: Adults: 559 sec; 8- to 10-year-old: 888 sec and 4- to 6-year-old: 796 sec). There were two breaks throughout the experiment and participants could decide when to continue. However, both children and adults were told that if they took the breaks, each of these breaks could not be longer than 3 minutes. For each break a slide with a '*Take a break!*' caption and a picture of Bob getting closer to the treasure would appear on the screen, this motivated children and encouraged participants to rest for a moment (if they needed it). Participants could use a desktop/laptop or a tablet to do the experiment.

Scoring and data analysis

We removed the filler responses from the dataset and only considered the participants' responses to the target sentences as one outcome variable. Target responses that were HA were coded as 1 and Target responses that were LA were coded as 0, thus the outcome variable was binomial. To analyse the data, we built mixed-effects logistic regression models, which can be thought of as estimating the probability (in log-odds) of HA or LA responses given a specific condition (Jaeger, 2008). We used the lme4 package and the glmer function in the R programming environment (R version 3.5.2) and opted for a maximal random-effects structure for the construction of the models, as suggested by Barr, Levy, Scheepers & Tily (2013). Our predictors were Age Group as a three-level categorical variable: Adults, Younger (4- to 6-year-old) and Older (8- to 10-year-old); and Age in Months (only for children) and Trials as continuous variables. In all the models we used the participants and items parameters as random intercepts in our random-effect structure, and Age Group or Age in Months as random slopes if the model fit was significantly improved. We added the random slopes sequentially, that is, first to participants and then to items. We used Log-likelihood ratio tests to compare the models and the final models were those that resulted in the best model fit and could converge. We used dummy coding as the coding scheme. For Age Group comparisons, the probability of HA responses for the adult group was represented in the intercept, so the adult group was always compared with the Younger group and later with the Older group. The predictor was later relevelled so the intercept represented the probability of HA responses for the Younger group when comparing the Younger group against the Older group. Positive coefficients show that the HA responses were more likely to occur in the tested predictor (continuous variable) or in the tested level of the predictor than the other level (categorical variable).

2.4.2 Results

We carried out three analyses, to test (1) overall effects of Age Group, (2) developmental effects, and (3) cumulative effects on interpreting ambiguous PPs when no prime was presented. To test children's and adults' baseline preferences for interpreting ambiguous PPs, the best-fitting mixed-effects logistic regression model contained the binomial outcome variable HA Responses (with HA responses coded as 1, and LA responses coded as

0) and Age Group as the predictor. To test for any developmental effects in children in the baseline condition, we continued to use the same HA Responses outcome variable and the best-fitting model included Age in Months (continuous variable only for children; centred prior to the analysis) as the predictor. To examine cumulative effects within a session in the baseline condition, we only focussed on analysing the first and last thirds of the data of the experiment and used HA responses as the outcome variable and Trials (continuous variable; 16 trials), Age group and their interactions as the predictors. For the cumulative effects analyses we focussed on examining the direction of the effect, that is whether participants were more likely to use more or fewer HA responses as the experiment progressed in the baseline condition. The random-effect structure of the three final models included participants and items as random intercepts and no random slopes. Figure 3 presents participants' HA responses in each age group. Table 1 shows a summary of results of Age Group comparisons.

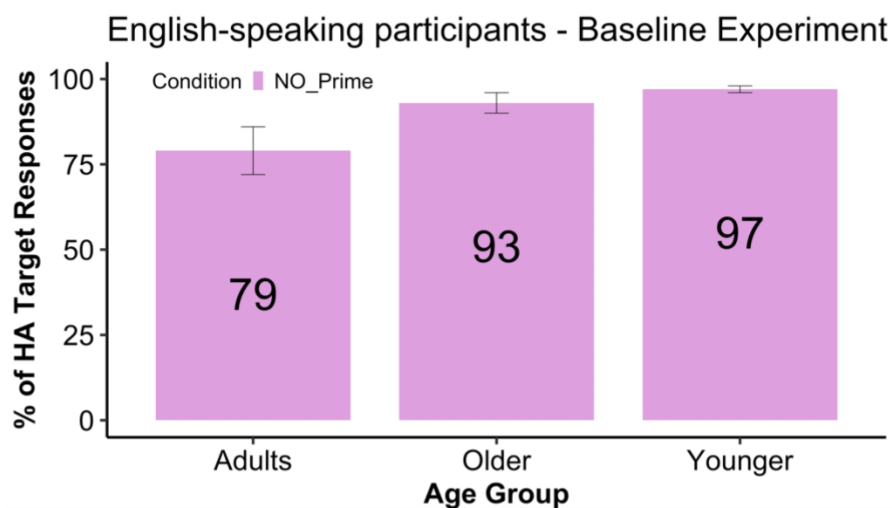

Figure 3. English-speaking participants: Proportion of HA target responses by age group: Baseline experiment.

Each participant responded to 24 fillers and 24 target sentences. All the participants had more than 80% of accurate filler responses, and therefore no participants were removed. Younger children correctly identified the matching picture in the filler sentences 633 (98%) times out 648, Older children correctly identified the matching picture in the filler sentences 480 (100%) times out of 480. Adults correctly identified the matching picture in the filler sentences 476 (99%) times out of 480. Adults also chose 378 (79%) HA responses and 102 (21%) LA target responses. Younger children chose 628 (97%) HA target responses and 20

(3%) LA target responses. Older children chose 446 (93%) HA target responses and 34 (7%) LA target responses (see figure 3).

Effects of Age Group

As shown in Figure 2, the Younger and Older groups of children were more likely to choose HA over LA responses in comparison to the adult group and these differences were statistically significant ($p < .05$) (Younger: M = 97; Older: M = 93 vs. Adults: M = 79). There was no statistically significant difference between the Younger and Older children ($p > .05$) (see Table 1 for a summary of results).

Developmental effect

As shown in Table 1 and Figure 4, Age in Months (continuous variable) did not significantly predict 4- to 6- and 8- to 10-year-old children's preferences. Although the numerical pattern seemed to be that children were more likely to select fewer HA responses and more LA responses as they grew older, this effect was not statistically significant ($p > .05$). This means that the likelihood of choosing a HA response over a LA response in the baseline condition between the ages of 4 and 10 did not increase or decrease as a function of age. (see Figure 4 and Table 1).

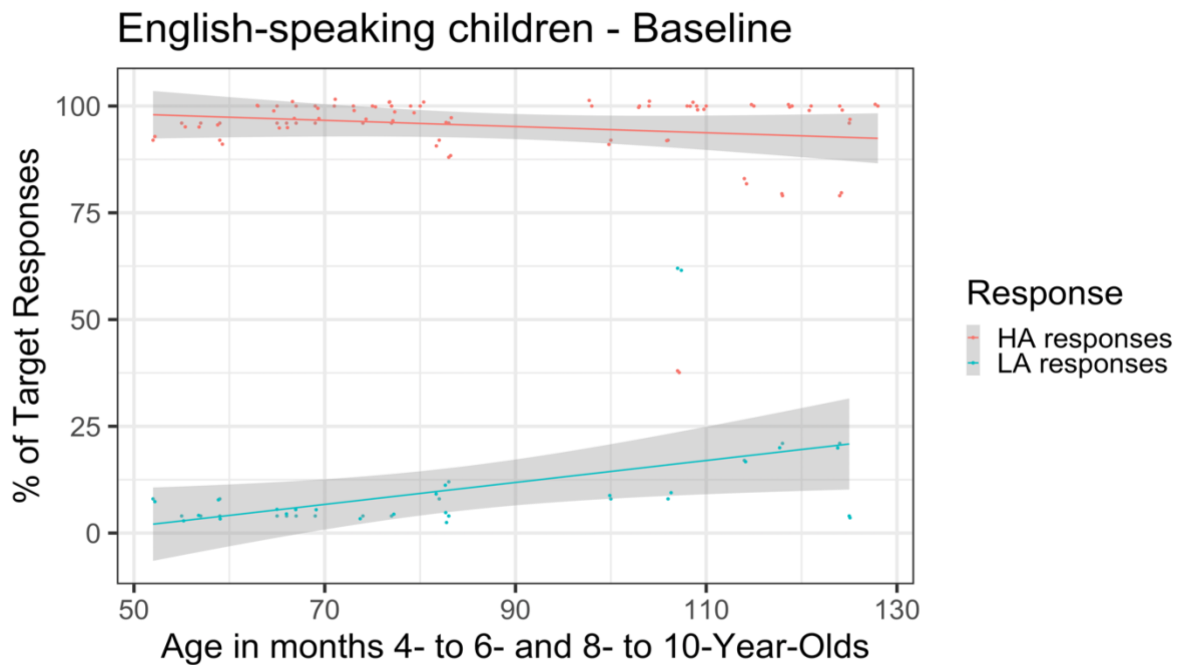

Figure 4. English-speaking children: Proportion of HA and LA target responses by Age in Months in Younger and Older children. Baseline Experiment

Cumulative effects

The best-fitting model revealed an effect of Age Group between the Younger children and the adults ($p < .01$), but not between the Younger and the Older children or between the Older children and the adults (Table 1). There was no main effect of Trials, however, there was an interaction between the Older vs. the Younger children and Trials ($p <.05$). To unpack the interaction, we ran a model with HA responses as the outcome variable and Trials as a predictor for each child group separately. The random-effect structure of the model included participants and items as random intercepts and no random slopes. In the Older group, the model revealed an effect of Trials (<.05) suggesting that the likelihood of choosing a HA response increased as the experiment progressed. In the Younger group, the effect of Trials was not significant ($p>.05$) (see Table 1).

Experiment	Effects	Predictor	Coefficient	SE	Z value	p
Baseline	Effects of Age Group	Intercept (Adults & Younger)	2.58	0.60	4.29	**<.001**
		Age Group (Older vs. Adults)	1.95	0.85	2.27	**<.05**
		Age Group (Younger vs. Adults)	2.06	0.77	2.65	**<.01**
		Age Group (Older vs. Younger)	-0.11	0.83	-0.13	.894
	Developmental effect	Intercept	4.41	1.16	3.78	**<.001**
		Age Months	-0.11	0.29	-0.38	.698
	Cumulative effects	Intercept	2.46	0.89	2.74	**<.01**
		Age Group (Older vs. Adults)	1.21	1.16	1.04	.296
		Age Group (Younger vs. Adults)	3.20	1.18	2.71	**<.001**
		Age Group (Older vs. Younger)	-1.99	1.23	-1.61	.105
		Trials	0.07	0.05	1.39	.162
		Age Group (Older vs. Adults) x Trials	0.11	0.08	1.40	.161
		Age Group (Younger vs. Adults) x Trials	-0.12	0.07	-1.57	.114
		Age Group (Older vs. Younger) x Trials	0.23	0.09	2.48	**<.05**
	Cumulative effects Older group	Intercept	5.25	2.55	2.05	**<.05**
		Trials	0.20	0.08	2.30	**<.05**
	Cumulative effects Younger group	Intercept	4.63	1.11	4.16	**<.001**
		Trials	-0.07	0.09	-0.76	.443

Table 1. English-speaking participants: Summary of mixed-effects logistic regression models with Age Group, Age in Months and Trials as predictors for experiment 1(Experiment 1, Baseline).

2.4.3 Interim discussion

Experiment 1 served as a baseline to examine English-speaking 4- to 6- and 8- to 10-year-old children's and adults' PP attachment preferences. We also tested whether 4- to 6- and 8- to 10-year-olds showed a developmental pattern that would suggest a change in the processing of globally ambiguous sentences at this age stage and whether children and adults would show cumulative effects in the baseline condition. We found that 4- to 6 and 8- to 10-year-old children and adults were more likely to have a preference for HA than for LA when

they were not primed. However, we did not find significant age-group level differences between the 4- to 6- and 8- to 10-year-olds or any effects modulated by Age in Months in children. We only found significant differences when comparing each child group with the adults. This suggests that the Younger and Older children processed globally ambiguous sentences (when no prime is presented) in a similar way and that the likelihood of choosing a HA response decreases in adulthood. However, these effects should be interpreted with caution and future research should attempt to replicate these results, as it could be the case that the Older and Younger children did not show a significant difference in their attachment preferences due to lack of power.

The age at which children no longer show significant differences in their PP attachment preferences from those of adults is still unknown. Future research should continue to investigate developmental patterns in the comprehension of PP attachment ambiguities.

Adults and 8- to 10-year-olds only showed a numerically stronger preference for HA responses by the end of the experiment than when they started the task. The interaction between Age Group (Younger and Older) and Trials, and the significant effect of Trials on the Older group, but not on the Younger group, suggested that the 8- to 10-year-olds showed more sensitivity to cumulative experience than the 4- to 6-year-olds and adults and that they self-primed with their preferred analysis (i.e., HA) over the course of the experiment.

In experiment 2, we sought to understand the role of recent language experience better by investigating whether 4- to 6- and 8- to 10-year-old English-speaking children already showed existing and stable abstract representations of the HA and LA analyses when processing globally ambiguous sentences and whether they were susceptible to cumulative experience. To do this, we investigated whether the presence of a prime sentence before a target sentence, when the prime and target sentences involved different verbs, influenced how children interpreted ambiguous PPs, and furthermore whether children and adults showed cumulative effects of exposure to LA analyses.

2.5 Experiment 2: Non-Repeated Verb

Experiment 1 served as a baseline to establish children's and adults' PP attachment preferences. Given the findings of the existence of lexically-dependent priming effects in 5- to 6-year-old French-speaking children and adults in Havron et al.'s (2020) study, in experiment 2, we aimed to investigate whether 4- to 6- and 8- to 10-year-old English-speaking children interpreted globally ambiguous sentences in the same way they interpreted a prior prime sentence in the absence of lexical overlap. We aimed to seek evidence for existing and stable abstract representations of the HA and LA analyses in children and adults during language comprehension. The adult group served as the control group and the results from experiment 1 served as the baseline for this experiment. We followed the same procedure and used the same language comprehension web-based sentence-picture matching task from Experiment 1, with the same target sentences but with different participants. Additionally, we constructed 24 globally ambiguous sentences that served as the prime sentences. Each target sentence was preceded by a prime sentence and each pair of prime and target sentences involved a different verb. We analysed the priming effects in children and adults and compared the children's performance with that of adults. To look for developmental differences in 4- to 6- and 8- to 10-year-old children, we examined the effect of Age in Months and the effect of priming as well as the interaction between these two variables. This allowed more fine-grained investigation of developmental changes in children's PP attachment preferences, given that in the other analyses we compared different age groups. Cumulative effects within a session in children and adults were also examined. For all the analyses we used a binomial outcome variable, where HA responses were coded as 1 and LA responses were coded as 0.

English-speaking adults were expected to show priming effects in the absence of lexical repetition between the prime and target sentences, as previous research has found (e.g., Pickering et al., 2013). However, since there is mixed evidence regarding the priming effects and the development of children's syntactic representations, we predicted that children may or may not show priming effects. Early abstraction accounts argue that during the early stages of language development younger children have abstract representations rather than representations that are bound to lexical items. Therefore, these accounts predict lexically-independent priming effects in the three age groups. By contrast, error-based learning accounts predict that such lexically-independent priming effects should be stronger in young children

than adults. Thus, depending on how much experience Younger children vs. Older children may have, then, Younger children should show stronger abstract priming effects than the Older children. Similarly, depending on how much experience Older children vs. adults may have, then, Older children should show stronger abstract priming effects than the adults.

If, on the other hand, no lexically-independent priming effects were found in children, then an experiment in which the verb is repeated between the prime and target sentences should be carried out, as this would indicate whether children's syntactic representations of the HA and LA analyses may still have a lexical component.

We also predicted that children and adults would show cumulative effects. That is, children would have had less experience with the LA interpretation, therefore they would be less likely to predict it, meaning that each new exposure to the LA analysis would be more surprising to them than it would be to the adults. Therefore, children would need to adjust their representation of the LA analysis more in response to each new instance than the adults would do, which would mean, as the experiment progresses, children's likelihood of choosing LA should increase (and so the likelihood of choosing HA should decrease) to a greater extent than in adults. Thus, the Younger children were expected to show more cumulative effects than the Older children, and similarly, the Older children were expected to show more cumulative effects than the adults.

2.5.1 Methods

Participants

A total number of 109 English-speaking 4- to 6- and 8- to 10-year-old children and 50 adult native speakers of English (42 female, 8 male) took part in this online experiment in their homes using a computer or tablet. All the participants in experiment 2 were different from those in experiment 1. We removed three 4- to 6-year-olds and one 8- to 10-year-old because all their responses for the LA primes were incorrect. Additionally, we excluded three 4-to -6-year-olds and two 8-to 10-year-olds because they showed more than 20% of inaccurate prime responses. We ended up with the data of fifty 4- to 6-year-olds (mean age 5;5, 27 female, 23 male), fifty 8-to 10-year-olds (mean age 9;1, 26 female, 24 male) and fifty adult students from the University of Edinburgh ranging in age from 18 to 34 (mean age 20). The recruitment process and the participation criteria were the same as experiment 1.

Design

We used a 3 x 2 mixed design with Age Group (Adults vs. Older vs. Younger) as a between-participants and within-items factor, and Prime condition (HA vs. LA) as a within-participants and -items factor.

Materials

To investigate the effect of priming without lexical repetition, we followed the same paradigm as Branigan et al. (2005) and Pickering et al. (2012) but utilised the materials from our baseline experiment. Additionally, we constructed 24 globally ambiguous sentences that served as the primes and paired them with the target sentences e.g., Prime: '*The girl is pushing the teacher with the ball*'. There were two versions of each prime sentence. In the HA prime condition, the prime sentence was presented with two pictures that matched an HA interpretation, and in the LA prime condition, the prime sentence was presented with two pictures that matched an LA interpretation. Each of these pairs of pictures, consisted of a matching and a mismatching picture. The mismatching picture always involved the same action as in the prime sentence but a different object (see figure 5).

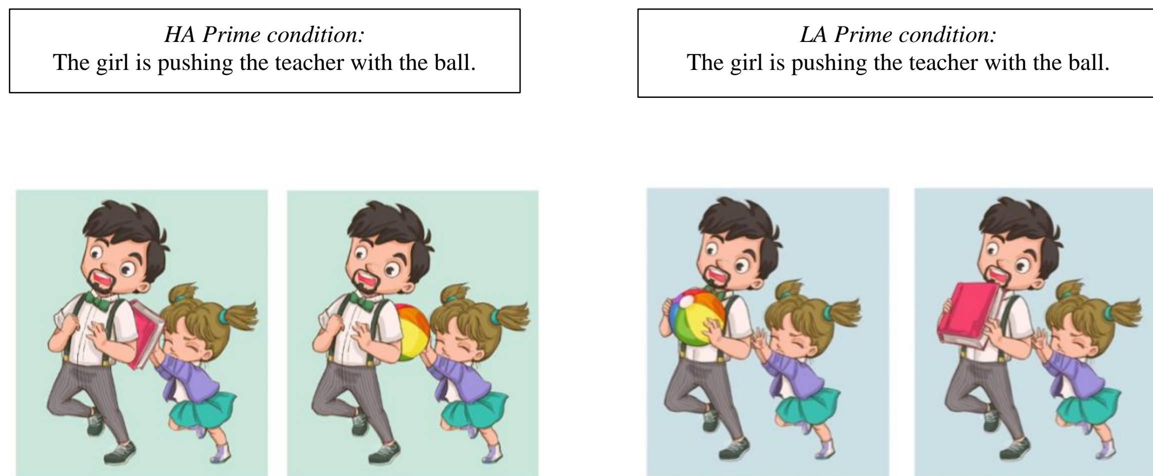

Figure 5. Example of the two picture-matching versions of a Prime sentence.

The same verbs that were used for the target sentences in experiment 1 were also used for the primes. A native speaker of English trained in the field of psycholinguistics recorded the audios for the prime sentences. The position of the pictures of the prime sentences was randomised and counterbalanced, therefore it could appear either on the right or left side of the screen. Likewise, the position of the agent in the prime pictures was also right-to-left oriented

for half the trials and left-to-right oriented for the other half. All the pictures were designed by a professional illustrator.

An experimental item was comprised of a prime sentence such as 1) followed by a target sentence such as 2). There was always an intervening filler after each experimental item. Prime and target sentences did not share the same verb.

Item: 1) Prime sentence: The girl is pushing the teacher with the ball.
2) Target sentence: The girl is touching the dog with the banana.
Filler: 3) The dog is chasing the sheep.

We randomised the order of all the sentences (primes, targets and fillers) and then created two fixed lists (A and B), with the constraint that there would be an intervening filler after each target sentence and that the prime and target sentences would not share the same verb. Each list was comprised of 24 fillers, 12 items from the HA prime condition and 12 items from the LA prime condition. Each participant listened to a total of 72 sentences. The same 24 target sentences and their corresponding pairs of pictures appeared in both lists; however, primes were crossed between the two lists. For example, the pairs of pictures of the 12 HA prime sentences that appeared in list A would appear in list B but as the LA prime versions. Each participant was randomly allocated to one of the lists. Each sentence was considered as one individual trial.

To make sure that there was no bias towards the modifier or the instrumental interpretations of the prime sentences, we measured the prosodic breaks of each sentence between the NP (e.g., the teacher) and the PP (e.g., with the ball) for the instrumental interpretation, and between the verb (e.g., pushing) and the NP (e.g., the teacher) for the modifier interpretation. Then we ran a two-sample t-test to make sure that there was no statistically significant difference between the prosodic breaks ($p > .05$).

Procedure

The experimenter followed the same procedure as in the baseline experiment. The task lasted 10 minutes in total without breaks. There were three optional breaks throughout the task and participants could decide when to continue (mean of task completion time: Adults: 719 sec, 8- to 10-year-olds: 1,011 sec and 4- to 6-year-olds: 1,075 sec).

Scoring and data analysis

Only the participants' responses to the target sentences were analysed as one outcome variable. We followed the same procedure to code the outcome variable and conduct the analyses as in experiment 1. Our predictors were Age Group as a three-level categorical variable: Adults, Younger and Older; Age in Months (only for children) and Trials as continuous variables and Prime condition as a two-level categorical variable: HA prime, LA prime. In all the models we used the participants and items parameters as random intercepts in our random-effect structure, and Age Group, Prime or Age in Months as random slopes if the model fit was significantly improved. We first added the random slopes to participants and then for items. We used Log-likelihood ratio tests to compare the models and the final models were those that resulted in the best model fit and could converge. For Age Group and Prime type comparisons the probability of HA responses for the adult group is represented in the intercept. The predictor was later relevelled so the intercept could represent the probability of HA responses for the Younger group. Positive coefficients show that the HA responses were more likely to occur in the tested predictor (continuous variable) or in the tested level of the predictor than the other level (categorical variable).

2.5.2 Results

We carried out three analyses to test (1) overall effects of Prime, Age Group, and the interaction between these two (2) developmental effects of Age in Months, Prime, and the interaction between these two, and (3) cumulative effects on interpreting ambiguous PPs in the presence of a prime that involved a different verb than the target sentence.

To test the effect of priming without lexical repetition between the prime and target sentence in English-speaking children's and adults' PP attachment preferences, we built a mixed-effects logistic regression model containing the binomial outcome variable HA responses (with HA responses coded as 1, and LA responses coded as 0). We ran the model with Age Group and Prime and the interaction between them as predictors.

To examine any developmental patterns in children, we used the same outcome variable as model 1 and built a second model with Age in Months (continuous variable with only the children; centred prior to the analysis) and Prime and their interactions as the predictors.

To examine cumulative effects within a session in the presence of a prime that involved a different verb than the target, we analysed the first and last thirds of the data of the experiment

and used HA responses as the outcome variable and Trials (continuous variable; 16 trials), Age group, Prime and their interactions as the predictors. For the cumulative effects analyses we focussed on examining the direction of the effect, that is whether participants were more likely to use more or fewer HA responses as the experiment progressed in the presence of a prime that involved a different verb than the target.

The random-effect structure of the two final models included participants and items as random intercepts and no random slopes. Figure 6 presents participants' HA responses in each Age group by Prime. Table 2 shows a summary of results of the comparisons of the predictors.

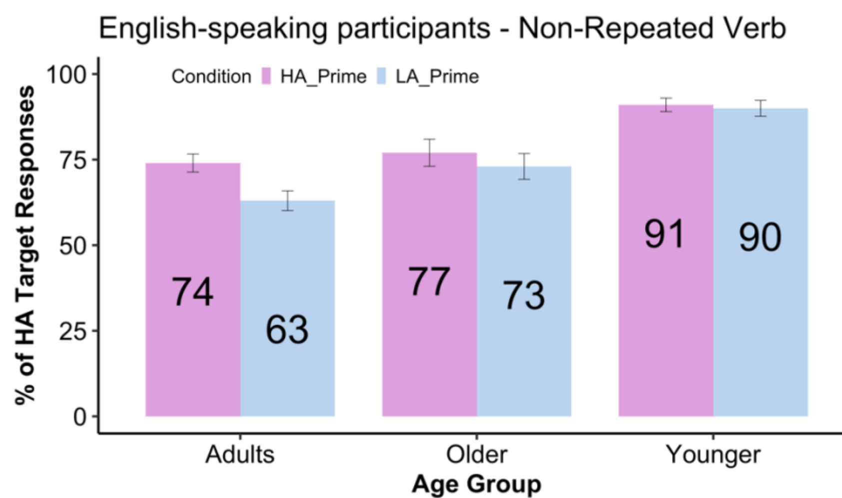

Figure 6. English-speaking participants: Proportion of HA target responses after a HA prime and a LA prime by age group: Non-Repeated Verb experiment

Each participant responded to 24 fillers, 24 prime sentences and 24 target sentences. Items in which the prime picture was incorrectly chosen were removed. We removed 10 items in the adult group, 36 items in the Younger group and 16 items in the Older group out of 1200 items per group.

Adults correctly identified the matching picture in the prime trials 1,190 (99%) times out of 1,200. Of these 1,190 trials, 593 (50%) were HA primes, and 597 (50%) were LA primes. In these trials, participants chose 816 (69%) HA target responses and 374 (31%) LA target responses.

The Younger children correctly identified the matching picture in the prime trials 1,164 (97%) times out of 1,200. Of these 1,164 trials, 587 (50%) were HA primes, and 577 (50%)

were LA primes. In these trials, participants chose 1,056 (91%) HA target responses and 108 (9%) LA target responses.

The Older children correctly identified the matching picture in the prime trials 1,184 (99%) times out of 1200. Of these 1,184 trials, 590 (50%) were HA primes, and 594 (50%) were LA primes. In these trials, participants chose 888 (75%) HA target responses and 296 (25%) LA target responses. Each participant had 80% or more of accurate prime responses.

All the participants had more than 80% of accurate filler responses. The Younger children correctly identified the matching picture in the filler sentences 1,171 (98%) times out 1,200, Older children correctly identified the matching picture in the filler sentences 1,186 (99%) times out of 1,200. Adults correctly identified the matching picture in the filler sentences 1,186 (99%) times out of 1,200.

Effects of Age Group

The comparison between adults and children showed a main effect of Prime suggesting that overall, participants were less likely to choose an HA response after an LA prime than after an HA prime ($p < .001$). We also found an effect of Age Group between the Younger group and adults ($p <.001$) and between the Younger group and Older group ($p <.001$), but not between the Older group and adults ($p >.05$) (Younger HA prime M =91, LA prime M= 90; Older HA prime M = 77, LA prime M = 73; Adults HA prime M = 74, LA prime M = 63). This suggested that the Younger group was more likely to choose HA over LA responses than the adults and the Older group, and that the number of HA and LA responses between the Older group and Adults did not differ significantly. The Age Group by Prime interaction was not significant for the Younger group vs. adult comparison, or for the Older vs. adult comparison (although the latter was marginal: $p =.08$) (Table 2 for a summary of results).

Developmental effect

The analysis with Age in Months as a continuous variable revealed a main effect ($p < .001$) suggesting that, as children got older, they were more likely to choose fewer HA responses and more LA responses. There was no difference by age in the likelihood of choosing an HA after an HA prime compared to after a LA prime. Also, the effect of Prime was no longer reliable in this analysis. (see Figures 7).

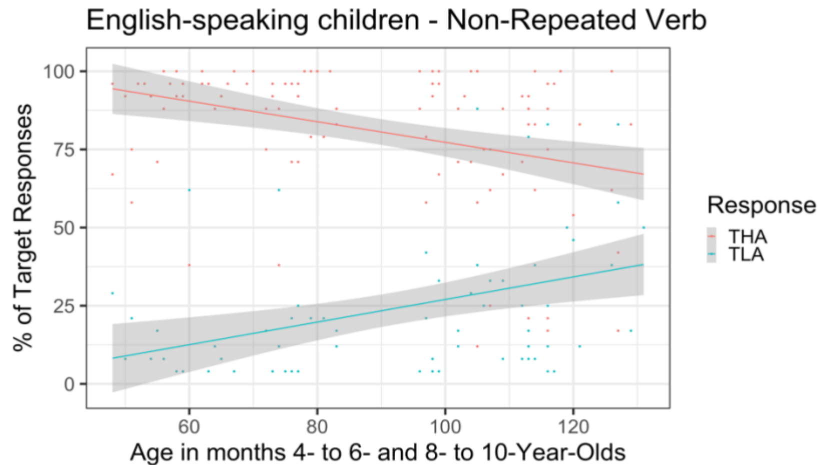

Figure 7. English-speaking participants: Proportion of HA and LA responses by Age in Months in Younger and Older children: Non-Repeated Verb experiment. THA = HA target responses; TLA = LA target responses

Cumulative effects

The model revealed an effect of Age Group between the Younger children and adults ($p < .01$) and between the Younger and Older children ($p <.05$), but not between the Older children and adults (>.05). This suggests that, if we analyse only the first and last thirds of the data of the Non-Repeated verb experiment, the Younger group chose more HA than LA responses in comparison to the Older group and adults. We also found a main effect of Prime ($p <.05$), but not of Trials ($p >.05$) or of the interactions between Trials, Age Group and Prime. That is, the likelihood of choosing HA responses did not vary from the first third to the last third of the experiment overall, or between different age groups, or as a function of exposure to a preceding prime (see Table 1).

Experiment 2	Effects	Predictor	Coefficient	SE	Z value	p
Non-Repeated Verb	Effects of Age Group	Intercept	1.38	0.28	4.91	**<.001**
		Age Group (Older vs. Adults)	0.50	0.34	1.49	.136
		Age Group (Younger vs. Adults)	2.00	0.36	5.48	**<.001**
		Age Group (Older vs. Younger)	-1.50	0.37	-4.04	**<.001**
		Prime (LA vs. HA)	-0.64	0.14	-4.59	**<.001**
		Age Group (Older vs. Adults) x Prime	0.37	0.21	1.71	.085
		Age Group (Younger vs. Adults) x Prime	0.42	0.26	1.63	.102
		Age Group (Older vs. Younger) x Prime	-0.05	0.27	-0.19	.842
	Developmental effect	Intercept	2.73	0.26	10.14	**<.001**
		Age in Months	-0.86	0.21	-3.93	**<.001**
		Prime (LA vs. HA)	-0.24	0.14	-1.66	.096
		Age in Months x Prime	-0.03	0.13	-0.28	.770
	Cumulative effects	Intercept	1.65	0.52	3.12	**<.01**
		Age Group (Older vs. Adults)	0.40	0.48	0.83	.406
		Age Group (Younger vs. Adults)	1.63	0.54	2.97	**<.01**
		Age Group (Older vs. Younger)	-1.22	0.56	-2.18	**<.05**
		Prime (LA vs. HA)	-0.89	0.36	-2.44	**<.05**
		Trials	-0.02	0.05	-0.49	.618
		Age Group (Older vs. Adults) x Prime	0.49	0.54	0.90	.366
		Age Group (Younger vs. Adults) x Prime	0.61	0.64	0.96	.337
		Age Group Older vs. Younger) x Prime	-0.12	0.60	-0.18	.857
		Age Group (Older vs. Adults) x Trials	0.00	0.04	0.08	.932
		Age Group (Younger vs. Adults) x Trials	0.01	0.04	0.35	.719
		Age Group (Older vs. Younger) x Trials	-0.01	0.04	-0.27	.781
		Prime (LA vs. HA) x Trials	0.02	0.03	0.79	.424
		Age Group (Older vs. Adults) x Prime x Trials	-0.02	0.05	-0.43	.664
		Age Group (Younger vs. Adults) x Prime x Trials	-0.04	0.06	-0.68	.495
		Age Group (Older vs. Younger) x Prime x Trials	0.02	0.06	0.29	.767

Table 2. English-speaking participants: Summary of mixed-effects logistic regression models with Age Group, Prime, Age in Months and Trials as predictors for experiment 2 (Non-Repeated Verb).

2.5.3 Interim discussion

The Non-repeated Verb experiment investigated whether 4- to 6- and 8- to 10-year-old English-speaking children and adults interpreted globally ambiguous sentences in the same way they interpreted a prior prime sentence in the absence of verb repetition. Our aim was to seek evidence for existing and stable abstract representations of the HA and LA analyses in children and adults during language comprehension. Additionally, we examined developmental changes in the processing of PP attachment preferences, and furthermore whether children and adults showed cumulative effects of exposure to LA analyses when prime and target pairs involved a different verb.

Our findings revealed a main effect of Prime in participants, however, this effect was no longer reliable in children after removing the adult data. This may suggest that children's abstract representations of the LA analysis may be more weakly represented than adults'. However, these results may also suggest unstable abstract priming effects in children that may be difficult to detect and therefore more power may be required.

Age-group level differences in the overall PP preferences between the Younger children and Older children as well as between the Younger children and adults were significant, but not between the Older children and adults. When analysing developmental differences in children, Age in Months was a strong predictor for the overall preferences for HA vs. LA, that is, as children grew older, the more likely they were to choose fewer HA responses (and therefore more LA responses). We did not find significant effects of cumulative experience in any of the age groups. That is, the likelihood of choosing an HA response did not vary from the first third to the last third of the experiment overall, or between different age groups, or as a function of exposure to a preceding prime that did not involve the same verb as the target sentence.

Given that in experiment 2 we found unreliable abstract priming effects in children, in experiment 3, we sought to understand the role of recent language experience better by investigating whether children's syntactic representations of the HA and LA analyses might have some lexically-specific component, and whether children might also be susceptible to cumulative experience. To do this, we investigated whether the presence of a prime sentence

before a target sentence, when the prime and target sentences involved the same verbs, influenced how children interpreted ambiguous PPs, and furthermore whether children and adults showed cumulative effects of exposure to the HA and LA analyses.

2.6 Experiment 3: Repeated Verb

In experiment 2 we examined whether 4- to 6- and 8- to 10-year-old English-speaking children and adults showed evidence of existing and stable abstract representations of the HA and LA analyses during language comprehension. We found a main effect of Prime, however, this effect was no longer reliable in children when the adults' responses were removed from the analyses.

In experiment 3, we aimed to investigate whether children's representations of the HA and LA analyses may have some lexically-specific component. We followed the same procedure and used the same language comprehension web-based sentence-picture matching task as in experiment 2, with the same stimuli but with different participants. Each target sentence was preceded by a prime sentence and each pair of prime and target sentences involved the same verb. We analysed the priming effects in participants and compared the children's performance with that of adults, who served as the control group. To look for developmental differences in 4- to 6- and 8- to 10-year-old children, we examined the effect of Age in Months and the effect of priming as well as the interaction between these two variables. This allowed more fine-grained investigation of developmental changes in children's PP attachment preferences. Cumulative effects within a session in children and adults were also examined.

To look for evidence of a lexical boost, we compared experiment 2 (Non-Repeated Verb) against experiment 3 (Repeated Verb) and examined whether the differences in the overall PP preferences and priming effects in participants were significant.

To examine whether participants were susceptible to the HA and LA primes, we also compared the overall PP preferences in participants of experiment 1 (Baseline) against the ones of experiment 2 (Non-Repeated-Verb) and experiment 3 (Repeated-Verb). For all the analyses we used a binomial outcome variable, where HA responses were coded as 1 and LA responses were coded as 0.

Adults were expected to show lexically-dependent priming effects and a lexical boost, as previous structural priming studies have found (e.g., Pickering et al., 2013; Branigan et al., 2005). Both 4- to 6- and 8- to 10-year-old children were also expected to show lexically-dependent priming effects and possibly a lexical boost, as reported by previous studies (Havron et al., 2020; Rowland et al., 2012; Peter, Chang, Pine, Blything, & Rowland, 2015; Thothathiri & Snedeker, 2008).

If the Younger children showed a stronger effect of the lexical boost than the Older children and the adults, this would support usage-based lexicalist accounts that suggest that syntactic representations in young children may have a lexically-specific component. If this were the case, then the Older children may also show a stronger effect of the lexical boost than the adults. Such enhanced priming effects when the verb is repeated between the prime and the target sentences would also be consistent with the residual activation account (Pickering & Branigan, 1998) that predicts facilitated processing of the target sentences and stronger priming effects when there is verb overlap between the prime and target sentences.

However, under the error-based learning model, a lexical boost is only predicted in the old children and adults, but not in young children, since its nature relies on explicit memory, skills that are still underdeveloped in young children. Thus, under this model, we predicted that the lexical boost would develop across age. Therefore, 4- to 6-year-olds were not expected to show a lexical boost. Adults, on the other hand, were expected to show a stronger lexical boost than the 8- to 10-year-old children. This would support previous research by Rowland et al. (2012) and Peter et al. (2015) who found larger effects in the size of the lexical boost in adults than in young children, although see Branigan and McLean (2016) who found no difference in the context of much more robust effects.

If children did no show evidence of lexically-dependent priming effects, this would suggest that they had difficulties in understanding and accepting the LA alternative prime, suggesting that, children may not have been able to overcome the lexical bias for VP attachment given that most of the verbs used in the prime and target sentences favoured the HA analysis. This would be consistent with previous developmental studies that have found that verb-specific information is one of the most reliable cues that children at a young age tend to use in sentence processing, and that the incorporation of different cues in language comprehension (i.e., recent experience, referential information) is a process that develops over time (e.g., Snedeker & Trueswell, 2004; Kidd et al., 2010).

Both children and adults were expected to be susceptible to the proportion of HA and LA primes resulting in cumulative effects. However, because of the high prediction error in children, they were expected to show larger cumulative effects than adults since they might be more sensitive to the less predicted and thus surprising LA structure across the experiment. That is, children would have had less experience with the LA interpretation, therefore they would be less likely to predict it, meaning that each new exposure to the LA analysis would be more surprising to them than it would be to the adults. Therefore, children's likelihood of choosing the LA analysis should increase (and so the likelihood of choosing the HA analysis should decrease) to a greater extent than in adults. Thus, the Younger children were expected to show larger cumulative effects than the Older children and the Older children were expected to show larger cumulative effects than adults.

2.6.1 Methods

Participants

A total number of 111 native English-speaking children and 50 adult native speakers of English (39 female, 11 male) took part in this online experiment in their homes using a computer or tablet. All the participants were different from experiment 1 and 2. We removed two 4- to 6-year-olds and two 8- to 10-year-old because all their responses for the LA primes were incorrect. Additionally, we excluded four 4- to 6-year-olds and three 8- to 10-year-olds because they showed more than 20% of inaccurate prime responses. We ended up with the data of fifty 4-to 6-year-olds (mean age 5;6, 20 female, 30 male), fifty 8-to 10-year-olds (mean age 9;1, 32 female, 18 male) and fifty adult students from the University of Edinburgh ranging in age from 18 to 34 (mean age 21). The recruitment process and the participation criteria were identical to experiment 1.

Design

We used the same design as in experiment 2.

Materials

To investigate the effect of priming with lexical repetition, we used the same fillers, primes, target sentences, and pre-recorded sentences that we used in experiment 2. An

experimental item was comprised of a prime sentence such as 1) followed by a target sentence such as 2). The only constraint was that the same verb was shared between the prime and target sentence. There was always an intervening filler after each experimental item.

Item: 1) Prime sentence: The girl is pushing the teacher with the ball.
2) Target sentence: The boy is pushing the dog with the key.
Filler: 3) The dog is chasing the sheep.

We randomised the order of all the sentences (prime, target and filler sentences) and created two fixed lists (A and B) for this experiment. We followed the same process to create the two lists with the constraint that there would be an intervening filler after each target sentence and that the prime and target sentences would share the same verb. Each participant was randomly allocated to one of the lists. Each sentence was considered as one individual trial.

To make sure that there was no bias towards the modifier or the instrumental interpretations of the prime sentences, we measured the prosodic breaks of each sentence between the NP (e.g., the teacher) and the PP (e.g., with the ball) for the instrumental interpretation, and between the verb (e.g., pushing) and the NP (e.g., the teacher) for the modifier interpretation. Then we ran a two-sample t-test to make sure that there was no statistically significant difference between the prosodic breaks ($p > .05$).

Procedure

The experimenter followed the same procedure as experiment 2. The task lasted 10 minutes in total without breaks. There were three optional breaks throughout the task and participants could decide when to continue (mean of task completion time: Adults 650 sec, 8- to 10-year-olds 897 sec and 4- to 6-year-olds 1,190 sec).

Scoring and data analysis

The scoring and the data analysis procedures were identical to experiment 2. We followed the same procedure to code the outcome variable and conduct the analyses as in experiments 1 and 2. Our predictors were Age Group as a three-level categorical variable: Adults, Younger and Older; Age in Months (only for children) and Trials as continuous variables and Prime condition as a two-level categorical variable: HA prime, LA prime. We followed the same procedure as in experiment 2 to build the random-effect structure of the

models. Age Group, Prime or Age in Months were included as random slopes if the model fit was significantly improved. The final models were those that resulted in the best model fit and could converge. For Age Group and Prime type comparisons the probability of HA responses for the adult group was represented in the intercept. The predictor was later relevelled so the intercept could represent the probability of HA responses for the Younger group. Positive coefficients show that the HA responses were more likely to occur in the tested predictor (continuous variable) or in the tested level of the predictor than the other level (categorical variable).

2.6.2 Results

We carried out six analyses, to test (1) overall effects of Prime, Age Group, and the interaction between these two (2) developmental effects of Age in Months, Prime, and the interaction between these two, (3) cumulative effects on interpreting ambiguous PPs in the presence of a prime that involved the same verb than the target sentence.

To test the effect of priming with verb repetition in children's and adults' PP attachment preferences and to test for any developmental patterns, we built two models and conducted the same analyses as in experiment 2. We ran the first model with Age Group and Prime and the interactions between them as predictors.

To examine developmental patterns in children, we built a second model with Age in Months (continuous variable with only the children; centred prior to the analysis) and Prime and their interactions as the predictors.

To examine cumulative effects within a session in the presence of a prime that involved the same verb than the target, we analysed the first and last thirds of the data of the experiment and used HA responses as the outcome variable and Trials (continuous variable; 16 trials), Age group, Prime and their interactions as the predictors. For the cumulative effects analyses we focussed on examining the direction of the effect, that is, whether participants were more likely to choose more or fewer HA responses as the experiment progressed in the presence of a prime that involved the same verb than the target. The random-effect structure of the final models included participants and items as random intercepts and no random slopes. Figure 8 presents participants' HA responses in each age group. Table 3 shows a summary of results of the comparisons of the predictors.

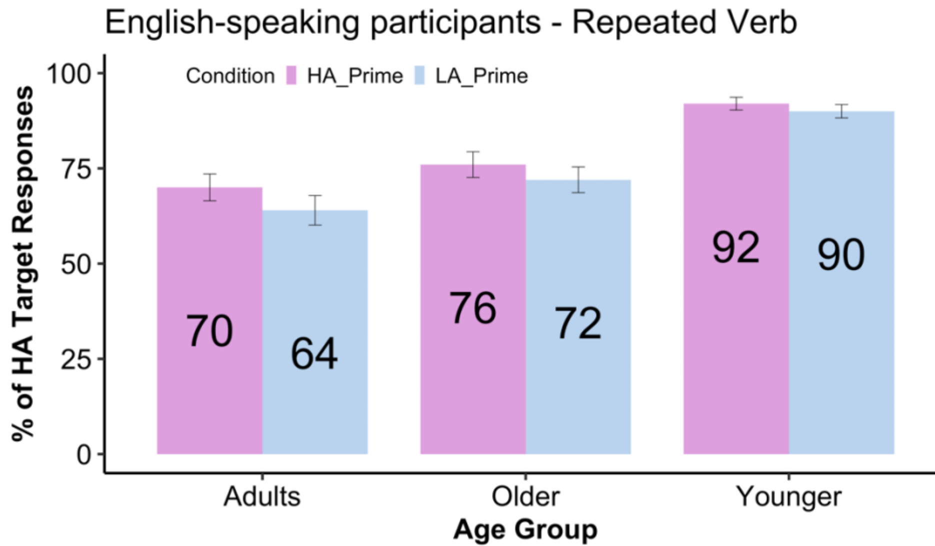

Figure 8. English-speaking participants: Proportion of HA target responses after a HA prime and a LA prime by age group: Repeated Verb experiment

Each participant responded to 24 fillers, 24 prime sentences and 24 target sentences. Items in which the prime picture was incorrectly chosen were removed. We removed 3 items in the adult group, 36 items in the Younger group and 7 items in the Older group out of 1,200 items in each group.

Adults correctly identified the matching picture in the prime trials 1,197 (100%) times out of 1,200. Of these 1,197 trials, 598 (50%) were HA primes, and 599 (50%) were LA primes. In these trials, participants chose 804 (67%) HA target responses and 393 (33%) LA target responses.

The Younger children correctly identified the matching picture in the prime trials 1,164 (97%) times out of 1,200. Of these 1,164 trials, 593 (50%) were HA primes, and 571 (50%) were LA primes. In these trials, participants chose 1,059 (91%) HA target responses and 105 (9%) LA target responses.

The Older children correctly identified the matching picture in the prime trials 1,193 (99%) times out of 1200. Of these 1,193 trials, 594 (50%) were HA primes, and 599 (50%) were LA primes. In these trials, participants chose 880 (74%) HA target responses and 313 (26%) LA target responses. Each participant had 80% or more of accurate prime responses.

All the participants had more than 80% of accurate filler responses. Younger children correctly identified the matching picture in the filler sentences 1,170 (98%) times out 1,200,

Older children correctly identified the matching picture in the filler sentences 1,190 (99%) times out of 1,200. Adults correctly identified the matching picture in the filler sentences 1,194 (99%) times out of 1,200.

Effects of Age Group

The analysis by Age Group showed a main effect of Prime suggesting that children and adults were less likely to choose an HA response after an LA prime than after an HA prime when there was verb repetition between the prime and target sentence ($p < .01$). We also found an effect of Age Group between the Younger group and adults ($p <.001$) and between the Younger group and Older group ($p <.001$), but not between the Older group and adults ($p >.05$) (Younger HA prime M = 92, LA prime M= 90; Older HA prime M = 76, LA prime M = 72; Adults HA prime M = 70, LA prime M = 64). These results suggest that the Younger group chose more HA over LA responses than the Older group and the adults. Given that the number of HA and LA responses between the Older group and Adults did not differ significantly, this suggests that the Older group showed a similar pattern to the adults in the way they processed globally ambiguous sentences when there was verb overlap between the prime and target sentences. The model did not reveal any significant interactions between Age group and Prime (see Table 3 for a summary of results).

Developmental effect

The analysis targeting developmental effects in children revealed a main effect of Age in Months ($p < .001$) suggesting that, as children got older, they were more likely to choose fewer HA responses and more LA responses. We also found an effect of Prime ($p < .05$) but not an interaction between Prime and Age in Months suggesting that irrespective of age, 4- to 10-year-old children showed immediate lexically-dependent priming effects and thus were more likely to choose fewer HA responses after a LA prime than after a HA prime (see Table 3 and Figure 9).

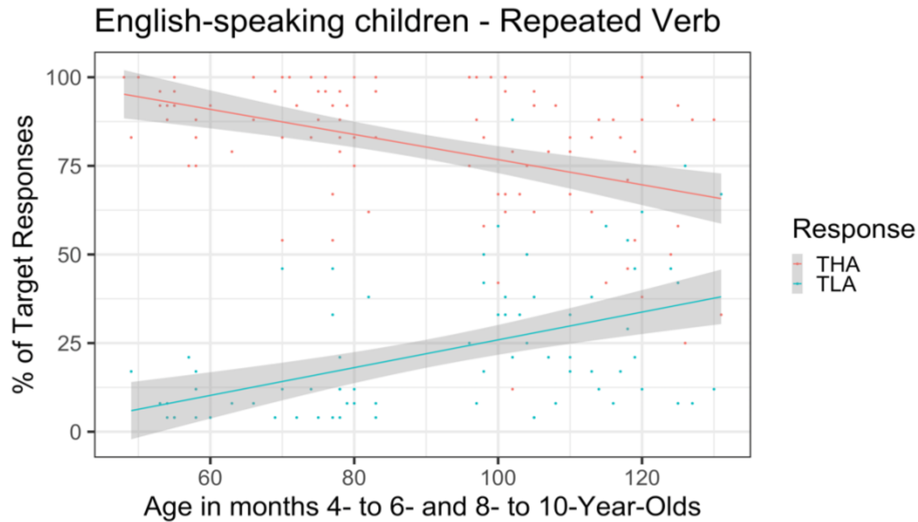

Figure 9. English-speaking participants: Proportion of HA and LA responses by Age in Months in Younger and Older children: Repeated Verb experiment. THA = HA target responses; TLA = LA target responses

Cumulative effects

The model for cumulative effects revealed an effect of Age Group between the Older children and adults (p <.05) and between the Younger children and adults (p < .01), but not between the Older and the Younger children (p>.05). This suggests that, if we analyse only the first and last thirds of the data of the Repeated verb experiment, both the Younger and the Older children chose more HA than LA responses in comparison to the adults. We also found a main effect of Prime (p <.05), but not of Trials (p>.05). This suggested that the likelihood of choosing HA did not vary from the first third to the last third overall, or between different age groups, or as a function of exposure to a preceding prime. No interactions between Age Group and Prime or between Age Group and Prime and Trials were found. In the interaction between Age Group (Older vs. Adults) and Trials, there was a larger numerical difference between the two prime conditions as the experiment progressed, but this did not reach statistical significance (p =.08) (see Table 3).

Experiment	Effects	Predictor	Coefficient	SE	Z value	p
Repeated Verb	Effects of Age Group	Intercept	1.37	0.27	4.91	**<.001**
		Age Group (Older vs. Adults)	0.31	0.34	0.92	.356
		Age Group (Younger vs. Adults)	1.84	0.36	5.08	**<.001**
		Age Group (Older vs. Younger)	-1.53	0.36	-4.20	**<.001**
		Prime (LA vs. HA)	-0.40	0.14	-2.75	**<.01**
		Age Group (Older vs. Adults) x Prime	0.12	0.21	0.59	.552
		Age Group (Younger vs. Adults) x Prime	0.20	0.25	0.79	.429
		Age Group (Older vs. Younger) x Prime	-0.07	0.26	-0.30	.763
	Developmental effects	Intercept	2.41	0.22	10.81	**<.001**
		Age in Months	-0.91	0.17	-5.19	**<.001**
		Prime (LA vs. HA)	-0.29	0.13	-2.13	**<.05**
		Age in Months x Prime	0.11	0.13	0.82	.410
	Cumulative effects	Intercept	1.87	0.55	3.40	**<.001**
		Age Group (Older vs. Adults)	1.43	0.56	2.54	**<.05**
		Age Group (Younger vs. Adults)	2.18	0.67	3.24	**<.01**
		Age Group (Older vs. Younger)	-0.75	0.70	-1.06	.280
		Prime (LA vs. HA)	-0.83	0.39	-2.10	**<.05**
		Trials	-0.07	0.05	-1.51	.129
		Age Group (Older vs. Adults) x Prime	0.77	0.63	1.22	.220
		Age Group (Younger vs. Adults) x Prime	1.08	0.83	1.30	.191
		Age Group (Older vs. Younger) x Prime	-0.30	0.88	-0.35	.726
		Age Group (Older vs. Adults) x Trials	-0.07	0.04	-1.75	.080
		Age Group (Younger vs. Adults) x Trials	0.01	0.05	0.34	.730
		Age Group (Older vs. Younger) x Trials	-0.09	0.06	-1.61	.106
		Prime (LA vs. HA) x Trials	0.05	0.03	1.37	.170
		Age Group (Older vs. Adults) x Prime x Trials	-0.08	0.06	-1.32	.184
		Age Group (Younger vs. Adults) x Prime x Trials	-0.06	0.08	-0.85	.395
		Age Group (Older vs. Younger) x Prime x Trials	-0.01	0.08	-0.13	.889

Table 3. English-speaking participants: Summary of mixed-effects logistic regression models with Age Group, Prime, Age in Months and Trials as predictors for experiment 2 (Repeated Verb).

Effect of lexical repetition

To test the effect of lexical repetition between the prime sentence and target sentence in children's and adults' preferences for interpreting ambiguous PPs, we compared the Non-Repeated Verb experiment against the Repeated Verb experiment. To do this, we combined the data from these two experiments and built a mixed-effects logistic regression model with the binomial outcome variable HA responses (HA responses coded as 1, and LA responses coded as 0) and ran the model with Age Group, Prime, Experiment (2 levels: Non-Repeated verb; Repeated verb) and the interactions between them as predictors. The random-effect structure of the final model included participants and items as random intercepts and Experiment as a random slope. Table 4 shows a summary of the results of Age Group, Prime and Experiment comparisons as well as their interactions, where the probability of HA responses after a HA prime for the Adult group in the Non-Repeated Verb experiment is represented in the intercept. We later relevelled the predictor so the intercept could represent the probability of HA responses after a HA prime for the Younger group in the Non-Repeated Verb experiment. Positive coefficients show that HA target responses were more likely to occur in the tested level of the predictor than the other level (categorical variable).

The model revealed a main effect of Prime suggesting that, when combining the data of the Repeated-Verb and Non-Repeated Verb experiments, participants were less likely to choose an HA response after a LA prime than after an HA prime ($p < .001$).
We also found an effect of Age Group between the Younger group and adults ($p <.001$) and between the Younger group and Older group ($p <.001$), but not between the Older group and adults ($p >.05$), (Younger ($n = 100$) HA prime $M =92$, LA prime $M= 90$; Older ($n = 100$) HA prime $M = 76$, LA prime $M = 73$; Adults ($n = 100$) HA prime $M = 72$, LA prime $M = 64$). This means that the Younger group was more likely to choose HA over LA responses than the adults and Older group, and that the number of HA and LA responses between the Older group and Adults did not differ significantly. No other main effects or significant interactions in the model were found (see Table 4 for a summary of results).

Experiments	Predictor	Coefficient	SE	Z value	p
Non-Repeated Verb vs. Repeated Verb	Intercept	1.29	0.24	5.38	**<.001**
	Age Group (Older vs. Adults)	0.47	0.32	1.48	.136
	Age Group (Younger vs. Adults)	1.91	0.34	5.48	**<.001**
	Age Group (Older vs. Younger)	-1.43	0.35	-4.05	**<.001**
	Prime (LA vs. HA)	-0.60	0.13	-4.44	**<.001**
	Experiment (Repeated Verb vs. Non-Repeated Verb)	0.01	0.32	0.05	.955
	Age Group (Older vs. Adults) x Prime	0.35	0.21	1.68	.091
	Age Group (Younger vs. Adults) x Prime	0.39	0.25	1.53	.125
	Age Group (Older vs. Younger) x Prime	-0.03	0.26	-0.13	.894
	Age Group (Older vs. Adults) x Experiment (Repeated Verb vs. Non-Repeated Verb)	-0.17	0.46	-0.36	.712
	Age Group (Younger vs. Adults) x Experiment (Repeated Verb vs. Non-Repeated Verb)	-0.11	0.49	-0.22	.821
	Age Group (Older vs. Younger) x Experiment (Repeated Verb vs. Non-Repeated Verb)	-0.05	0.50	-0.11	.908
	Prime x Experiment (Repeated Verb vs. Non-Repeated Verb)	0.22	0.19	1.14	.250
	Age Group (Older vs. Adults) x Prime x Experiment (Repeated Verb vs. Non-Repeated Verb)	-0.24	0.29	-0.81	.413
	Age Group (Younger vs. Adults) x Prime x Experiment (Repeated Verb vs. Non-Repeated Verb)	-0.19	0.36	-0.53	.580
	Age Group (Older vs. Younger) x Prime x Experiment (Repeated Verb vs. Non-Repeated Verb)	-0.04	0.37	-0.12	.902

Table 4. English-speaking participants: Summary of mixed-effects logistic regression models with Age Group, Prime and Experiment as predictors. Effect of lexical repetition.

Effect of priming

To compare the children's and adults' preferences for interpreting ambiguous PPs in the absence and presence of a prime, we created two datasets, one with the combined data of the Baseline and Non-Repeated Verb experiments and another one with the Baseline and the Repeated-Verb experiments. We used the binomial outcome variable HA responses (HA responses coded as 1, and LA responses coded as 0) and included in the two best-fitting models Age Group, Experiment (2 levels: Baseline vs. (Non)-Repeated verb) and the interactions between them as predictors. The random-effect structure of the final models included participants and items as random intercepts and Experiment as a random slope. Tables 5 and 6

show a summary of results of Age Group and Experiment comparisons and their interactions, where the probability of HA responses for the Adult group in the Baseline experiment is represented in the intercept. We later relevelled the predictor so the intercept could represent the probability of HA responses for the Younger group in the Baseline experiment. Positive coefficients show that HA target responses were more likely to occur in the tested level of the predictor than the other (categorical variable).

The comparison between the Baseline and the Non-Repeated Verb experiments revealed a main effect of Experiment suggesting that participants were less likely to choose HA responses in the Non-Repeated Verb experiment than in the Baseline experiment ($p < .05$) (Younger: Baseline M =97, Non-Rep Verb M= 91; Older: Baseline M = 93, Non-Rep Verb M = 75; Adults: Baseline M = 79, Non-Rep Verb M = 69). We also found an effect of Age Group between the Younger group and adults ($p <.01$) and between the Older group and adults ($p <.05$), but not between the Older and the Younger groups ($p >.05$). This means that, when combining the data of the Baseline and Non-Repeated Verb experiments, the Younger and the Older groups chose more HA over LA responses than the adults, and that the number of HA and LA responses between the Older and the Younger groups did not differ significantly. The model did not reveal any significant interactions between Age Group and Experiment (see Table 5 for a summary of results).

Experiments	Predictor	Coefficient	SE	Z value	p
Baseline vs. Non-Rep. Verb	Intercept	2.64	0.61	4.28	**<.001**
	Age Group (Older vs. Adults)	2.00	0.87	2.28	**<.05**
	Age Group (Younger vs. Adults)	2.10	0.79	2.65	**<.01**
	Age Group (Older vs. Younger)	-0.09	0.85	-0.11	.909
	Experiment (Non-Repeated Verb vs. Baseline)	-1.61	0.63	-2.52	**<.05**
	Age Group (Older vs. Adults) x Experiment (Non-Repeated Verb vs. Baseline)	-1.30	0.93	-1.39	.163
	Age Group (Younger vs. Adults) x Experiment (Non-Repeated Verb vs. Baseline)	0.13	0.86	0.15	.878
	Age Group (Older vs. Younger) x Experiment (Non-Repeated Verb vs. Baseline)	-1.43	0.92	-1.55	.119

Table 5. English-speaking participants: Summary of mixed-effects logistic regression models with Age group and Experiment as predictors. Effect of priming between the Baseline experiment and the Non-Repeated Verb experiment.

The comparison between the Baseline and the Repeated Verb experiments also revealed a main effect of Experiment suggesting that participants chose fewer HA responses in the Repeated Verb experiment than in the Baseline experiment ($p < .05$) (Younger: Baseline M =97, Rep-Verb M= 91; Older: Baseline M = 93, Rep-Verb M = 74; Adults: Baseline M = 79, Rep-Verb M = 67). We also found an effect of Age Group between the Younger group and adults ($p <.01$) and between the Older group and adults ($p <.05$), but not between the Older and the Younger groups ($p >.05$). There were no significant interactions in the model. (see Table 6 for a summary of results).

Experiments	Predictor	Coefficient	SE	Z value	p
Baseline vs. Repeated Verb	Intercept	2.54	0.58	4.32	**<.001**
	Age Group (Older vs. Adults)	1.93	0.84	2.27	**<.05**
	Age Group (Younger vs. Adults)	2.04	0.76	2.66	**<.001**
	Age Group (Older vs. Younger)	-0.11	0.82	-0.13	.893
	Experiment (Repeated Verb vs. Baseline)	-1.41	0.62	-2.28	**<.05**
	Age Group (Older vs. Adults) x Experiment (Repeated Verb vs. Baseline)	-1.56	0.90	-1.72	.085
	Age Group (Younger vs. Adults) x Experiment (Repeated Verb vs. Baseline)	-0.11	0.83	-0.13	.894
	Age Group (Older vs. Younger) x Experiment (Repeated Verb vs. Baseline)	-1.45	0.89	-1.62	.104

Table 6. English-speaking participants: Summary of mixed-effects logistic regression models with Age group and Experiment as predictors. Effect of priming between the Baseline experiment and the Repeated Verb experiment.

2.6.3 Interim discussion

Given that we did not find evidence of lexically-independent priming effects in the Non-Repeated Verb experiment, in the Repeated Verb experiment we investigated whether 4- to 6- and 8- to 10-year-old English-speaking children and adults showed evidence of lexically-dependent priming effects when the verb overlapped between the prime and target sentences.

This would suggest that there is a link between the abstract and lexical representations of the HA and LA analyses in children and adults. We also examined developmental differences in 4- to 6- and 8- to 10-year-olds' PP attachment preferences and whether priming effects in children and adults accumulated throughout the experiment.

We found a main effect of Prime in participants and this effect continued to be reliable in children after removing the adult data in the developmental differences analysis. The effect of Prime in children was not modulated by Age in Months, that is, younger children were as likely as older children to choose HA responses after a HA prime and LA responses after a LA prime. These findings suggest that the representations of the LA structures in children may have a lexically-specific component.

Age-group level differences in the overall PP preferences between the Younger and Older groups as well as between the Younger children and adults were found to be significant but not between the Older children and adults. This pattern was also reflected when analysing only the children's data. Age in Months was a strong predictor of the overall number of HA and LA responses. That is, as children got older, the likelihood of choosing HA responses decreased, and therefore the likelihood of choosing LA responses increased.

We did not find an effect of the lexical boost or any cumulative effects in any of the age groups. However, we did find an overall effect of priming when comparing the Baseline experiment against the Non-Repeated Verb experiment and against the Repeated-Verb experiment. That is, when children and adults were not exposed to the primes, they tended to choose more HA responses than when they were exposed to the LA and HA primes.

2.7 General discussion

Previous developmental structural priming studies have tried to address the questions about the nature and development of children's syntactic representations. However, to this day, there is still mixed evidence about how children represent language and about the developmental stage at which children start to show adult-like patterns when they process language. Lexically-independent priming effects in younger children have been interpreted as evidence of the existence of abstract representations of particular structures, supporting early abstraction accounts. In contrast, according to usage-based lexicalist accounts, a stronger lexical boost in younger children than in older children and adults has been taken as evidence

that young children's syntactic representations of language may have a lexically-specific component. What is more, an implicit error-based learning mechanism has been suggested to be the source of structural priming effects and cumulative experience. Thus, to investigate the nature and development of children's syntactic representations, in the current study we used a structural priming paradigm that examined lexically-dependent and lexically-independent priming effects of PP attachment ambiguities during language comprehension in 4- to 6- and -8- to 10-year-old English-speaking children and adults. By using a forced-choice picture selection task, we particularly examined whether PP attachment preferences were immediately affected by the absence and presence of verb overlap between the prime and target sentences and whether the accumulation of individual experiences of HA and LA interpretations across the experiment influenced children's and adults' syntactic choices during language comprehension.

In all the experiments, we found that children and adults showed an overall preference for HA over LA. However, participants also showed sensitivity to linguistic recent experience that involved mixed exposure to both the HA and LA interpretations.

In experiment 1 (Baseline), children and adults were more likely to choose an HA interpretation than an LA interpretation of a PP in a globally ambiguous sentence in the baseline condition. PP attachment preferences between the Younger and Older children did not differ significantly, however, both child groups' attachment preferences did differ significantly when being compared against the adults'. Additionally, in the baseline condition, only the Older children seemed to have self-primed themselves with their preferred analysis (i.e., HA) that resulted in a tendency to choose more HA interpretations than LA interpretations in the last third of the experiment than in the first third of the experiment.

In experiment 2 (Non-Repeated Verb) we analysed structural priming effects, and although we found a main effect of Prime, this effect was no longer reliable when only the children's data were analysed (i.e., in the developmental effects model). Only when the prime sentence verb was the same as the target sentence verb (Repeated Verb experiment), both the Younger and Older children were more likely to choose an HA interpretation after an HA prime and a LA interpretation after a LA prime, and this effect was not modulated by Age in Months. Neither the children nor the adults showed enhanced priming effects when the verb was repeated between the prime and target sentence (lexical boost).

When comparing only the overall proportion of HA vs. LA responses, irrespective of whether the prime verb was the same (Experiment 3) or different (Experiment 2) from the target sentence verb, the Older children and adults did not differ significantly. In contrast, the Younger group did differ from the Older children and the adults suggesting that Age Group was a strong predictor for the overall number of HA and LA interpretations. Similar results were also reflected when using Age in Months as a predictor in the two priming experiments but not in the Baseline experiment. That is, as children got older, the likelihood of choosing HA responses decreased and the likelihood of choosing LA increased.

Developmental difference

To understand the influence of structural priming on children's PP attachment preferences (HA vs. LA), we first examined their development without the influence of primes (Baseline experiment). The three age groups were found to show a stronger preference for the HA interpretation than the LA interpretation: 4- to 6-year-olds (97%), 8- to 10-year-olds (93%) and adults (79%). No age differences were found between the two child groups or when Age in Months was used as a predictor to detect developmental differences in children, however, we did find that each child group differed significantly from the adults. These patterns suggest that Age Group was a predictor for PP attachment preferences in the baseline condition. That is, adults showed evidence that they could have access to both the HA and LA structures, whereas for the Younger and Older children, the HA structure was much more easily accessible than the LA structure in the baseline condition.

The question as to when children start to show similar attachment preferences for globally ambiguous sentences to those of adults when no prime is presented remains unresolved, however, our data suggest that it should be when children are older than 10 years of age, presumably at some point during their adolescence. These findings are, to some extent, consistent with previous studies with 4- to 6-year-old children that suggest that, when no prime is presented, the developing parser usually interprets globally ambiguous sentences with a VP-attachment analysis as a result of an over-reliance on frequency-based information of verbs and structures. That is, children at a very young age tend to rely on bottom-up information such as lexico-syntactic and semantic knowledge of familiar verbs to guide their parsing commitments (e.g., Snedeker & Trueswell, 2004; Kidd et al., 2010). Thus, because the majority

of the verbs that we used for the task were instrumental verbs (*pat, push, poke, move, touch* and *tickle)* that is, they favoured the HA analysis of the ambiguous PP, this would explain why, in the baseline condition, children had easy access to the HA analysis but struggled to access the LA structure when interpreting the ambiguous sentences.

However, the fact that even at the age of 10, children still continued to show similar patterns to those of 4- to 6-year-old children is striking. Previous studies have suggested that the development of cognitive control may be associated with the time at which children start considering other alternative analyses for the same structure. Novick, Trueswell and Thompson (2005) argued that cognitive control may reflect the same underlying mechanisms that are responsible for ambiguity resolution in sentence processing. They suggested that conflict resolution is addressed by attentional processes and mechanisms that are controlled by the left inferior frontal gyrus located in the prefrontal cortex, a region that is underdeveloped in children and that matures during adolescence. Therefore, similar recovery mechanisms to those of adults would not be expected to occur in childhood, but during adolescence. Future research should investigate at what age children start to show adult-like patterns when interpreting globally ambiguous sentences when no prime is presented, and whether this developmental change may be associated with further language experience (experience that will have to be different from the experience children had when they were between the ages of 4 and 10), the development of cognitive control or possibly something else.

To address the question about the nature of children's syntactic representations, we examined whether their PP attachment preferences were influenced by recent experience of a structure or a structure in association with a particular verb. Evidence from previous structural priming studies on language comprehension has shown how syntactic repetition affects the subsequent processing of a sentence in English-speaking children and adults (e.g., Thothathiri & Snedeker, 2008; Pickering et al., 2012). Moreover, priming effects have been shown to be enhanced (lexical boost) when the prime and target sentences share the same verb showing a link between lexical and abstract representations (Pickering & Branigan, 1998). Under early abstraction accounts, authors have often interpreted structural priming effects as evidence for an existing abstract representation of a particular syntactic structure (e.g., Bock, 1986; Branigan, Pickering & Cleland, 2000). In contrast, usage-based lexicalist accounts have proposed that when young children show stronger lexically-dependent priming effects than older children and adults, this may suggest that younger children's language knowledge may

be governed by lexically-specific representations that gradually become abstract and more stable as children get older (e.g., Tomasello, 2000; Savage, Lieven, Theakston, & Tomasello, 2003; Ninio, 2006).

The participants in our study showed significant main effects of Prime in the absence and presence of lexical repetition between prime and target pairs. Children showed reliable priming effects when prime and target pairs shared the same verb but not when the prime and target pairs involved a different verb. However, since the interaction between Experiment and Prime was not significant, we cannot be certain whether recent experience of a structure in association with a particular verb made the HA and LA structures more accessible to participants than when a structure was not associated with a particular verb.

Although the children in our study showed no evidence of a significant lexical boost, the fact that they showed priming effects when there was verb overlap between the prime and target sentence, is still consistent with the residual activation account (Pickering & Branigan, 1998).That is, the strengthened association between the co-activation of the lemma and combinatorial nodes when processing a prime and a subsequent target sentence facilitated the accessibility of the HA and LA structures in children, making them more likely to interpret a globally ambiguous sentence with a HA interpretation after interpreting a HA prime, and to interpret a globally ambiguous sentence with a LA interpretation after interpreting a LA prime.

Our results are consistent, to some extent, with previous research by Havron et al. (2020), who found immediate lexically-dependent priming effects in 5- to 6-year-old French-speaking children and adults with no interaction with age group during language comprehension. Havron et al. exposed participants to HA and LA primes and measured the likelihood of choosing a LA analysis after a LA prime in comparison to a HA prime (11 prime-target pairs and 6 unambiguous fillers). After every two LA prime trials, participants were exposed to a HA prime trial and possibly an unambiguous filler sentence. After controlling for cumulative priming and removing the adult data from the analyses, 5- to 6-year-old children continued to show reliable cumulative priming effects, but not lexically-dependent priming effects.

The fact that in Havron et al. participants showed priming effects when there was lexical overlap between prime and target pairs, is consistent with our results and supports the idea that lexical repetition facilitates the processing of a sentence (Pickering & Branigan,

1998). However, in Havron et al. such lexically-dependent and cumulative priming effects may have arisen due to the fact that after every two LA prime trials only one HA prime trial followed. Thus, this may have temporarily reinforced the representation of the LA analysis when interpreting the target sentences.

Regardless of the methodology in Havron et al. (2020), their study provided evidence that French-speaking children between the ages of 5 and 6 were sensitive to other sources of top-down information such as language experience when interpreting PP attachment ambiguities during language comprehension. Moreover, our findings have also confirmed that children between the ages of 4 and 6, but also between 8 and 10 showed sensitivity to recent language experience in the absence and presence of lexical repetition between prime and target pairs, and that priming effects may be enhanced when prime and target pairs involve the same verb.

An error-driven implicit learning mechanism has been proposed to be the source of structural priming and cumulative effects. This proposal explains that for priming to occur the parser must encounter a structure that does not match the most frequent and predicted syntactic construction (i.e., HA analysis). With enough exposure to the less predicted structure, such previously dispreferred structure will become preferred. (Chang, Dell & Bock, 2006). It is also expected that the strength of the linguistic representation will determine the priming effect and its size. That is, weaker linguistic representations in less proficient speakers (e.g., younger children) may lead to stronger priming effects due to an error-driven implicit learning mechanism, as reported in previous studies (Peter et al., 2015; Rowland et al., 2012). Thus, according to this account, priming will not occur if individuals cannot predict both constructions. In other words, individuals must have already existing representations of both the HA and LA analyses, so they are able to predict the two structures and show priming effects.

Based on our results, we did not find evidence that the less preferred structure (i.e., LA) resulted in stronger priming effects in Younger children than in Older children and adults. We suggest that both 4- to 6- and 8- to 10-year-old children struggled to have access to the LA structural alternative and as a result, lexically-independent priming effects were less reliable than when prime and target pairs shared the same verb. However, what may have hindered children's accessibility to the LA analysis resulting in less reliable lexically-independent priming effects?

Previous language processing studies in English-speaking children as young as 3 years of age have shown how children are able to interpret globally ambiguous sentences with a LA interpretation provided that the globally ambiguous sentence contains a modifier- or an equi-biased verb (e.g., perception verbs such as *see* or *choose*) (Zimmer, 2017; Snedeker & Trueswell, 2004). These studies show evidence that young children have already acquired the LA structural analysis since they are able to comprehend a globally ambiguous sentence with a LA interpretation.

Thus, we suggest that the children in our study may have struggled to interpret the globally ambiguous sentences with a LA analysis because they had difficulties overcoming verb-biases. That is, due to the prevalence of instrumental verbs used in our task (*pat, push, poke, move, touch, and tickle*), which favoured the HA interpretation of the ambiguous PP, we believe that this may have led participants to show a strong preference for the HA analysis when comprehending the globally ambiguous sentences in the presence and absence of a prime. To interpret language, young children tend to show an over-reliance on bottom-up information such as lexico-syntactic and semantic knowledge of familiar verbs in comparison to top-down information e.g., referential context cues, plausibility (e.g., Snedeker & Trueswell, 2004; Kidd et al., 2010). Once children accumulate enough evidence about the different linguistic environments in which familiar verbs appear, then they start utilising less reliable sources of information to interpret language. However, incorporating the less-reliable cues into their parsing strategies is a process that develops over time. This would explain why the participants in our study showed a stronger preference for hight-attachment over low-attachment.

It is essential that future research incorporates a variety of modifier-biased verbs or only equi-biased verbs in the materials to better capture the influence of structural priming on the development of children's syntactic representations of PP attachment ambiguities.

The fact that the 8- to 10-year-old children in our study did not show reliable lexically-independent priming effects, is yet another striking finding given the wide age range of this child group. Moreover, it is also surprising that lexically-dependent priming effects were not modulated by Age in Months in children, suggesting that children between the ages of 4 and 10 do not differ significantly in the way they process globally ambiguous sentences when there is lexical repetition between the prime and target sentence. These results are problematic for usage-based lexicalist accounts to explain, since they predict a stronger lexical boost effect in young children than in older children and adults.

Our findings may be explained by the error-based learning account that suggests that the nature of the lexical boost is in the explicit memory, and since explicit memory skills are usually underdeveloped in younger children this would explain why they sometimes may or may not show a lexical boost. However, in the current study, the older children and adults did not show significant effects of a lexical boost either. We are not sure as to why adults did not show a lexical boost in our study, given the fact that in Pickering et al.'s (2012) adults showed enhanced priming effects when there was verb repetition between prime and target sentences. Future research should investigate the role of the lexical boost and structural priming for this type of ambiguity during language comprehension in children and adults in more detail.

At this point, it is still unclear when children start to show reliable lexically-independent priming effects in globally ambiguous sentences. Future research should also examine at what point in children's development they begin to show adult-like lexically-independent priming effects for this type of ambiguity and the source that gives rise to this developmental change.

Why did the children in our study show no reliable lexically-independent priming effects if they answered the HA and LA primes correctly?

Different factors may have influenced children's responses. For example, it is possible that the children in our study may have based their responses on the entities that they heard in the sentences. For instance, for the prime sentence *The girl pushed the teacher with the ball,* children may have identified the words *girl, teacher* and *ball* and may have chosen the picture that depicted those entities. However, this explanation is unlikely given the fact that children's accuracy for the filler trials was between 98% and 99%, and, in particular, there was one set of filler trials that had the agent and the patient reversed (e.g., *The queen is kissing the teacher* vs. *The teacher is kissing the queen*). Thus, for children to answer this filler trial correctly, children needed to work out the syntax of the sentence.

Another factor that may have influenced the children's responses may have been that children received help from their parents. We consider this factor to be unlikely as well, since parents were specifically told during the Zoom session that they could only help children with technical issues such as problems with the internet, tablet or computer. However, since this was an online task and the experimenter could not observe the children while they were doing it, we do not have evidence that the parents did not influence their children's responses.

Cumulative Priming

Our results provide evidence that the children and adults in our study were susceptible to the priming condition. When comparing participants' overall PP preferences in the presence of a prime (Non-Repeated Verb and Repeated Verb) against the overall PP preferences in which participants were not exposed to the primes (Baseline experiment), we found a main effect of Experiment with no Age Group interactions. This indicates that when participants experienced frequent and equal exposure to the HA and LA primes irrespective of whether there was verb overlap between the prime and target sentences, their overall PP preferences were altered to some extent. That is, participants tended to choose more HA responses when they were not primed (Baseline experiment), than in a context where they were exposed to the HA and LA primes (Non-Repeated Verb and Repeated Verb experiments).

In a context where children were exposed to the primes with and without verb repetition, the overall likelihood of selecting a LA analysis developed with Age in Months in children but it increased considerably as children got older. This was not the case in the baseline condition, as Age in Months was not a predictor for the overall PP preferences when children were not primed.

This pattern was also reflected when comparing the overall PP preferences by Age Group when no prime was presented and in the presence of a prime (irrespective of verb repetition). That is, the Younger and the Older groups interpreted globally ambiguous sentences in a similar way in the baseline condition. However, when children were exposed to the LA and HA structures within a session, the Younger and the Older groups showed significant differences in their overall PP preferences, with the Older group showing fewer HA responses than the Younger group. Moreover, when participants were exposed to the primes (irrespective of lexical repetition), there were no significant differences in the overall PP preferences between the Older group and adults. Thus, we suggest that it was the LA prime that modulated the children's PP attachment preferences by decreasing the overall number of their HA responses and increasing the number of their LA responses.

We believe the Older children were more influenced than the Younger children merely because Older children had more linguistic experience. That is, as children got older, they gradually started to incorporate other sources of information to interpret language (e.g., recent linguistic experience), and thus they were more likely to adopt the LA analysis than the Younger children.

Although both groups of children did not show reliable lexically-independent priming effects, exposing them to the same proportion of HA and LA primes during a language comprehension task resulted in children's structural preferences being adjusted to some degree due to the accumulation of individual experiences of the LA structure.

To examine whether children and adults showed cumulative effects within a session, we analysed only the first and last third of the data of each priming experiment. Specifically, we examined the effects of Trial, Prime and their interaction to predict whether participants' HA responses increased or decreased as the experiment progressed.

We did not find an effect of Trials or an interaction between Trials and Prime in any of the age groups when we combined and analysed the first and last thirds of the data. However, we found an effect of cumulative experience in the baseline condition in the Older children. This suggested that, as the experiment went on, the Older children's overall HA responses increased by the end of the experiment. This pattern reflected self-priming effects. That is, in the Baseline experiment, the Older group tended to choose HA interpretations, and those individual experiences of interpreting the globally ambiguous sentences mostly with a HA analysis accumulated throughout the task and gave rise to an even increased proportion of HA responses by the end of the experiment.

The fact that we only found effects of cumulative experience in the Older group in the baseline condition, but not in the Younger group or the adults, shows a developmental difference in children. This may suggest that between the ages of 8 and 10, children may be at a developmental stage where they show more sensitivity to linguistic patterns in the environment to guide their sentence comprehension, which may result in a gradual rather than an immediate adaptation of their structural preferences when interpreting language.

Future research in the lab with globally ambiguous sentences is needed to determine whether children between the ages of 4 and 10 show the same structural priming patterns during language comprehension as in the current study.

2.8 Conclusion

The current study investigated the nature and development of syntactic representations of globally ambiguous sentences in English-speaking 4- to 6- and 8- to 10-year-old children and adults during a language comprehension task. We examined whether the PP attachment preferences in children and adults were influenced by recent experience of a structure or a structure in association with a particular verb and whether children and adults showed cumulative priming effects.

Participants showed a main effect of Prime in the absence and presence of lexical repetition between prime and target pairs with no interactions with Age Group. However, when the adult data were removed from the analyses, children only showed a reliable priming effect when prime and target pairs involved the same verb. These results suggest that children's abstract representations may be more weakly represented than in adults, and that more power may be needed to detect lexically-independent priming effects. Participants also tended to choose more HA responses in the baseline condition than in a context where they received mixed exposure to HA and LA structures within a session. This reflected that children were susceptible to the primes and that their PP preferences were altered to some extent.

Our results support previous studies that have found that the incorporation of other cues such as recent linguistic experience to guide sentence processing takes time and develops gradually as children grow older.

3 Priming Prepositional-Phrase attachment ambiguities in Spanish-speaking children and adults during language comprehension

To better understand language acquisition, developmental language studies have explored the nature and development of children's mental representations of language. However, to this day, children's language development is still unclear. Structural priming paradigms are experimental methods that have been informative about the development and nature of children's syntactic representations and the role of language experience. However, until now, most of the developmental structural priming research, has focussed on studying a limited number of syntactic structures in English-speaking children, especially in language production. Therefore, the mechanisms involved in structural priming during language comprehension in children remain understudied. What is more, developmental structural priming studies in language comprehension and with children whose first language is not English are very limited. This is not ideal, as it is important to understand whether current theories of language development, and specifically the role of language experience in development, hold across languages.

Thus, the aim of the current study was to better understand the nature and development of 4- to 6- and 8- to 10-year-old Spanish-speaking children's and adults' language representations during language comprehension. In particular, we examined the role of recent language experience on the resolution of globally ambiguous sentences in Spanish (e.g., *La niña está tocando al perro con el plátano*) (*The girl is touching the dog with the banana*).

3.1 Introduction

Language involves complex processes that to this day, researchers are still trying to understand. However, despite its complexity, language comprehension is such an efficient process that almost anyone can master it since a very young age. However, on rare occasions, people may encounter an ambiguous sentence resulting in the misinterpretation of the structure. The strategies that the language processor adopts to solve a syntactic ambiguity are still under debate. However, one of the most influential language processing theories has been The

Garden-Path model (e.g., Frazier & Fodor, 1978), which proposes two sentence processing principles that are language universal: *Minimal attachment* and *Late closure*.

Minimal attachment postulates that when processing an ambiguous sentence, comprehenders select the simplest syntactic analysis with the fewest nodes, whereas Late closure stipulates that new incoming information should be associated with the most recent phrase or clause. Such principles had been widely adopted within the psycholinguistics community until Cuetos and Mitchell (1988) questioned their universality by showing evidence that the syntactic preferences in Spanish were not the same as in English. For example, in the ambiguous sentence (1) *The daughter of the colonel who was standing on the balcony*, it is not clear to which of the two nouns (*daughter* or *colonel*) the relative clause (RC) (*who was standing on the balcony*) should be attached. If the RC is attached to the first noun, this is often referred to as *high attachment* (HA), if the RC is attached to the second noun, this is known as *low attachment* (LA). According to the Garden Path model, the Late closure principle predicts LA for this ambiguous sentence, however, Cuetos and Mitchell found that Spanish speakers tended to show a preference for HA for these syntactic ambiguities. These findings were later confirmed by various studies that were carried out in different languages (e.g., French: Mitchell, Cuetos & Zagar, 1990; German: Hemforth, Konieczny, Scheepers, & Strube, 1998; Dutch: Brysbaert & Mitchell, 1996).

After Cuetos and Mitchell's findings, different accounts aimed at explaining such variability were proposed. One of those accounts was the Tuning hypothesis (e.g., Mitchell & Cuetos, 1991a; Cuetos, Mitchell, & Corley, 1996), which argued that during ambiguity resolution, the initial analysis is not selected based on fixed rules or universal principles (e.g., the Garden-path model), but on the person's experience with the language. That is, exposure patterns of a particular structure (i.e., experience) are what will shape and give rise to attachment preferences. Therefore, this account predicts that exposure to one type of attachment will change someone's attachment preferences. However, if statistical properties have not yet been accumulated at the time when facing the syntactic ambiguity, attachment preferences will be unbiased (i.e., HA: 50% and LA: 50%) and will gradually change towards one direction as soon as the language processor starts receiving biased information from the input.

Although this account does not offer an explanation about how the language processor builds structures or how it deals with reanalysis mechanisms, it offers an explanation as to why

we seem to prefer certain analyses over others highlighting the important role of language experience. (See Chapter 1, section 1.3.3 for a detailed description of this hypothesis).

One way to test the effect of recent language experience during ambiguity resolution is by using a structural priming paradigm. By using this technique, we can manipulate the language input and study to what extent recent language experience affects our syntactic choices during language comprehension. Structural priming can also offer information about how individuals represent language, the nature of those linguistic representations and the mechanisms involved that may lead to structural changes.

Thus, in the current study we used a priming technique to better understand the nature and development of Spanish-speaking children's language representations and the mechanisms involved in structural priming during language comprehension.

The motivation of the present study is threefold. First, studying priming effects in populations whose first language is other than English is very important since the majority of the structural priming studies have been conducted in English. This, of course, is not ideal, as researchers tend to assume that all the findings that come from structural priming studies carried out with English-speaking populations apply to all the languages.

Second, a limited number of structures has only been studied in syntactic priming research in children (e.g., active vs. passive; double object construction vs. prepositional object construction; agent-first relative clause vs. patient-first relative clauses). However, to our knowledge, there are no studies that examine ambiguous sentences and the effect of structural priming in Spanish-speaking children. Only two studies have examined relative clause ambiguities (NP-PP-RC) and their development in Spanish (Cuetos, Mitchell & Corley, 1996; Aranciba-Gutiérrez, Bizama Muñoz, Sáez Carrillo, 2015) and there is only one study with 5- to 6-year-old children that has investigated priming effects on PP attachment ambiguities in French (Havron, Scaff, Carbajal, Linzen, Barrault & Christophe, 2020).

Third, most of the research in structural priming has focussed on language production studies while structural priming studies in language comprehension remain understudied, especially in Spanish-speaking children.

Thus, to address the previous issues, the aim of the current study was to explore the nature and development of children's mental representations of language during language comprehension by analysing structural priming in PP ambiguities. In particular, we used the Spanish equivalent of the globally ambiguous structure (e.g., '*La niña está tocando al perro con el plátano)* (*The girl is touching the dog with the banana),* in which individuals may adopt either the HA analysis (VP-attachment or instrumental interpretation), where the ambiguous prepositional phrase (PP) *with the banana* modifies the verb (i.e., the girl uses the banana to touch the dog); or the LA analysis (NP-attachment or modifier interpretation) where the PP modifies the noun *dog* (i.e., the dog with the banana is touched by the girl). We refer to these preferences as high- (HA) and low-attachment (LA) because in the former the PP attaches to the VP, which is 'high' in the syntax tree, whereas in the latter, the PP attaches to the NP, which is 'low' in the syntax tree.

3.2 Structural priming

Structural priming paradigms have been widely used to explore the underlying representations of language in children and adults and the mechanisms involved that give rise to priming effects, which are widely linked with language acquisition. Structural priming refers to when the processing of a sentence (i.e., *prime sentence*) facilitates the production or comprehension of a subsequent sentence (i.e., *target sentence*) with the same structure (e.g., Branigan & Pickering, 2017). This occurs because the processing of the prime sentence activates the representation of that structure resulting in an increased likelihood of producing that same structure in a subsequent sentence or selecting that same analysis in the following sentence during comprehension (e.g., Bock, 1986; Branigan, Pickering & Cleland, 2000; Ferreira & Bock, 2006).

For example, the processing of a double object structure as in *The girl gave the boy the toy* will facilitate the production or comprehension of a subsequent double object structure. That is, after hearing or reading the prime sentence, it will be more likely for an individual to produce another double object structure (e.g., *The boy gave the lady the ball*) than a prepositional object structure (e.g., *The boy gave the ball to the lady*).

Evidence for abstract representations has been taken when priming effects occur in the absence of verb repetition between the prime and target sentence (i.e., lexically-independent). Moreover, if prime and target sentence share the same content words e.g., same verb or same noun, (lexically-dependent), priming effects may be enhanced, this effect is referred to as the *lexical boost* (Pickering & Branigan, 1998). Priming effects have been demonstrated in language production (e.g., in children: Huttenlocher, Vasilyeva, & Shimpi, 2003; Messenger, Branigan & McLean, 2011; Peter et al., 2015; Branigan & McLean, 2016; Messenger, 2021) and in language comprehension (e.g., in children: Thothathiri & Snedeker, 2008; Havron et al., 2020).

Language acquisition researchers have tried to explain the nature and development of children's mental representations of language. However, it is still unclear how children represent language. Developmental priming studies in children are still limited and inconsistent, especially in language comprehension. Moreover, while some studies have reported lexically-independent priming effects in children (Thothathiri & Snedeker, 2008; Bencini & Valian, 2008; Huttenlocher, Vasilyeva, & Shimpi, 2003; Rowland et al., 2012; Branigan & McLean, 2016), others have not (Savage et al., 2003; Goldwater, Tomlinson, Echols, & Love, 2011).

Usage-based lexicalist accounts propose that children at a young age start with lexically-dependent representations of language, and as they get older, their mental representations gradually become abstract (lexically-independent) due to the linguistic experience they gain from verb-specific patterns that they find in the input (Savage, Lieven, Theakston, & Tomasello, 2003; Rowland, Chang, Ambridge, Pine, & Lieven, 2012; Peter, Chang, Pine, Blything, & Rowland, 2015).

By contrast, early abstraction accounts propose that during the early stages of language development, children already possess higher-level linguistic categories and abstract representations of language, that is, they do not go through a phase where their language representations are lexically-dependent (Pinker, 1989; Fisher, 2001). For example, lexically-independent priming effects in young children would be considered as evidence of existing abstract representations under the early abstraction accounts.

Two main accounts explain priming effects and the lexical boost. The error-based learning account (e.g., Chang, Dell & Bock, 2006), argues that an error-driven implicit learning mechanism is responsible for structural priming effects and language acquisition while lexically-dependent priming effects may only reflect transient activation of language representations. Chang et al. propose that learning is the consequence of a parser encountering a structure that does not match the predicted or expected construction. Moreover, it has also been proposed that processing dispreferred sentences (e.g., passive voice) will lead to strong priming effects due to high prediction error (*prime surprisal*) (e.g., Jaeger & Snider, 2006).

Under this account, the lexical boost is explained by the explicit memory, where it originates and decays rapidly. Since young children have not yet fully developed their memory skills in comparison to older children and adults, the lexical boost may or may not arise in children. However, under this account, priming effects will also vary depending on the learning rate that will result from the individuals' language experience and their propensity to learn a language. (See Chapter 1, section 1.4 for a detailed description of this account).

Under the residual activation account (Pickering & Branigan, 1998), priming effects are explained by the activation of lemmas (e.g., *give, pass*), combinatorial nodes and the links between these two. Lemmas are closely linked to combinatorial nodes, which are the ones that convey the structure. That is, the lemma *give* may be associated with the NP,NP and the NP,PP combinatorial nodes. So, whenever a speaker produces a prepositional-object construction (e.g., *The girl gave the apple to the boy*) the lemma *give* will activate the NP,PP combinatorial node. Therefore, lexically-independent priming effects are the result from the residual activation of a combinatorial node (e.g., NP,PP). However, when a prime and target sentence share the same verb (e.g., *give*), the priming effect will result from the pre-activation of the lemma (*give*), the combinatorial node (NP,PP) and the strengthened link between the lemma and combinatorial node, resulting in enhanced priming effects (i.e., the lexical boost). (See Chapter 1, section 1.4 for a detailed description of this account).

In a structural priming study, Branigan et al. (2005) investigated the role of recent language experience in the resolution of PP ambiguities in English-speaking adults during language comprehension. By using a forced-choice picture selection task, the authors exposed participants to HA and LA primes and target sentences such as *The policeman is prodding the doctor with the gun*. The PP *with the gun* can attach to either the verb indicating HA as in (*The policeman uses the gun to prod the doctor*) or to the noun (doctor) indicating LA as in (*The*

doctor with the gun is prodded by the policeman). The authors measured the likelihood of choosing a HA interpretation after a HA prime and a LA prime in the absence and presence of verb overlap between the prime and target sentences. Branigan et al. only found lexically-dependent priming effects in adults. However, Pickering et al. (2013), ran the same experiment and found that adults showed lexically-dependent and-independent priming effects as well as a lexical boost. Furthermore, cumulative priming effects were also found when prime and target sentences were adjacent and separated by fillers. The authors argued that a Type II error may have been the reason why lexically-independent priming effects were not found in Branigan et al. (2005). (See Chapter 1, section 1.5 for a detailed description of this study).

By using a different picture-matching task and the same methodology as in Branigan et al. (2005) and Pickering et al. (2013), Havron et al. (2020) also examined the role of recent language experience by examining lexically-dependent priming effects on globally ambiguous sentences (e.g., *The girl is tickling the baby with the brush)* but in 5- to 6-year-old French-speaking children and adults during language comprehension. There were three different conditions, an alternating condition (exposure to both HA and LA primes), an only HA condition, and an only LA condition. The authors measured the likelihood of selecting a LA interpretation after a LA prime, after a HA prime and when there was mixed exposure of the two primes. Havron et al. results showed that 5- to 6-year-old French-speaking children were sensitive to recent language experience that influenced children's PP attachment preferences of globally ambiguous sentences during language comprehension. That is, participants showed a main effect of prime and reliable cumulative priming effects when there was verb repetition between the prime and target sentence in the alternating condition, suggesting lexically-dependent priming effects in children. (See Chapter 1, section 1.5 for a detailed description of this study).

However, it is still unknown whether young French-speaking children may also show lexically-independent priming effects and cumulative effects. Thus, based on the findings of Havron et al. (2020), Branigan et al. (2005) and Pickering et al. (2013), the current study may shed some light on the existence of stable abstract representations but in Spanish-speaking children and adults.

There are very few structural priming studies with Spanish-speaking children. Most of them have focussed on investigating the development of passive structures and clitics. For example, in two structural priming blocked-design studies, by using a picture-description task,

Gamez, Shimpi, Waterfall and Huttenlocher (2008) and Gamez and Shimpi (2016) tested whether young Spanish-speaking children could be primed with a rare passive structure in Spanish (*fue*-passive). In Gamez et al. (2008), 4- and 5-year-old children were primed from comprehension to production, however, they did not show priming effects with the structure they had originally been primed (i.e., *fue*-passive), instead they used other types of passive structures that also emphasised the patient (e.g., *se*-passive, function passive). In Gamez et al. (2016) structural priming effects with the *fue*-passive were only found when 6-year-old children repeated the prime sentences, that is, from production to production, but not from comprehension to production. The authors argued that for still-emerging structures such as the *fue*-passive, the repetition of primes is necessary in Spanish-speaking children, as this may improve attention skills and/or may provide them with additional practice of the structure in question. In a more recent priming study, during a picture-description task, Cooperson and Taliancich-Klinger (2022) examined priming of direct object clitic pronouns and prepositional phrases in Spanish-speaking 4- to 6- year-olds. The authors found that children only showed priming effects of prepositional phrases, but not of clitics, when they repeated the prime sentences.

The findings of these studies with Spanish-speaking children suggest that exposure to language input seems to have an effect on the children's syntactic choices to some extent, however, even when children repeat the prime, priming effects may not necessarily arise during language production for infrequent and still-emerging structures in Spanish such as the *fue*-passive or the clitics in young children.

The effect of frequency and language exposure to attachment preferences in Spanish has also been tested in children. Cuetos, et al. (1996) carried out a study in which three groups of Spanish-speaking children (7, 8 and 9-year-olds) answered a series of questionnaires with NP-PP-RC ambiguities. They found a significant relationship between the children's age and the proportions of their HA preferences in their answers. That is, the older the children were, the more inclined they were to show HA judgements (7-year-olds = 59.1%; 8-year-olds = 72.7%; 9-year-olds = 74.9%).

In a further three-stage study, the authors tested whether the frequency of exposure to HA and LA analyses could alter Spanish-speaking children's attachment preferences in NP-PP-RC ambiguities. The authors found a significant effect on the proportion of the children's HA preferences. Children who were in the HA condition, showed an even stronger tendency to choose HA analyses (Pre-test: 71.44%; Post-test: 92.17%). However, children in the LA bias

group did not show a similar pattern (Pre-test: 29.20%; Post-test: 27.81%). The results from the HA bias group were expected, however, the results from the LA bias group were unanticipated. The authors explained that the LA bias group may have been exposed to external HA biases during the two-week period of the experimental study leading to a reduced effect for the LA condition. (See Chapter 1, section 1.3.5 for a detailed description of this study). Cuetos et al. (1996) provided evidence that not only Spanish-speaking adults showed a strong preference for HA, but also Spanish-speaking children.

In a more recent study, Aranciba-Gutiérrez et al. (2015) examined HA vs. LA preferences of NP-PP-RC ambiguities and their relationship with animacy and memory in 7-, 10-, and 13- year -old Spanish-speaking children and adults. The authors found that the 7-year-old group showed a preference for the LA analysis when the two nouns were animate and of different gender and also when they were of the same gender. However, only when the two nouns were animate and of different gender the LA interpretation reached statistical significance. Interestingly, none of the age groups showed a significant preference for any of the two analyses when the first noun was inanimate and the second one was animate. The authors argued that having the second noun as animate may have neutralised the bias resulting in a large preference for LA interpretations , although not large enough to overcome the HA preference. It was also suggested that as children got older, they tended to show similar attachment preferences as those of adults, that is, children gradually developed a strong preference for HA. (See Chapter 1, section 1.3.5 for a detailed description of this study).

Although no effects of frequency exposure to the HA and LA analyses were tested in Aranciba-Gutiérrez et al. (2015)'s study, the authors showed more evidence that Spanish-speaking populations show a strong preference for HA, as suggested by previous research (Cuetos & Mitchell, 1988; Carreiras & Clifton Jr., 1999).

The current study

To test the effect of language experience on the resolution of PP ambiguities during language comprehension in Spanish-speaking children, we followed the same paradigm as Branigan et al. (2005) and Pickering et al. (2013), but with different pictures and pre-recorded spoken sentences. Our aim was to study the nature and development of Spanish-speaking children's mental representations of language during language comprehension by analysing

structural priming in PP ambiguities. We looked for evidence of lexically-dependent and lexically-independent priming effects as well as cumulative effects in the three age groups: 4- to 6-year-old children, 8- to 10-year-old children and adults.

The usage-based lexicalist accounts propose that during the early stages of language development, children's representations of language are still bound to lexically-specific items. Therefore, these accounts predict that 4- to 6-year-old children will show a stronger lexical boost in comparison to the 8- to 10-year-old children and adults. If the three age groups show evidence for a lexical boost, this would also be consistent with the residual activation account (Pickering & Branigan, 1998), that predicts enhanced priming effects when there is verb overlap between prime and target sentence as a result of the activation of the lemma, combinatorial nodes, and the strengthened association between the two.

If, however, 4- to 6-year-old children show evidence of lexically-independent priming effects, and no difference in the effect of the lexical boost with the 8- to 10-year-old children and adults, this would support early-abstraction accounts, that argue that children start with already abstract language representations that are not bound to lexically-specific information.

The error-based learning account predicts that the Young children will show stronger lexically-independent priming effects, than the Older children and adults especially because the LA analysis is rare and less frequent. Such effects, in both children and adults, should accumulate since each encounter with a structure will rely on the prediction error and re-adjustment processes governed by the error-driven implicit learning mechanism. However, Older children will show less accentuated lexically-independent priming effects than the 4- to 6-year-old children, but stronger lexically-independent priming effects than the adults.

Under this account, the lexical boost increases with age. That is, since the lexical boost relies on explicit memory skills, abilities that are still underdeveloped in young children, then the Older children and adults should show a lexical boost, but not the Younger children.

Cumulative effects should also be consistent with an implicit error-based learning mechanism, that is, individual experiences of structural readjustment should accumulate when processing a less frequent structure making it more likely to be re-used. Therefore, participants were expected to show an increase in the overall number of their LA interpretations as the experiment progressed. The Younger children may show stronger cumulative effects because of their high prediction error rates and their little experience with the language (Chang et al.,

2006) or because of their reduced competition when selecting the final analysis (Pickering & Branigan, 1999).

The above predictions were mostly based on findings from developmental structural priming studies in language production in English-speaking populations. Most of those findings come from priming two non-ambiguous structures that share only one interpretation (e.g., active vs. passive; double object vs. prepositional object). By contrast, the current study examined structural priming of globally ambiguous sentences in Spanish during language comprehension i.e., only one surface form, but with two different interpretations.

Therefore, in light of the limited structural priming studies with globally ambiguous sentences in Spanish-speaking children during language comprehension, we might find unanticipated results. One of them is that children may not show priming effects. Because we do not know the age at which Spanish-speaking children acquire the LA interpretation for this type of ambiguity, children may be unwilling to accept the LA prime resulting in no lexically-dependent and lexically -independent priming effects. We hypothesised that since the LA interpretation for this type of ambiguity is infrequent in Spanish, it is therefore late-emerging in children making it difficult to prime, similar to the case of the clitics and the *fue*-passive structure in Spanish during language production, as shown in Gamez et al. (2008; 2016) and Cooperson and Taliancich-Klinger (2022). Another point to consider was that mixed exposure to 12 LA primes (and 12 HA primes) in our task might not be enough to cause immediate priming effects or even modulate such a strongly fixed HA preference to some extent in children, and possibly adults.

3.3 Experiment 1: Baseline PP attachment preferences in Spanish-speaking children and adults

In this experiment, we set out to establish Spanish-speaking children and adults' preferences for interpreting ambiguous PPs in the absence of a prime (referred to as the 'baseline' experiment/condition). To do this, in a language comprehension web-based sentence-picture matching task, 4- to 6 and 8- to 10-year-old children and adults listened to globally ambiguous sentences such as *La niña está tocando al perro con el plátano* (*The girl is touching the dog with the banana)* and selected one of the two pictures shown on a screen/tablet. Both pictures were potential matches to the sentence; however, one matched the

HA interpretation, and the other one the LA interpretation. We analysed children's and adults' responses and compared the children's performance with that of adults, who served as the control group. We also examined the effect of age in children and cumulative effects within a session in children and adults.

Given the overall HA preference that has been found in Spanish-speaking populations with RC ambiguities (NP-PP-RC) (e.g., Cuetos & Mitchell, 1988; Carreiras & Clifton Jr., 1999), we expected that participants' responses would show a stronger preference for HA than LA, especially because the LA interpretation is less frequent in Spanish. Therefore, we hypothesised that because of the little experience with the language that 4- to 6-year-old children have, their LA analysis may still be fragile, leading them to adopt only HA interpretations. Therefore, we predicted that the younger the participants were, the stronger the preference for HA. If, however, the language experience that has accumulated throughout the years in an individual plays no role in the processing of globally ambiguous sentences, then children's and adults' performance should not differ.

In a different analysis, we also tested whether Age in Months within 4- to 6 and 8- to 10-year-old children predicted developmental changes in the processing of PP attachment preferences. This allowed more fine-grained investigation of developmental changes, given that in other analyses we compared different age groups. When looking for developmental patterns in children, we expected to see fewer HA responses and more LA responses as children grew older. If we did not find this pattern, this would suggest that, when no prime was presented, children between 4 and 10 process globally ambiguous sentences in the same way and that future studies would need to test children older than 10 to examine at what point children (or possibly adolescents) start to show different processing patterns for globally ambiguous sentences from those of 4- to 10-year-olds.

Additionally, we examined whether children and adults showed cumulative effects within a session when no prime was prsented. Because of the absence of the primes, in particular the LA prime, participants were expected to show cumulative effects by self-priming themselves with their preferred analysis (i.e., HA). This would result in an increased number of HA responses by the end of the experiment.

3.3.1 Methods

Participants

A total number of 40 native Spanish-speaking children and 25 adult native speakers of Spanish (14 female, 11 male) took part in this online experiment from their homes using a computer or tablet. We recruited twenty 4- to 6-year-olds (mean age 5;5, 7 female, 13 male), we refer to them as the Younger Group; twenty 8- to 10-year-old children (mean age 9;2, 12 female, 8 male), we refer to them as the Older Group; and twenty-five adult students from the Anahuac University (North campus) Mexico, ranging in age from 19 to 25 (mean age 21).
Children were recruited through social media groups for parents in Mexico. None of the participants had a history of language disorders or learning disabilities and had little or no knowledge of a second language. All children's parents/caregivers provided written consent before the experiment and received an electronic £4 Amazon gift card after the experiment. Adults received participation credits for one of their courses from their University. Children also received an electronic certificate of participation. All the participants resided in Mexico and had lived in Mexico most of their life.

Design

We used a mixed design with Age Group as a between-participants factor (Adults vs. Older vs. Younger) within items.

Materials, Procedure, Scoring and Data analysis

To investigate Younger and Older Spanish-speaking children's PP attachment preferences and their development, we examined their comprehension preferences in contexts without an immediately preceding prime, which also served as the baseline for the following experiments. We used the same materials, design and followed the same procedure, scoring and data analysis as the Baseline experiment with the English-speaking 4- to 6 and 8- to 10-year-old children and adults from Chapter 2 (see Experiment 1, Chapter 2). The only difference was that the sentences were pre-recorded in Spanish (verbs: *acariciar (pat), empujar (push), picar (poke), mover (move), tocar (touch)* and *hacer reir (tickle)*). All these verbs were instrument-biased verbs. A native speaker of Spanish recorded the audios. The task lasted 7

minutes in total without breaks (mean of task completion time: Adults: 627 sec; 8- to 10-year-olds: 976 sec and 4- to 6-year-olds: 1009 sec). See Figures 1 and 2 and appendix for materials.

Target sentence:
La niña está tocando al perro con el plátano
(The girl is touching the dog with the banana)

Filler sentence:
El perro está persiguiendo a la oveja
(The dog is chasing the sheep)

Figure 1. Spanish-speaking participants: Example of a Target sentence and a Filler sentence

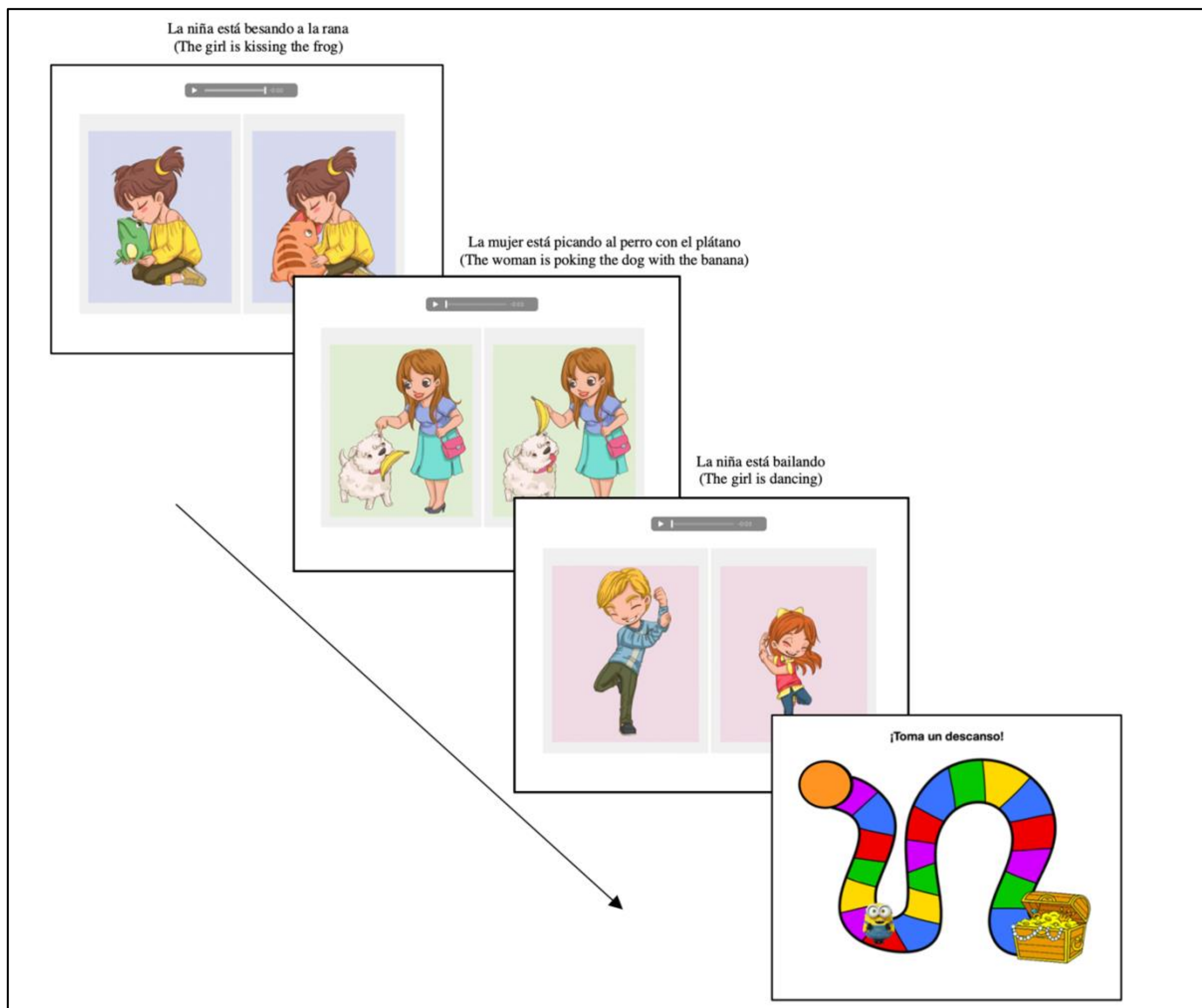

Figure 2. Spanish-speaking participants: Example of one of the sequences: Filler – Target sentence – Filler –Take-a-break slides.

3.3.2 Results

We carried out three analyses, to test (1) overall effects of Age Group, (2) developmental effects, and (3) cumulative effects on interpreting ambiguous PPs whe no prime was presented. To measure children's and adults' baseline preferences for interpreting ambiguous PPs, the best-fitting mixed-effects logistic regression model contained the binomial outcome HA Responses variable (with HA responses coded as 1, and LA responses coded as 0) and Age Group as the predictor. To test for any developmental effects in children in the baseline condition, we used the HA Responses outcome variable and the best-fitting model

included Age in Months (continuous variable only for children; centred prior to the analysis) as the predictor. To examine cumulative effects within a session in the baseline condition, we analysed the first and last thirds of the data of the experiment and used HA responses as the outcome variable and Trials (continuous variable; 16 trials), Age group and their interactions as the predictors. For the cumulative effects analyses we examined the direction of the effect, that is whether participants were more likely to use more or fewer HA responses as the experiment progressed when no prime was presented. The random-effect structure of the three final models included participants and items as random intercepts and no random slopes. Figure 3 presents participants' HA responses in each age group. Table 1 shows a summary of results of Age Group comparisons.

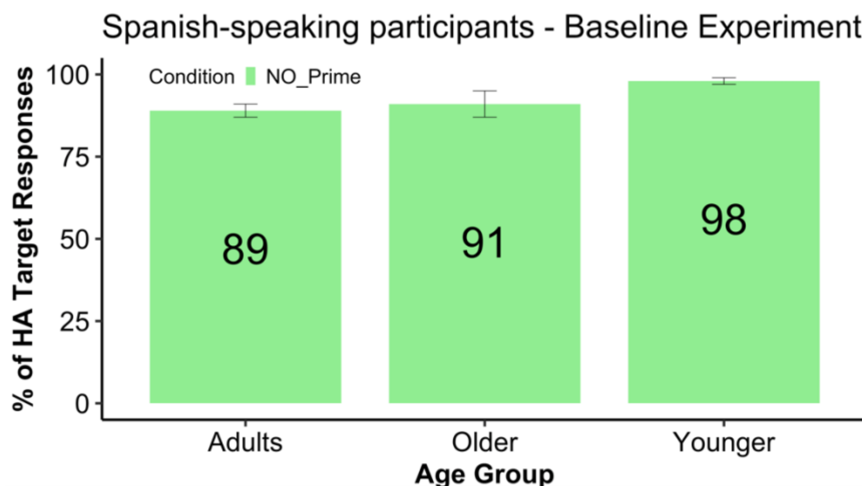

Figure 3. Spanish-speaking participants: Proportion of HA target responses by age group: Baseline experiment.

Each participant responded to 24 fillers and 24 target sentences. All the participants had more than 80% of accurate filler responses, and therefore no participants were removed. Younger children correctly identified the matching picture in the filler sentences 468 (98%) times out 480, Older children correctly identified the matching picture in the filler sentences 475 (99%) times out of 480. Adults correctly identified the matching picture in the filler sentences 588 (99%) times out of 600. Adults also chose 533 (89%) HA responses and 67 (11%) LA target responses. Younger children chose 471 (98%) HA target responses and 9 (2%) LA target responses. Older children chose 438 (91%) HA target responses and 42 (9%) LA target responses (see figure 3).

Effects of Age Group

Figure 3 shows how children and adults had an overall preference for the HA analysis. However, the only age group comparison that was significant was the one between the Younger children and the adults ($p < .01$). That is, in the baseline condition, the Younger group was more likely to interpret a globally ambiguous sentence with a HA analysis than a LA analysis in comparison to the adults. Interestingly, although the Older children chose fewer HA responses than the Younger group, and more HA responses than the adults, the Older group did not differ from any of the other two groups significantly (Younger: M = 98; Older: M = 91; Adults: M = 89). This suggests that, when there is no exposure to a prime, the Older group may be at a stage in which they have already started to show adult-like patterns for interpreting globally ambiguous sentences, but at the same time, such patterns do not differ enough from the ones of the Younger group yet. See Table 1 for a summary of results.

Developmental effect

As shown in Table 1 and Figure 4, the pattern that 4- to 6- and 8- to 10-year-old children showed was that they chose fewer HA responses and more LA responses as they grew older. However, the effect of Age in Months did not reach statistical significance ($p > .05$). This means that in the baseline condition, the likelihood of choosing an HA over an LA response between the ages of 4 and 10 did not increase or decrease as a function of Age in Months. (see Figure 4 and Table 1).

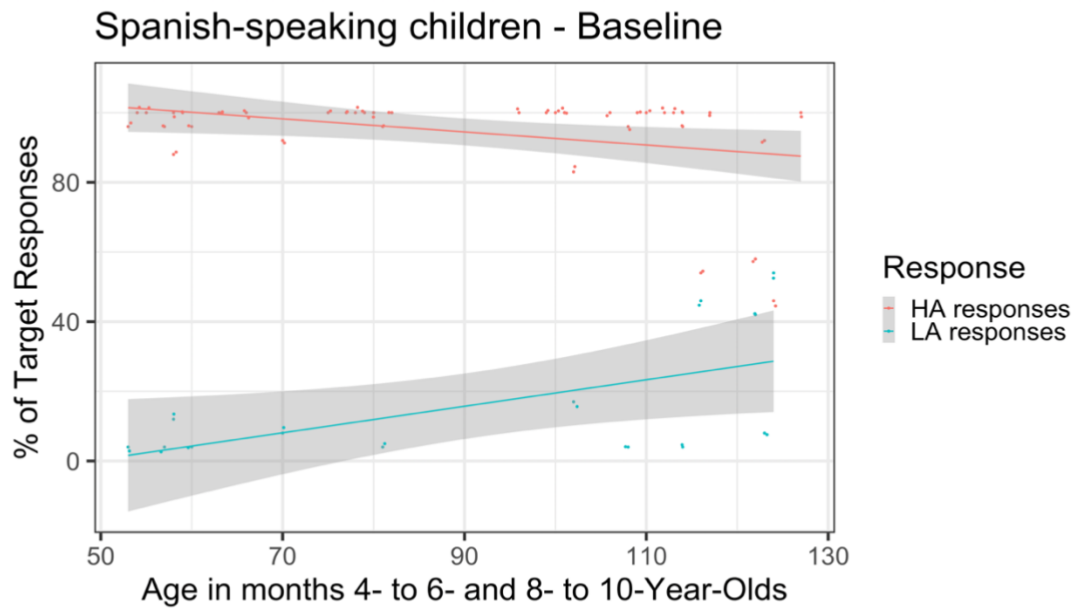

Figure 4. Spanish-speaking children: Proportion of HA and LA target responses by Age in months in Younger and Older children. Baseline Experiment

Cumulative effects

The best- fitting model revealed an effect of Age Group between the Younger children and the adults ($p < .05$), a marginal effect between the Older and the Younger children ($p = .058$), but not between the Older children and the adults ($p > .05$). There was no main effect of Trials or an interaction between the Age Group and Trials, suggesting that, in the baseline condition, as the experiment progressed, the likelihood of choosing a HA response did not vary within a session in children and adults (see Table 1).

Experiment	Effects	Predictor	Coefficient	SE	Z value	p
Baseline	Effects of Age Group	Intercept (Adults & Younger)	2.99	0.45	6.52	**<.001**
		Age Group (Older vs. Adults)	1.12	0.68	1.64	.100
		Age Group (Younger vs. Adults)	2.37	0.73	3.20	**<.01**
		Age Group (Older vs. Younger)	-1.25	0.79	-1.58	.113
	Developmental effect	Intercept	5.21	0.84	6.18	**<.001**
		Age Months	-0.71	0.48	-1.47	.141
	Cumulative effects	Intercept (Adults & Younger)	2.97	0.73	4.05	**<.001**
		Age Group (Older vs. Adults)	0.53	0.85	0.62	.534
		Age Group (Younger vs. Adults)	2.83	1.16	2.43	**<.05**
		Age Group (Older vs. Younger)	-2.30	1.21	-1.89	**.058**
		Trials	0.02	0.06	0.44	.654
		Age Group (Older vs. Adults) x Trials	0.04	0.06	0.60	0.54
		Age Group (Younger vs. Adults) x Trials	-0.10	0.09	-1.10	0.26
		Age Group (Older vs. Younger) x Trials	0.14	0.10	1.43	.152

Table 1. Spanish-speaking participants: Summary of mixed-effects logistic regression models with Age Group, Age in Months and Trials as predictors for experiment 1(Experiment 1, Baseline).

3.3.3 Interim discussion

Experiment 1 served as a baseline to examine Spanish-speaking 4- to 6- and 8- to 10-year-old children's and adults' PP attachment preferences. We also tested whether 4- to 6- and 8- to 10-year-olds showed a developmental pattern that would suggest a change in the processing of globally ambiguous sentences at this age stage and whether children and adults would show cumulative effects when no prime was presented.

We found that participants were more likely to have a preference for HA than for LA when they were not primed. However, the Younger children were more likely to choose HA responses than the adults. This suggests that, when no prime is presented, the likelihood of choosing an HA response over an LA response decreases when children become adults. The fact that the Older group's proportion of HA responses did not differ significantly from the Younger children's and the adults', may suggest how the Older group is slowly progressing into acquiring adult-like attachment preferences.

When analysing developmental patterns, 4- to 10-year-old children showed a strong preference for HA, but this preference was not modulated by Age in Months. This is consistent with the Age Group analyses described above, whereby no significant differences in the proportion of HA responses between the Younger and the Older group were found. This suggests that, when no prime is presented, Spanish-speaking children between 4 and 10 process globally ambiguous sentences in a similar way, and that the likelihood of choosing an HA response decreases when children become adults.

Cumulative effects were not found in any of the age groups; however, these may have been because the three groups were already showing ceiling effects throughout the experiment.

In experiment 2, we sought to understand the role of recent language experience better by investigating whether 4- to 6- and 8- to 10-year-old Spanish-speaking children already showed existing and stable abstract representations of the HA and LA analyses when processing globally ambiguous sentences and whether they were susceptible to cumulative experience of the LA structure. To do this, we investigated whether the presence of a prime sentence before a target sentence, when the prime and target sentences involved different verbs, influenced how children interpreted ambiguous PPs, and furthermore whether children and adults showed cumulative effects of exposure to LA analyses.

3.4 Experiment 2: Non-Repeated Verb

Experiment 1 served as a baseline to establish Spanish-speaking children's and adults PP preferences during language comprehension. In experiment 2, we aimed to investigate whether 4- to 6- and 8- to 10-year-old Spanish-speaking children and adults interpreted

globally ambiguous sentences in the same way they interpreted a prior prime sentence in the absence of lexical overlap. Our aim was to examine whether children and adults already showed existing and stable abstract representations of the HA and LA analyses during language comprehension, and whether they were influenced to the same extent by recent language experience that involved a prime sentence with a different verb from the target sentence. The adult group served as the control group and the results from experiment 1 served as the baseline for this experiment.

We analysed the priming effects in children and adults and looked for developmental patterns in children by using Age in Months as a predictor. This allowed more fine-grained investigation of developmental changes in children's PP attachment preferences. We further examined cumulative effects within a session in participants.

We followed the same procedure and used the same language comprehension web-based sentence-picture matching task as in the Non-Repeated Verb experiment with the English-speaking 4- to 6 and 8- to 10-year-old children and adults from Chapter 2 (see Experiment 2, Chapter 2), but with the stimuli in Spanish and with Spanish-speaking participants.

We predicted that Spanish-speaking adults would show structural priming effects in the absence of verb overlap between the prime and target sentence. As for children, since we do not know the age at which Spanish-speaking children start to accept the LA analysis, we predicted that children may or may not show priming effects. If adults and both child groups showed lexically-independent priming effects, with no age group by prime differences, this would suggest that children have already existing abstract and stable representations of the HA and LA structures. If this were the case, this would support early abstraction accounts that suggest that during the early stages of language development, children start with abstract representations of language.

By contrast, if Younger children showed stronger priming effects than the Older children and adults, this would be consistent with the error-based learning accounts, which argue that priming effects may be more accentuated in less experienced speakers such as young children. If this were the case, then, the Older children would also need to show stronger priming effects than the adults.

Cumulative effects would also be consistent with the error-based learning accounts. That is, the three age groups would be expected to accumulate such individual experiences of

the less frequent LA analysis resulting in effects of cumulative experience. However, stronger cumulative effects would be expected to be shown by the Younger children due to their high prediction error rates with the dispreferred LA structure than the Older children and adults.

If, on the other hand, both groups of children did not show lexically-independent priming effects, then an experiment in which the verb is repeated between the prime and target sentences should be carried out, as this would indicate whether children's syntactic representations of the HA and LA analyses may still have a lexical component.

3.4.1 Methods

Participants

A total number of 117 Spanish-speaking 4- to 6- and 8- to 10-year-old children and 50 adult native speakers of Spanish took part in this online experiment in their homes using a computer or tablet. All the participants in experiment 2 were different from those in experiment 1. We removed four 4- to 6-year-olds and four 8- to 10-year-olds because all their responses for the LA primes were incorrect. Additionally, we excluded five 4- to 6-year-olds and four 8- to 10-year-olds because they showed more than 20% of inaccurate prime responses. We ended up with the data of fifty 4- to 6-year-olds (n = 50, mean age 5;4, 28 female, 22 male), fifty 8- to 10-year-olds (n = 50, mean age 9;6, 20 female, 30 male) and fifty adult students from the Anahuac University (North campus) Mexico ranging in age from 18 to 24 (mean age 20). All the participants resided in Mexico and had lived in Mexico most of their life. The recruitment process and the participation criteria were the same as experiment 1

Design

We used a 3 x 2 mixed design with Age Group (Adults vs. Older vs. Younger) as a between-participants and within-items factor, and Prime condition (HA vs. LA) as a within-participants and -items factor.

Materials, Procedure, Scoring and Data analyses

To investigate the effect of priming without lexical repetition, we used the same materials and followed the same procedure, scoring and data analyses as in the Non-Repeated

Verb experiment with the English-speaking 4- to 6 and 8- to 10-year-old children and adults from Chapter 2 (see Experiment 2, Chapter 2). The only difference was that filler, prime and target sentences were pre-recorded in Spanish (verbs: *acariciar (pat), empujar (push), picar (poke), mover (move), tocar (touch)* and *hacer reir (tickle)*). The task lasted 10 minutes in total without breaks (mean of task completion time: Adults: 860 sec; 8- to 10-year-olds:1,322 sec and 4- to 6-year-olds: 1,486 sec). See Figure 5 for an example of the two versions of a Prime sentence.

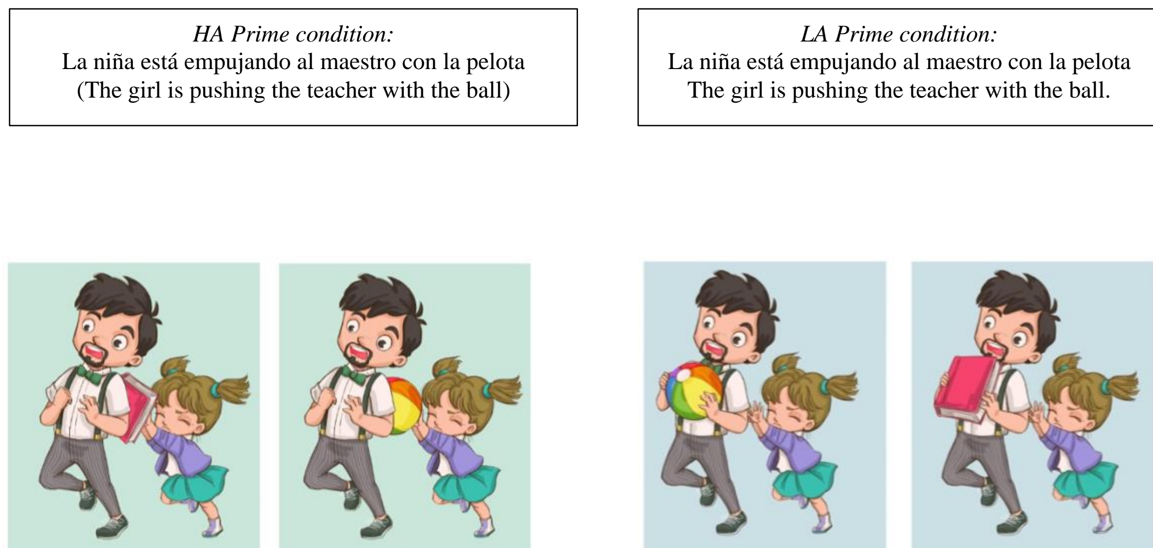

Figure 5. Example of the two picture-matching versions of a Prime sentence.

An experimental item was comprised of a prime sentence such as 1) followed by a target sentence such as 2). There was always an intervening filler after each experimental item. Prime and target sentences did not share the same verb.

Item: 1) Prime sentence: *La niña está empujando al maestro con la pelota*
(The girl is pushing the teacher with the ball)
2) Target sentence: *La niña está tocando al perro con el plátano*
(The girl is touching the dog with the banana)

Filler: 3) *El perro está persiguiendo a la oveja.*
(The dog is chasing the sheep)

3.4.2 Results

We carried out three analyses to test (1) overall effects of Prime, Age Group, and the interaction between these two (2) developmental effects of Age in Months, Prime, and the interaction between these two, and (3) cumulative effects on interpreting ambiguous PPs in the presence of a prime that involved a different verb than the target sentence.

To test the effect of priming and cumulative experience without lexical repetition between the prime and target sentence in Spanish-speaking children and adults' PP attachment preferences, we built a mixed-effects logistic regression model containing the binomial outcome variable HA responses (with HA responses coded as 1, and LA responses coded as 0). We ran the model with Age Group and Prime and the interactions between them as predictors.

To examine any developmental patterns in children, we used the same outcome variable as model 1 and built a second model with Age in Months (continuous variable with the child group only; centred prior to the analysis) and Prime and their interactions as the predictors.

To examine cumulative effects within a session in the presence of a prime that involved a different verb than the target, we analysed the first and last thirds of the data of the experiment and used HA responses as the outcome variable and Trials (continuous variable; 16 trials), Age group, Prime and their interactions as the predictors. For the cumulative effects analyses we focussed on examining the direction of the effect, that is, whether participants were more likely to use more or fewer HA responses as the experiment progressed in the presence of a prime that involved a different verb than the target.

The random-effect structure of the final model for the effects of Age Group included participants and items as random intercepts and no random slopes. The random-effect structure of the final model for the developmental effect included participants and items as random intercepts with Age in Months as random slopes. The random-effect structure of the final model for cumulative effects included participants and items as random intercepts and no random slopes. Figure 6 presents participants' HA responses in each age group. Table 2 shows a summary of results of the comparisons of the predictors.

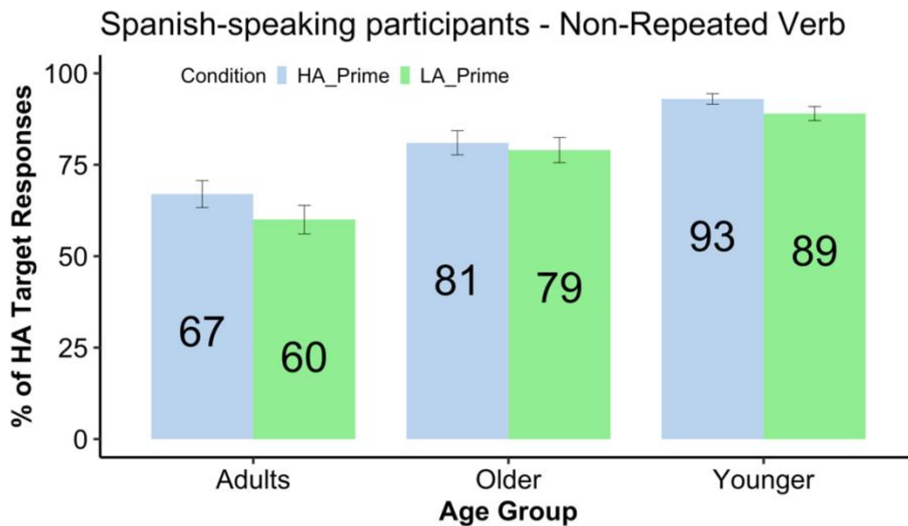

Figure 6. Spanish-speaking participants: Proportion of HA target responses after a HA prime and a LA prime by age group: Non-Repeated Verb experiment

Each participant responded to 24 fillers, 24 prime sentences and 24 target sentences. Items in which the prime picture was incorrectly chosen were removed. We removed 11 items in the adult group, 24 items in the Younger group and 18 items in the Older group out of 1200 items per group.

Adults correctly identified the matching picture in the prime trials 1,189 (99%) times out of 1,200. Of these 1,189 trials, 594 (50%) were HA primes, and 595 (50%) were LA primes. In these trials, participants chose 754 (63%) HA target responses and 435 (37%) LA target responses.

The Younger children correctly identified the matching picture in the prime trials 1,176 (96%) times out of 1,200. Of these 1,176 trials, 592 (50%) were HA primes, and 584 (50%) were LA primes. In these trials, participants chose 1,075 (91%) HA target responses and 101 (9%) LA target responses.

The Older children correctly identified the matching picture in the prime trials 1,182 (99%) times out of 1200. Of these 1,182 trials, 595 (50%) were HA primes, and 592 (50%) were LA primes. In these trials, participants chose 948 (80%) HA target responses and 239 (16%) LA target responses. Each participant had 80% or more of accurate prime responses.

All the participants had more than 80% of accurate filler responses. Younger children correctly identified the matching picture in the filler sentences 1,165 (97%) times out 1,200, Older children correctly identified the matching picture in the filler sentences 1,192 (99%)

times out of 1,200. Adults correctly identified the matching picture in the filler sentences 1,184 (99%) times out of 1,200.

Effects of Age Group

The comparison between children and adults showed a main effect of Prime suggesting that overall, participants were less likely to choose an HA response after an LA prime than after an HA prime when the verb was not repeated between prime and target (p < .01) (Younger HA prime M =93, LA prime M= 89; Older HA prime M = 81, LA prime M = 79; Adults HA prime M = 67, LA prime M = 60). We also found an effect of Age group when comparing the Older children against the adults (p <.001), the Younger group against the adults (p<.001) and the Older children against the Younger group (p <. 001). This suggested that both the Younger and the Older children were more likely to choose HA over LA responses than the adults. However, when comparing the two child groups against each other, the Older group was more likely to choose fewer HA responses (and therefore more LA responses) in comparison to the Younger group. There were no interactions between Age group and Prime (see Table 2 for a summary of results).

Developmental effect

The analysis with Age in Months as a continuous variable did not reveal significant effects (p >.05) in Spanish-speaking children. Although the pattern with Age in Months was that as children grew older, they were more likely to choose fewer HA responses than LA responses for globally ambiguous sentences, this effect was not significant (p>.05).

Children continued to show a reliable main effect of Prime, even after removing the adult data from the analyses (p <.01). This suggested that children were more likely to choose fewer HA responses after a LA prime than after a HA prime. However, when Age in Months interacted with Prime, the model revealed a marginal effect (p = .062) suggesting that the older children were, the more they tended to choose *more* HA responses after a LA prime than a HA prime (see Figure 7).

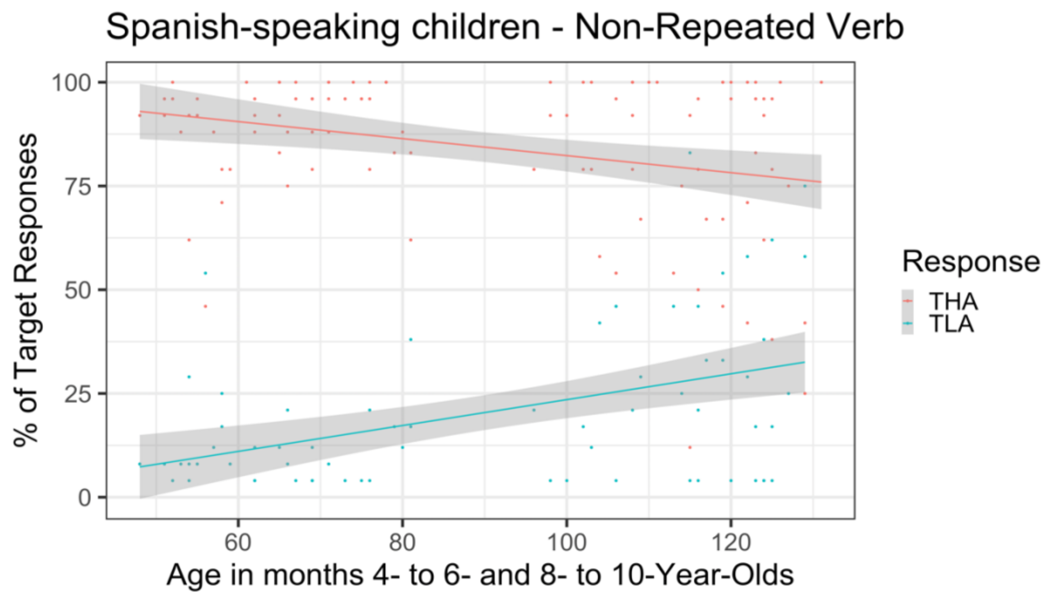

Figure 7. Spanish-speaking participants: Proportion of HA and LA responses by Age in Months in Younger and Older children: Non-Repeated Verb experiment. THA = HA target responses; TLA = LA target responses

Cumulative effects

The model revealed significant Age group differences between the Older children and adults (p<.05), the Younger children and adults (p<.001) and between the two child groups (p<.05). That is, if we analyse the responses of only the first and last thirds of the data, the child groups were more likely to interpret a globally ambiguous sentence with a HA analysis than a LA analysis in comparison with the adults. However, when comparing the two child groups against each other, the Older children tended to choose fewer HA than LA interpretations for globally ambiguous sentences than the Younger group. We did not find a main effect of Prime (p>.05) or of Trials (p>.05) or any interactions between Age Group, Prime or Trials, except for one between Age group (Older vs. Younger) and Prime (see Table 2).

Experiment 2	Effects	Predictor	Coefficient	SE	Z value	p
Non-Repeated Verb	Effects of Age Group	Intercept	1.10	0.29	3.70	**<.001**
		Age Group (Older vs. Adults)	1.24	0.37	3.35	**<.001**
		Age Group (Younger vs. Adults)	2.48	0.39	6.36	**<.001**
		Age Group (Older vs. Younger)	-1.24	0.40	-3.11	**<.01**
		Prime (LA vs. HA)	-0.45	0.14	-3.18	**<.01**
		Age Group (Older vs. Adults) x Prime	0.31	0.22	1.41	.157
		Age Group (Younger vs. Adults) x Prime	-0.12	0.26	-0.48	.626
		Age Group (Older vs. Younger) x Prime	0.44	0.28	1.58	.112
	Developmental effect	Intercept	2.97	0.26	11.43	**<.001**
		Age in Months	-0.32	0.25	-1.26	.205
		Prime (LA vs. HA)	-0.39	0.14	-2.65	**<.01**
		Age in Months x Prime	0.27	0.14	1.86	**.062**
	Cumulative effects	Intercept	1.66	0.49	3.36	**<.001**
		Age Group (Older vs. Adults)	1.11	0.53	2.09	**<.05**
		Age Group (Younger vs. Adults)	2.47	0.66	3.73	**<.001**
		Age Group (Older vs. Younger)	-1.36	0.68	-1.97	**<.05**
		Prime (LA vs. HA)	-0.69	0.38	-1.80	0.07
		Trials	-0.04	0.04	-0.96	.335
		Age Group (Older vs. Adults) x Prime	0.51	0.60	0.85	.390
		Age Group (Younger vs. Adults) x Prime	-1.05	0.73	-1.43	.150
		Age Group (Older vs. Younger) x Prime	1.57	0.77	2.02	**<.05**
		Age Group (Older vs. Adults) x Trials	-0.01	0.04	-0.42	.672
		Age Group (Younger vs. Adults) x Trials	-0.02	0.05	-0.40	.685
		Age Group (Older vs. Younger) x Trials	0.00	0.05	0.07	.941
		Prime (LA vs. HA) x Trials	0.02	0.03	0.75	.450
		Age Group (Older vs. Adults) x Prime x Trials	-0.03	0.06	-0.51	.609
		Age Group (Younger vs. Adults) x Prime x Trials	0.09	0.07	1-30	.190
		Age Group (Older vs. Younger) x Prime x Trials	-0.12	0.07	-1.64	.100

Table 2. Spanish-speaking participants: Summary of mixed-effects logistic regression models with Age Group, Prime, Age in Months and Trials as predictors for experiment 2 (Non-Repeated Verb).

3.4.3 Interim discussion

The Non-repeated Verb experiment investigated whether 4- to 6- and 8- to 10-year-old Spanish-speaking children and adults interpreted globally ambiguous sentences in the same way they interpreted a prior prime sentence in the absence of verb repetition. Our aim was to seek evidence for existing and stable abstract representations of the HA and LA analyses in children and adults during language comprehension. Additionally, we examined developmental changes in the processing of PP attachment preferences, and furthermore whether children and adults showed cumulative effects of exposure to LA analyses when prime and target pairs involved a different verb.

We found a main effect of Prime suggesting that participants were more likely to choose more HA responses after an HA prime than an LA prime. Furthermore, when looking for developmental differences, children continued to show a reliable priming effect even after removing the adult data from the analyses. This may suggest that 4- to 6- and 8- to 10-year-old Spanish-speaking children may have abstract representations of the HA and LA analyses for globally ambiguous sentences during language comprehension. This is surprising, given that we had predicted that due to the infrequent nature of the LA analysis in Spanish, children may have the LA representation fragile and less stable than the HA representation.

The models also revealed differences in the overall PP preferences across the three groups. That is, in the presence of a prime that does not share the same verb as the target sentence, the two child groups were more likely to choose more HA responses than the adults. Significant differences in the overall PP preferences were also found between the Younger and the Older children, with the Older group showing fewer HA responses than the Younger group.

This reflects a developmental pattern that was not found when participants were not exposed to the primes (Baseline experiment). That is, exposure to the two primes modulated the overall proportion of HA responses in participants. It may be the case that in the baseline condition, we did not see clear differences across the age groups because all the participants were already showing ceiling effects.

We also found a marginal effect on the interaction of Age in Months and Prime. That is, as children grew older, they were more likely to choose *more* HA responses after an LA

prime than an HA prime. Although, this was a marginal effect, future research should investigate whether this pattern can be replicated in Spanish-speaking children between the ages of 8 and 10. We did not find significant effects of cumulative experience in any of the age groups. That is, the likelihood of choosing an HA response did not vary from the first third to the last third of the experiment overall, or as a function of exposure to a preceding prime that did not involve the same verb as the target sentence.

In experiment 2 we found evidence of lexically-independent priming effects in Spanish-speaking children. In Experiment 3, we sought to understand the role of recent language experience better and look for evidence of a lexical boost in children and adults, and whether Spanish-speaking participants might be susceptible to cumulative experience. To do this, we investigated whether the presence of a prime sentence before a target sentence, when the prime and target sentences involved the same verbs, influenced how children interpreted ambiguous PPs, and furthermore whether children and adults showed cumulative effects of exposure to LA analyses.

3.5 Experiment 3: Repeated-Verb

In experiment 2 we examined whether 4- to 6- and 8- to 10-year-old Spanish-speaking children and adults showed evidence of existing and stable abstract representations of the HA and LA analyses during language comprehension. We found a main effect of Prime, and this effect continued to be reliable in children once the adults' responses were removed from the analyses. These findings suggested that children showed evidence of abstract representations of the HA and LA analyses of globally ambiguous sentences.

In experiment 3, we aimed to investigate whether Spanish-speaking children and adults might show a strong lexical boost when the prime shared the same verb with the target sentence during language comprehension. We followed the same procedure and used the same language comprehension web-based sentence-picture matching task as in experiment 2, with the same stimuli but with different participants. Each target sentence was preceded by a prime sentence and each pair of prime and target sentences involved the same verb. We analysed the priming effects in participants and compared the children's performance with that of adults, who served as the control group.

To look for developmental differences in children, we examined the effect of Age in Months, and the effect of priming as well as the interaction between these two variables. This allowed more fine-grained investigation of developmental changes in children's PP attachment preferences. Cumulative effects within a session in children and adults were also examined.

To look for evidence of a lexical boost, an additional analysis was run to examine whether the differences in the overall PP preferences and in the priming effects in the absence and presence of verb repetition were significant.

To examine the overall influence of priming on attachment preferences in Spanish-speaking participants, we compared the proportion of HA responses in the baseline condition with the proportion of the HA responses when participants were exposed to the primes, (i.e., Baseline experiment vs. Non-repeated Verb experiment; Baseline experiment vs. Repeated verb experiment). For all the analyses we used a binomial outcome variable, where HA responses were coded as 1 and LA responses were coded as 0.

If children and adults showed a lexical boost, this would support the residual activation account that predicts that, irrespective of age, enhanced priming effects will result from the activation of the lemma, combinatorial node and the strengthened association of these two (Pickering & Branigan, 1998).

If, on the other hand, a lexical boost were only found in Older children and adults, but not in the Younger group, this would support the error-based learning account (e.g., Chang, Dell & Bock, 2006) that argues that the nature of the lexical boost comes from explicit memory skills, skills which are more likely to be developed in older individuals. If this were the case, cumulative effects should also arise across the three groups, with the Younger group showing possibly stronger cumulative effects as a result of their higher prediction error in comparison to the Older children's and adults'. To be consistent with this prediction, then the Older group would also need to show stronger cumulative effects than the adults.

If we found that there were no differences in the lexical boost by Age Group, this would support early abstraction accounts that suggest that young children do not go through a stage in which their representations are more lexically-specific than those of adults'.

3.5.1 Methods

Participants

A total number of 116 native Spanish-speaking children and 50 adult native speakers of Spanish (39 female, 11 male) took part in this online experiment in their homes using a computer or tablet. All the participants were different from experiments 1 and 2. We removed five 4- to 6-year-olds and three 8- to 10-year-olds because all their responses for the LA primes were incorrect. Additionally, we excluded four 4- to 6-year-olds and four 8- to 10-year-olds because they showed more than 20% of inaccurate prime responses. We ended up with the data of fifty 4- to 6-year-olds (mean age 5;6, 22 female, 28 male), fifty 8- to 10-year-olds (mean age 9;2, 28 female, 22 male) and fifty adult students from the Anahuac University (North campus) Mexico ranging in age from 18 to 29 (mean age 20). All the participants resided in Mexico and had lived in Mexico most of their life. The recruitment process and the participation criteria were identical to experiment 1.

Design

We used the same design as in experiment 2.

Materials, Procedure, Scoring and Data analysis

To investigate the effect of priming with lexical repetition between prime and target sentence in Younger and Older Spanish-speaking children and adults, we used the same materials and followed the same procedure, scoring and data analyses as in the Repeated Verb experiment with the English-speaking 4- to 6 and 8- to 10-year-old children and adults from Chapter 2 (see Experiment 3, Chapter 2). The only difference was that the stimuli were in Spanish. The task lasted 10 minutes in total without breaks (mean of task completion time: Adults: 967 sec; 8- to 10-year-olds:1,283 sec and 4- to 6-year-olds: 1,370 sec).

An experimental item was comprised of a prime sentence such as 1) followed by a target sentence such as 2). The only constraint was that the same verb was shared between the prime and target sentence. There was always an intervening filler after each experimental item.

Item: 1) Prime sentence: *La niña está empujando al maestro con la pelota*

The girl is pushing the teacher with the ball.

2) Target sentence: *El niño está <u>empujando</u> al perro con la llave*

The boy is <u>pushing</u> the dog with the key.

Filler: 3) *El perro está persiguiendo a la oveja*

The dog is chasing the sheep

3.5.2 Results

We carried out six analyses, to test (1) overall effects of Prime, Age Group, and the interaction between these two (2) developmental effects of Age in Months, Prime, and the interaction between these two, (3) cumulative effects on interpreting ambiguous PPs in the presence of a prime that involved the same verb than the target sentence.

To test the effect of priming with verb repetition in children's and adults' PP attachment preferences and to test for any developmental patterns, we built two models and conducted the same analyses as in experiment 2. We ran the first model with Age Group and Prime and the interactions between them as predictors.

To examine developmental patterns in children, we built a second model with Age in Months (continuous variable with only the children; centred prior to the analysis) and Prime and their interactions as the predictors.

To examine cumulative effects within a session in the presence of a prime that involved the same verb than the target, we analysed the first and last thirds of the data of the experiment and used HA responses as the outcome variable and Trials (continuous variable; 16 trials), Age group, Prime and their interactions as the predictors. For the cumulative effects analyses we focussed on examining the direction of the effect, that is, whether participants were more likely to choose more or fewer HA responses as the experiment progressed in the presence of a prime that involved the same verb than the target. The random-effect structure of the final models included participants and items as random intercepts and no random slopes. Figure 8 presents participants' HA responses in each age group. Table 3 shows a summary of results of the comparisons of the predictors.

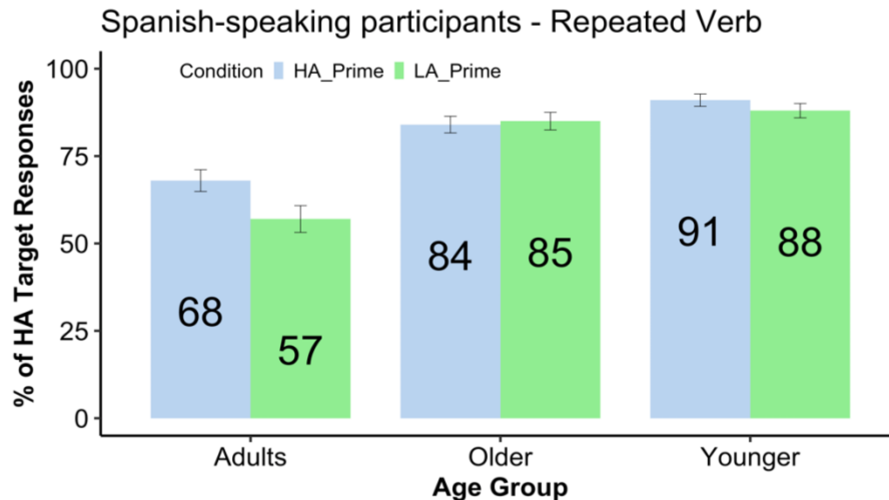

Figure 8. Spanish-speaking participants: Proportion of HA target responses after a HA prime and a LA prime by age group: Repeated Verb experiment

Each participant responded to 24 fillers, 24 prime sentences and 24 target sentences. Items in which the prime picture was incorrectly chosen were removed. We removed 7 items in the adult group, 43 items in the Younger group and 18 items in the Older group out of 1,200 items in each group.

Adults correctly identified the matching picture in the prime trials 1,193 (100%) times out of 1,200. Of these 1,193 trials, 597 (50%) were HA primes, and 596 (50%) were LA primes. In these trials, participants chose 745 (62%) HA target responses and 448 (38%) LA target responses.

The Younger children correctly identified the matching picture in the prime trials 1,157 (97%) times out of 1,200. Of these 1,157 trials, 585 (50%) were HA primes, and 572 (50%) were LA primes. In these trials, participants chose 1,037 (90%) HA target responses and 120 (10%) LA target responses.

The Older children correctly identified the matching picture in the prime trials 1,182 (99%) times out of 1200. Of these 1,182 trials, 591 (50%) were HA primes, and 591 (50%) were LA primes. In these trials, participants chose 999 (84%) HA target responses and 183 (16%) LA target responses. Each participant had 80% or more of accurate prime responses.

All the participants had more than 80% of accurate filler responses. Younger children correctly identified the matching picture in the filler sentences 1,167 (97%) times out 1,200, Older children correctly identified the matching picture in the filler sentences 1,180 (98%)

times out of 1,200. Adults correctly identified the matching picture in the filler sentences 1,190 (99%) times out of 1,200.

Effects of Age Group

The analysis by Age Group showed a main effect of Prime suggesting that children and adults were less likely to choose an HA response after an LA prime than after an HA prime when there was verb repetition between the prime and target sentence ($p < .001$) (Younger HA prime M = 91, LA prime M= 88; Older HA prime M = 84, LA prime M = 85; Adults HA prime M = 68, LA prime M = 57). We also found an effect of Age Group between the Older children and adults ($p<.001$), the Younger group and adults ($p<.001$) and when comparing the two child groups against each other ($p<.05$). This suggests that the two child groups were more likely to choose a HA interpretation than a LA interpretation for globally ambiguous sentences in comparison to the adults. However, when analysing the two child groups' responses, the Older group was more likely to choose fewer HA responses for globally ambiguous sentences than the Younger children. The model also revealed a significant interaction between Age group (Older vs. Adults) and Prime. Thus, to unpack this interaction, we analysed the effect of Prime in each age group separately and found a strong effect of Prime only in the adults ($p < .001$). See figure 8 and Table 3 for a summary of results).

Developmental effect

The analysis targeting developmental effects of PP attachment preferences when there was verb overlap between prime and target sentence in Spanish-speaking children revealed the following patterns. For the effect of Age in Months, it seemed that the older the children were, they tended to choose fewer HA responses and more LA responses.

Once we removed the adult data from the analyses, the effect of Prime was no longer reliable in children ($p>.05$). We did not find an effect on the interaction between Age in Months and Prime (see Table 3 and Figure 9).

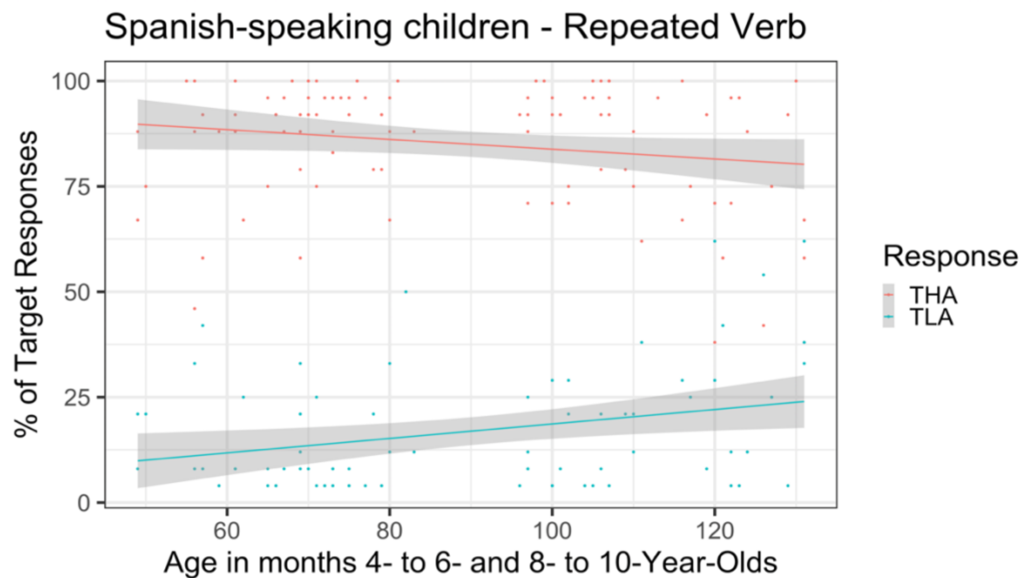

Figure 9. Spanish-speaking participants: Proportion of HA and LA responses by Age in Months in Younger and Older children: Repeated Verb experiment. THA = HA target responses; TLA = LA target responses

Cumulative effects

The model on cumulative effects revealed an effect of Age Group between the Older children and adults ($p <.001$), the Younger children and adults ($p < .001$) and the Older and Younger children ($p <.05$). This suggests that, if we analyse only the first and last thirds of the data of the Repeated Verb experiment, the Younger and the Older children chose more HA responses than LA responses in comparison to the adults. However, when analysing the responses of the two child groups, this time the Older group chose more HA responses than the Younger children. No main effects of Prime and Trials were found (both $p >.05$), however, significant interactions between Age group (Older vs. Adults) and Trials ($p<.01$), and Age group (Older vs. Younger) and Trials ($p <.001$) were found. To unpack these interactions, we analysed the effect of Prime and Trials and their interaction in each age group separately. We found a strong effect of Trials in the Older group ($p <.001$). This suggests that, as the experiment progressed, the Older group was more likely to choose fewer HA responses and more LA responses when interpreting globally ambiguous sentences. See Table 3.

Experiment	Effects	Predictor	Coefficient	SE	Z value	p
Repeated Verb	Effects of Age Group	Intercept	1.05	0.23	4.45	**<.001**
		Age Group (Older vs. Adults)	1.18	0.31	3.79	**<.001**
		Age Group (Younger vs. Adults)	1.93	0.32	5.91	**<.001**
		Age Group (Older vs. Younger)	-0.74	0.33	-2.22	**<.05**
		Prime (LA vs. HA)	-0.63	0.13	-4.58	**<.001**
		Age Group (Older vs. Adults) x Prime	0.76	0.22	3.44	**<.001**
		Age Group (Younger vs. Adults) x Prime	0.28	0.24	1.16	.244
		Age Group (Older vs. Younger) x Prime	0.48	0.26	1.80	.070
	Effects of Prime Older group	Intercept	2.36	0.29	8.02	**<.001**
		Prime (LA vs. HA)	0.09	0.18	0.54	.589
	Effects of Prime Younger group	Intercept	2.93	0.28	10.36	**<.001**
		Prime (LA vs. HA)	-0.34	0.21	-1.65	.098
	Effects of Prime Adults	Intercept	1.09	0.26	4.17	**<.001**
		Prime (LA vs. HA)	-0.65	0.14	-4.66	**<.001**
	Developmental effects	Intercept	2.65	0.20	12.12	**<.001**
		Age in Months	-0.31	0.22	-1.41	.156
		Prime (LA vs. HA)	-0.12	0.14	-0.85	.394
		Age in Months x Prime	0.11	0.13	0.85	.391
	Cumulative effects	Intercept	1.13	0.43	2.60	**<.01**
		Age Group (Older vs. Adults)	2.95	0.59	4.98	**<.001**
		Age Group (Younger vs. Adults)	1.47	0.53	2.76	**<.001**
		Age Group (Older vs. Younger)	1.47	0.65	2.25	**<.05**
		Prime (LA vs. HA)	-0.20	0.36	-0.56	.569
		Trials	-0.03	0.04	-0.74	.457
		Age Group (Older vs. Adults) x Prime	-0.42	0.70	-0.61	.540
		Age Group (Younger vs. Adults) x Prime	0.66	0.65	1.01	.311
		Age Group (Older vs. Younger) x Prime	-1.09	0.81	-1.34	.178
		Age Group (Older vs. Adults) x Trials	-0.14	0.04	-3.03	**<.01**
		Age Group (Younger vs. Adults) x Trials	0.06	0.04	1.34	.177
		Age Group (Older vs. Younger) x Trials	-0.21	0.05	-3.68	**<.001**
		Prime (LA vs. HA) x Trials	-0.03	0.03	-0.95	.341
		Age Group (Older vs. Adults) x Prime x Trials	0.10	0.06	1.58	.113

		Age Group (Younger vs. Adults) x Prime x Trials	-0.02	0.06	-0.39	.693
		Age Group (Older vs. Younger) x Prime x Trials	0.13	0.07	1.65	.098
	Cumulative effects Older group	Intercept	4.05	0.53	7.56	**<.001**
		Prime (LA vs. HA)	-0.84	0.58	-1.45	.146
		Trials	-0.17	0.04	-4.23	**<.001**
		Prime x Trials	0.09	0.05	1.69	.090
	Cumulative effects Younger group	Intercept	2.65	0.48	5.42	**<.001**
		Prime (LA vs. HA)	0.33	0.53	0.63	.523
		Trials	0.03	0.04	0.81	.417
		Prime x Trials	-0.04	0.05	-0.89	.372
	Cumulative effects Adults	Intercept	1.21	0.54	2.22	**<.05**
		Prime (LA vs. HA)	-0.21	0.36	-0.59	.554
		Trials	-0.03	0.05	-0.64	.517
		Prime x Trials	-0.03	0.03	-0.98	.327

Table 3. Spanish-speaking participants: Summary of mixed-effects logistic regression models with Age Group, Prime, Age in Months and Trials as predictors for experiment 2 (Repeated Verb).

Effect of lexical repetition

To test the effect of lexical repetition between the prime and target sentence in Spanish-speaking children's and adults' preferences for interpreting ambiguous PPs, we compared the data of the Non-Repeated Verb experiment against the Repeated Verb experiment. To do this, we combined the data from these two experiments and built a mixed-effects logistic regression model with the binomial outcome variable HA responses (HA responses coded as 1, and LA responses coded as 0) and ran the model with Age Group, Prime, Experiment (2 levels: Non-Repeated verb; Repeated verb) and the interactions between them as predictors. The random-effect structure of the final model included participants and items as random intercepts and Experiment as a random slope. Table 4 shows a summary of results of Age Group, Prime and Experiment comparisons as well as their interactions, where the probability of HA responses after a HA prime for the Adult group in the Non-Repeated Verb experiment is represented in the intercept. We later relevelled the predictor so the intercept could represent the probability of HA responses after a HA prime for the Younger group in the Non-Repeated Verb

experiment. Positive coefficients show that HA target responses were more likely to occur in the tested level of the predictor than the other (categorical variable).

The model revealed a main effect of Prime ($p < .01$) suggesting that, when combining the data in the absence and presence of verb overlap between the prime and target sentence, participants were more likely to choose fewer HA responses after a LA prime than after a HA prime (Younger ($n = 100$) HA prime $M =92$, LA prime $M= 89$; Older ($n = 100$) HA prime $M = 82$, LA prime $M = 82$; Adults ($n = 100$) HA prime $M = 68$, LA prime $M = 58$). We also found an effect of Age Group between the Older group and adults ($p <.001$), the Younger group and Adults ($p <.001$) as well as between the Older and the Younger children ($p >.001$). This means that the two child groups were more likely to choose more HA responses in comparison to the adults, however, when comparing the two child groups, the Older children were more likely to choose fewer HA responses in comparison to the Younger group. No other significant main effects or interactions were found in the model (see Table 4 for a summary of results).

Experiments	Predictor	Coefficient	SE	Z value	p
Non-Repeated Verb vs. Repeated Verb	Intercept	1.02	0.25	4.06	**<.001**
	Age Group (Older vs. Adults)	1.17	0.35	3.34	**<.001**
	Age Group (Younger vs. Adults)	2.38	0.37	6.39	**<.001**
	Age Group (Older vs. Younger)	-1.21	0.38	-3.16	**<.01**
	Prime (LA vs. HA)	-0.43	0.13	-3.13	**<.01**
	Experiment (Repeated Verb vs. Non-Repeated Verb)	0.00	0.31	0.00	.992
	Age Group (Older vs. Adults) x Prime	0.29	0.21	1.33	.183
	Age Group (Younger vs. Adults) x Prime	-0.17	0.25	-0.66	.503
	Age Group (Older vs. Younger) x Prime	0.46	0.27	1.68	.092
	Age Group (Older vs. Adults) x Experiment (Repeated Verb vs. Non-Repeated Verb)	-0.00	0.46	-0.01	.985
	Age Group (Younger vs. Adults) x Experiment (Repeated Verb vs. Non-Repeated Verb)	-0.47	0.49	-0.96	.334
	Age Group (Older vs. Younger) x Experiment (Repeated Verb vs. Non-Repeated Verb)	0.46	0.50	0.92	.355
	Prime x Experiment (Repeated Verb vs. Non-Repeated Verb)	-0.18	0.19	-0.94	.343
	Age Group (Older vs. Adults) x Prime x Experiment (Repeated Verb vs. Non-Repeated Verb)	0.47	0.31	1.53	.123
	Age Group (Younger vs. Adults) x Prime x Experiment (Repeated Verb vs. Non-Repeated Verb)	0.45	0.35	1.26	.205
	Age Group (Older vs. Younger) x Prime x Experiment (Repeated Verb vs. Non-Repeated Verb)	0.02	0.38	0.07	.941

Table 4. Spanish-speaking participants: Summary of mixed-effects logistic regression models with Age Group, Prime and Experiment as predictors. Effect of lexical repetition.

Effect of priming

To compare the Spanish-speaking children's and adults' preferences for interpreting ambiguous PPs in the absence and presence of a prime, we created two datasets, one with the combined data of the participants' responses of the baseline condition (Baseline experiment) and in the presence of a prime without verb repetition between prime and target sentence (Non-Repeated Verb experiment); and another dataset with the participants' responses of the baseline condition (Baseline experiment) and in the presence of a prime with verb repetition between

prime and target sentence (Repeated Verb experiment). We used the binomial outcome variable HA responses (HA responses coded as 1, and LA responses coded as 0) and included in the two best-fitting models Age Group, Experiment (2 levels: Baseline vs. (Non)-Repeated verb) and the interactions between them as predictors. The random-effect structure of the final models included participants and items as random intercepts and Experiment as a random slope. Tables 5 and 6 show a summary of results of Age Group and Experiment comparisons and their interactions, where the probability of HA responses for the Adult group in the Baseline experiment is represented in the intercept. We later relevelled the predictor so the intercept could represent the probability of HA responses for the Younger group in the Baseline experiment. Positive coefficients show that HA target responses were more likely to occur in the tested level of the predictor than the other (categorical variable).

The comparison between the data of the Baseline and the Non-Repeated Verb experiments revealed a strong main effect of Experiment ($p < .001$) suggesting that participants were less likely to choose HA responses in the Non-Repeated Verb experiment than in the Baseline experiment (Younger: Baseline M =98, Non-Rep Verb M= 91; Older: Baseline M = 91, Non-Rep Verb M = 80; Adults: Baseline M = 89, Non-Rep Verb M = 63). We also found an effect of Age Group between the Younger group and adults ($p < .01$) but not between the Older group and adults ($p > .05$) or between the Older group and the Younger children ($p > .05$). This means that, if we combine the responses of the baseline condition with the responses in the presence of a prime without verb repetition, the Younger group chose more HA over LA responses than the adults, however, the Older children's responses did not differ significantly with those of the adults and the Younger group. The model did not reveal any significant interactions between Age Group and Experiment ($p > .05$) (see Table 5 for a summary of results).

Experiments	Predictor	Coefficient	SE	Z value	p
Baseline vs. Non-Rep. Verb	Intercept	2.97	0.44	6.64	**<.001**
	Age Group (Older vs. Adults)	1.11	0.68	1.63	.101
	Age Group (Younger vs. Adults)	2.37	0.73	3.21	**<.01**
	Age Group (Older vs. Younger)	-1.25	0.78	-1.59	.110
	Experiment (Non-Repeated Verb vs. Baseline)	-2.11	0.48	-4.36	**<.001**
	Age Group (Older vs. Adults) x Experiment (Non-Repeated Verb vs. Baseline)	0.29	0.76	0.38	.702
	Age Group (Younger vs. Adults) x Experiment (Non-Repeated Verb vs. Baseline)	0.04	0.82	0.05	.960
	Age Group (Older vs. Younger) x Experiment (Non-Repeated Verb vs. Baseline)	0.25	0.87	0.29	.772

Table 5. Spanish-speaking participants: Summary of mixed-effects logistic regression models with Age group and Experiment as predictors. Effect of priming between the Baseline experiment and the Non-Repeated Verb experiment.

The comparison between the Baseline and the Repeated Verb experiments also revealed a main effect of Experiment ($p < .001$) suggesting that participants chose fewer HA responses than LA responses in the Repeated Verb experiment than in the Baseline experiment. (Younger: Baseline M =98, Rep Verb M= 90; Older: Baseline M = 91, Rep Verb M = 85; Adults: Baseline M = 89, Rep Verb M = 63). We also found an effect of Age Group between the Younger group and adults ($p <.01$) but not between the Older group and adults ($p >.05$) or between the Older group and the Younger group ($p >.05$). There were no significant interactions between Age group and Experiment in the model. See Table 6 for a summary of results).

Experiments	Predictor	Coefficient	SE	Z value	p
Baseline vs. Repeated Verb	Intercept	2.81	0.41	6.83	**<.001**
	Age Group (Older vs. Adults)	1.07	0.65	1.63	.101
	Age Group (Younger vs. Adults)	2.28	0.71	3.21	**<.01**
	Age Group (Older vs. Younger)	-1.21	0.76	-1.59	.110
	Experiment (Repeated Verb vs. Baseline)	-2.10	0.44	-4.68	**<.001**
	Age Group (Older vs. Adults) x Experiment (Repeated Verb vs. Baseline)	0.48	0.71	0.68	.495
	Age Group (Younger vs. Adults) x Experiment (Repeated Verb vs. Baseline)	-2.23	0.77	-0.29	.764
	Age Group (Older vs. Younger) x Experiment (Repeated Verb vs. Baseline)	0.71	0.81	0.87	.381

Table 6. Spanish-speaking participants: Summary of mixed-effects logistic regression models with Age group and Experiment as predictors. Effect of priming between the Baseline experiment and the Repeated Verb experiment.

3.5.3 Interim discussion

In experiment 3 we aimed to seek for evidence of a lexical boost and examine whether lexically-dependent priming effects would accumulate across the experiment. We examined whether the presence of a prime that shared the same verb with the target sentence would influence the interpretation of globally ambiguous sentences during language comprehension in Spanish-speaking children and adults. Since children showed evidence for lexically-independent priming effects in the previous study (Non-repeated verb experiment),

We found that participants showed significant age group differences. That is, in the presence of verb overlap between the prime and target sentence, the number of HA proportions was significantly different between the two child groups and adults indicating that the Younger and Older children were more likely to choose more HA responses than the adults. When comparing the two child groups, a significant difference was also found in the number of their HA responses, that is, the Older group tended to select fewer HA responses than the Younger

group. These patterns and results are similar to the results from our previous experiment, where there was no verb repetition.

We also found a main effect of Prime and an interaction between Prime and Age group. Once we analysed the interaction, the effect of Prime was only reliable in the adults. These results were later confirmed when we removed the adult data to look for developmental patterns and examined only the children's responses. We did not find an effect of Age in Months or an interaction between Prime and Age in Months, that is, younger children were as likely as older children to choose HA responses after a HA prime and LA responses after a LA prime.

When analysing cumulative effects, we found an interaction between Age group and Trials that resulted in a significant effect of Trials only in the Older group. This effect suggested that the 8- to 10-year-old children were more likely to choose fewer HA responses and more LA responses as the experiment progressed.

Evidence for the lexical boost was not found in participants. However, we did find significant differences when analysing the overall effect of priming when comparing the HA responses of the Baseline experiment against the HA responses of the Non-Repeated Verb and the Repeated-verb experiments. That is, participants' overall HA responses significantly decreased when they were exposed to the primes than when they did not receive any exposure to the primes. This reflects that participants were sensitive to the HA and LA primes and that such language experience modulated their attachment preferences to some extent.

The finding that we did not find lexically-dependent priming effects in experiment 3 is very unexpected, especially because children showed priming effects in the absence of verb overlap in experiment 2, thus, children were expected to show priming effects when prime and target shared the same verb in experiment 3. The implications will be discussed in the general discussion.

3.6 General discussion

By using a structural priming paradigm, we aimed to better understand the nature and development of Spanish-speaking children's language representations and the mechanisms involved in structural priming during language comprehension. To do this, we investigated the

role of recent language experience on the HA and LA analyses of PPs in globally ambiguous sentences in 4- to 6- and 8- to 10-year-old Spanish-speaking children and adults. Additionally, we examined to what extent the accumulation of individual language experiences with the HA and LA analyses affected children and adults during comprehension.

In experiment 1 (Baseline condition), we set out to establish Spanish-speaking children and adults' preferences for interpreting ambiguous PPs. We found that Spanish-speaking children and adults showed a strong preference for HA over LA. When children and adults were not exposed to the primes, the proportion of their HA responses differed significantly between the Younger group and the adults, but not between the two child groups and between the Older group and the adults.

In experiment 2 (Non-Repeated Verb), we sought to understand the role of recent language experience better by investigating whether children already showed existing and stable abstract representations of the HA and LA analyses when processing globally ambiguous sentences and whether they were susceptible to cumulative experience of the LA analyses. To do this, we analysed whether the presence of a prime that did not share the same verb as the target sentence would influence the interpretation of globally ambiguous sentences.

The three age groups showed significant differences in their overall PP preferences when being compared against each other, with the two child groups showing significantly more HA responses in comparison to the adults and the Older group showing significantly fewer HA responses than the Younger group. This suggested that the presence of the primes had an effect on the participants' syntactic choices during comprehension. Moreover, the overall PP preferences in the Older children were no longer similar to the adults', as in the Baseline experiment.

The three age groups also showed lexically-independent priming effects and this effect continued to be reliable once the adults' responses were removed from the analyses. This indicated that children and adults were more likely to show a HA response after a HA prime than after a LA prime in the absence of verb overlap. We also found a marginal interaction between Age in Months and Prime in children that may suggest that as children got older, they showed a tendency to select *more* HA responses after a LA prime than after a HA prime. Neither the children nor the adults showed cumulative effects.

Given the significant priming effects in the absence of verb overlap that we found in children and adults in experiment 2 (Non-Repeated verb), in experiment 3 (Repeated-Verb), we sought to look for evidence of the lexical boost and whether participants were susceptible to cumulative effects of experience with the LA analysis when prime and target shared the same verb.

When the verb was shared between the prime and target sentences, the three age groups continued to show significant differences in the proportion of their HA responses when being compared against each other. That is, the two child groups showed significantly more HA responses than the adults, and the Older children showed significantly fewer HA responses than the Younger group. These patterns were the same as the ones we found when there was no verb overlap between the prime and target sentence (i.e., Non-Repeated Verb, experiment 2).

The participants also showed a main effect of Prime and an interaction between Prime and Age group. When analysing the interaction, the effect of Prime was only significant in the adult group. This indicated that only the adults, but not the children, were more likely to choose an HA response after an HA prime than an LA prime when prime and target shared the same verb.

Interestingly, only the Older group showed significant cumulative effects of experience when the verb was shared between the prime and target sentence. That is, after comparing the first and last thirds of the experiment data, the Older children showed an effect of Trials, indicating that, as the experiment progressed, they showed an overall decrease in their HA responses (and therefore an increase in their overall LA responses).

We did not find evidence of a lexical boost when the participants' responses in the absence and presence of verb overlap were compared against each other.

Developmental differences

To better understand the role of recent language experience in the processing of globally ambiguous sentences in Spanish-speaking children and adults, we first examined their PP attachment preferences and their development in the baseline condition.

A strong HA preference was found in the three groups: 4- to 6-year-olds (98%), 8- to 10-year-olds (91%) and adults (89%). Age group differences between the two child groups and between the Older group and the adults were not found. This may suggest that by the age of 8 -10, children's language processing of globally ambiguous sentences (in the baseline condition) may have nearly become adult-like in Spanish. However, the fact that the Younger and the Older groups did not show significant differences in the proportion of their HA responses either, may also suggest that the three age groups may have shown ceiling effects resulting from a strongly fixed HA preference, with the adult group showing slightly more access to the LA analysis than the two child groups. These findings would be consistent with previous research that has found an overall HA preference with ambiguous RCs (NP-PP-RC) in Spanish-speaking adults (e.g., Cuetos & Mitchell, 1988; Carreiras & Clifton Jr., 1993,1999; Aranciba-Gutiérrez et al., 2015).

To address the question about the nature and development of Spanish-speaking children's mental representations of language, we examined the influence of recent language experience on the interpretation of globally ambiguous sentences in the absence and presence of verb overlap between the prime and target sentences. Previous developmental structural priming studies have found how the comprehension or production of a prime can affect the comprehension and production of a subsequent sentence (e.g., Thothathiri & Snedeker, 2008; Gamez et al., 2016; Peter et al., 2015). When priming effects occur in the absence of shared lexical content between the prime and target sentence, this has often been taken as evidence for existing abstract representations of language. If, however, the same verb is repeated between the prime and target sentences, priming effects will be enhanced (lexical boost) due to the activation of the lemma and combinatorial nodes and the strengthened link between these two (Pickering & Branigan, 1998). Evidence of lexically-independent priming effects in young children has been argued to reflect abstract representations of language under early-abstraction accounts (e.g., Bock, 1986; Branigan, Pickering & Cleland, 2000). In contrast, usage-based lexicalist accounts propose that young children's language representations are bound to lexically-specific items and that they gradually develop and become abstract. Hence, they

predict a larger lexical boost in younger children than in older children and adults (e.g., Tomasello, 2000; Savage, Lieven, Theakston, & Tomasello, 2003; Ninio, 2006).

The error-based learning model (Chang, Dell & Bock, 2006) argues that an error-driven implicit learning mechanism is responsible for structural priming effects and cumulative effects of experience. This model suggests that priming effects occur as a result of prediction errors and re-adjustments mechanisms. That is, when processing language, the parser predicts the most frequent structure e.g., active structure, if, however, the parser encounters another structure that does not match the predicted structure e.g., passive structure, this will cause high prediction error (i.e., a strong discrepancy between what is expected and what is actually encountered), this will result in readjusting the parser's structural preferences leading to long-term implicit learning effects. This, in turn, will cause immediate and cumulative lexically-independent priming effects. The lexical boost, on the other hand, is expected to be only short-lived because it does not rely on implicit learning mechanisms, instead it relies on the explicit memory. Thus, because of the underdeveloped children's memory and cognitive skills, children may or may not show a lexical boost**.** Additionally, under this account, it is also argued that for priming effects to occur, individuals should be able to predict the two structures. In other words, priming effects will not occur if individuals do not have existing representations of the two analyses.

If we consider the accounts described above, we may suggest that the results from the current study may be more compatible with early-abstraction accounts. The fact that the children in our study were more likely to choose an HA response after an HA prime than an LA prime in the absence of verb repetition between the prime and target sentences, may suggest that Spanish-speaking children between the ages of 4 and 10 may have stable abstract representations of the HA and LA analyses of globally ambiguous sentences. However, early abstraction accounts also predict that priming effects will occur when prime and target sentences share the same verb, and that the lexical boost should not differ between children and adults. Thus, in order for our results to be supported by early abstraction accounts, children needed to show lexically-dependent- and lexically-independent priming effects with no evidence for a lexical boost in children. This did not happen. In fact, our results are unexpected. It is usually the existence of a lexical boost and its effect size that tends to be controversial in developmental structural priming studies.

But why did the children in our study show reliable lexically-independent priming effects but not lexically-dependent priming effects if verb repetition is supposed to enhance priming effects?

Since the interaction between Experiment and Prime was not statistically significant, we cannot be certain that the lack of verb repetition *did* facilitate prime processing in our study; however, we have considered a plausible explanation as to why we obtained lexically-independent priming effects, but not lexically-dependent priming effects in children. It could be the case that children may not have adopted the LA analysis when processing the LA primes when the prime and target sentences shared the same verb, and instead their preferred analysis (i.e., HA) may have remained activated. Once children processed the target sentence that contained the same verb as the prime sentence, residual activation from the lemma, and combinatorial nodes and the strengthened link between these two gave rise to the adoption of the HA analysis again. Hence, the same mechanisms that create the lexical boost may have led to no priming effects when there was verb overlap between the prime and target sentences, but because children may not have interpreted the LA primes with an LA attached interpretation, but rather with an HA interpretation.

Assuming this plausible explanation were true, why would the absence of verb repetition have caused priming effects? We suggest that processing a structure that was not lexically-associated with the prime sentence may have forced children to construct new representations for the interpretation of the ambiguous sentences resulting in more opportunities to adopt an LA analysis and therefore improve the probabilities of selecting an LA interpretation for the target trials.

If we suggest that the children in our study were not able to adopt the LA analysis, then why did they choose the correct picture in the LA prime trials?

We considered the possibility that the children in our study may have solely based their answers on selecting the picture that depicted the entities that they heard. For example, in the LA prime trial e.g., *The girl is pushing the teacher with the ball*, it is possible that children selected the correct picture because they based their answers on the words they heard i.e., *girl, teacher* and *ball*. However, if we consider the accuracy of the filler trials, this explanation may be unlikely since the children in our study showed a filler trial accuracy between 97% and 99%. This shows that children were attentive and worked out the syntax of the sentences in the task. In particular, we refer to a set of filler trials that had the agent and the patient reversed (e.g., *The queen is kissing the teacher* vs. *The teacher is kissing the queen*). Therefore, in order to be

able to answer these filler trials correctly, children had to work out the syntax accordingly. Future research should investigate whether similar patterns to the ones in our study may result from forced-choice picture selection tasks for the comprehension of globally ambiguous sentences in the presence of priming in Spanish-speaking children.

Havron et al. (2020) also used a forced-choice picture selection task with French-speaking children, however, on prime trials, one picture corresponded to one of the two analyses (HA vs. LA depending on the condition) and the incorrect picture depicted the same two entities as the correct picture but with a different action. For example, for the prime sentence *The girl is tickling the baby with the brush*, there was a picture that depicted a baby with a brush being tickled by a girl (correct LA analysis), while the incorrect picture showed a baby using a brush to paint while being observed by a girl. Showing participants pictures in which, they focus on the action rather than on the objects/modifiers (e.g., brush), may force children to pay more attention to the structures and to increase their probabilities of adopting a LA analysis.

Another possible explanation as to why children may not have been able to adopt the LA analysis, is that children may have received help from their parents. However, this may be unlikely because parents were reminded not to influence their children's answers and only offer their help with the setting of the task or with internet-related issues if needed. However, because this was an online task and the experimenter did not observe children while doing the task, we do not know for sure how the parents' influence may have affected children's responses.

The fact that the children in our study showed evidence of priming effects in the absence of verb repetition between prime and target sentences does not suggest that they have abstract and stable representations of the LA analysis. If anything, based on our results, we believe that the representation of the HA analysis may be strongly fixed in Spanish-speaking children, whereas the representation of their LA analysis may still be weakly represented and fragile. Future research with 4- to 10-year-old Spanish-speaking children should investigate whether the comprehension of this type of ambiguity in the presence of priming shows similar results as the participants in our study.

Our results may also be compatible with the error-based learning model that predicts that in order for priming effects to occur, participants should have already existing representations of the HA and LA analyses so they can be able to predict them. Thus, the fact

that the participants in our study showed a main effect of prime, but only the adults showed a reliable priming effect in the presence of verb repetition between prime and target sentences, this may suggest that the children's representations of the LA analysis are still weakly represented, and because of this, children had difficulties predicting the LA analysis.

Our findings suggest that even by the age of 10, Spanish-speaking children have not yet developed an adult-like language processing system, as evidence of the differences we found in the way they process globally ambiguous sentences in the presence of a prime in comparison to the adults.

At this point, it is unclear when Spanish-speaking children start to show reliable evidence of abstract representations of the LA analysis for globally ambiguous sentences. Research in the field of language acquisition has provided findings indicating that very young children are sensitive to the distributional patterns present in the input they receive (Saffran, Newport & Aslin, 1996; Hudson & Newport, 2003). That is, children are able to track verb-specific and verb-general statistics, relying on these sources of information to facilitate the behaviour of verbs. In fact, previous studies have found, how children as young as five, often rely on bottom-up information, such as their understanding of lexico-syntactic and semantic knowledge of familiar verbs (e.g., lexical biases), rather than on top-down cues such as referential context information to influence their parsing commitments (Snedeker & Trueswell, 2004; Kidd et al., 2010; Trueswell et al., 1999). Moreover, once children have committed to an initial parse, they are less likely to revise it than adults are, even if other extra-linguistic cues are available (Kidd & Bavin, 2005; Kidd, Stewart & Serratrice, 2011). Such verb biases can lead children to exhibit preferences for one interpretation of an ambiguous sentence over another. Therefore, we believe that the prevalence of instrumental verbs used in our task (*pat, push, poke, move, touch, and tickle*), favoured the HA interpretation of the ambiguous PP respectively resulting in participants showing a pronounced inclination towards the HA analysis when interpreting the globally ambiguous sentences in our study.

Future research should investigate at what age Spanish-speaking children start to show adult-like language processing mechanisms, that is, at what age Spanish-speaking children no longer show differences with the adults in the way they process globally ambiguous sentences with and without the influence of the primes. Moreover, it is essential that researchers incorporate a wide range of modifier-biased verbs or only equi-biased verbs in the primes and target pairs to better capture the influence of structural priming on the development of children's syntactic representations of PP attachment ambiguities.

Cumulative Priming

To analyse to what extent the presence of the primes had affected the syntactic choices of Spanish-speaking children and adults during language comprehension, we compared the overall proportion of HA responses of the baseline condition against the overall proportion of HA responses of the priming experiments (i.e., Baseline vs. Non-Repeated Verb experiment; Baseline vs. Repeated-Verb experiment).

We found a strong effect of Experiment in both analyses, suggesting that participants were more likely to select HA responses in the baseline condition than in a context when they experienced frequent and equal mixed exposure to HA and LA primes irrespective of verb overlap. These effects suggest that Spanish-speaking participants were susceptible to the language input to which they were exposed reflecting changes in their PP attachment preferences to some degree. This may also be supported by the fact that in the Baseline experiment, the proportion of the HA responses in the Older group did not differ from the Younger group's and the adults'. However, when the three age groups were exposed to the prime condition, irrespective of whether there was verb repetition between the prime and target sentence, the three age groups showed significant differences in their overall PP preferences against each other.

To examine cumulative effects of experience directly, we analysed the first and last thirds of the three experiments and examined whether there was an effect of Trials and Prime and the interaction between these two. We only found an effect of Trials in the Older group when prime and target sentence shared the same verb (Repeated Verb experiment), indicating that as the experiment progressed, the Older children were less likely to choose an HA response and therefore more likely to choose an LA response. This may suggest that although the two child groups did not show immediate lexically-dependent priming effects, the Older group showed evidence of sensitivity to the primes reflecting that the accumulation of individual experiences of the LA analysis across the experiment led to some gradual changes in their PP attachment preferences.

3.7 Conclusion

By using a structural priming paradigm, we aimed to better understand the nature and development of Spanish-speaking children's language representations and the mechanisms involved in structural priming during language comprehension. To do this, we investigated the role of recent language experience on the HA and LA analyses of PPs in globally ambiguous sentences in 4- to 6- and 8- to 10-year-old Spanish-speaking children and adults. Additionally, we examined whether the accumulation of individual language experiences with the HA and LA analyses of globally ambiguous sentences affected children's and adults' PP attachment preferences.

At a trial level, we found a reliable main effect of Prime in the absence and presence of verb overlap between prime and target pairs, however, only the adults, not the children, showed a reliable effect of Prime when the verb was repeated between prime and target pairs. Moreover, only the 8- to 10-year-olds showed a cumulative effect of experience when there was verb repetition between prime and target sentence, by showing a decrease in their HA responses as the experiment progressed.

This is the first structural priming study that examines the influence of recent language experience in globally ambiguous sentences during language comprehension in 4- to 6- and 8- to 10-year-old Spanish-speaking children. Although we found unexpected structural priming effects in children, our results still provide evidence that Spanish-speaking children and adults showed sensitivity to the HA and LA primes, reflecting changes in the PP attachment preferences. Future structural priming research will have to investigate whether the same patterns that we found in our study can be replicated in Spanish-speaking populations.

4 Cross-linguistic differences between English and Spanish: Priming Prepositional-Phrase attachment ambiguities during language comprehension in children and adults

Two intriguing questions have been whether parsing strategies for sentence comprehension are universal or language-specific and whether the parser may be affected in the same way by language experience across languages. Two universal parsing principles, *Minimal Attachment* and *Late Closure* have been proposed under the Garden-Path model (e.g., Frazier & Fodor, 1978). Minimal attachment refers to when the parser selects the simplest analysis with the fewest nodes when processing a syntactic ambiguity. In contrast, Late Closure, refers to when the parser attaches new incoming information to the phrase or clause that is currently being processed so the parser does not overload. The universality of these two principles was questioned when Cuetos and Mitchell (1988) tested Spanish-speaking participants' attachment preferences for relative clause (RC) ambiguities (e.g., English: *The daughter of the colonel who was standing on the balcony;* Spanish: *La hija del coronel que estaba en el balcón*) and noticed a strong preference for high-attachment (HA) rather than low-attachment (LA). That is, based on the Late Closure principle, the ambiguous RC (*who was standing on the balcony*) should be attached to the second noun phrase (NP) (*the colonel)* rather than the first NP (*the daughter).*

After this, several studies tested attachment preferences for RC ambiguities in different languages other than English and confirmed such variability (e.g., Mitchell, Cuetos & Zagar, 1990; Hemforth, Konieczny, Scheepers, & Strube, 1998; Brysbaert & Mitchell, 1996). The differences in attachment preferences across languages have been subject to a lot of debate over the last decades. While some studies have reported a LA preference in English, Italian, European Portuguese, Romanian, (Fernández, 1999; Carreiras & Clifton Jr., 1999; Bergmann, Armstrong, & Maday, 2008; De Vincenzi & Job, 1993; Ehrlich, Fernández, Fodor, Stenshoel, & Vinereanu, 1999), others have found a consistent HA preference in Spanish, Galician, French, German, Dutch (Dussias, 2003; Fraga, García-Orza & Acuña, 2005; Cuetos & Mitchell, 1988; Carreiras & Clifton Jr., 1999; Aranciba-Gutiérrez, Bizama Muñoz, Sáez

Carrillo, 2015; Hemforth et al., 1998; Brysbaert & Mitchell, 1996; Mitchell, Cuetos & Zagar, 1990). However, previous studies have found mixed results within the same language (De Vincenzi & Job, 1993; Baccino et al., 2000; Hemforth, Fernandez, Clifton, Frazier, Konieczny & Walter, 2015). Such mixed evidence has been argued to be attributable to differences in the methodologies employed in the studies e.g., offline vs. online tasks, written vs. aural stimuli, prosodic breaks, differences in the prepositions of the structures e.g., *of* vs. *with*, etc (Goad, Brambatti Guzzo & White, 2021; De Vincenzi & Job, 1993; Baccino, De Vincenzi & Job, 2000). Thus, the question as to why people seem to prefer a particular analysis over another is still unanswered.

As mentioned above, attachment ambiguities have been shown to have different cross-linguistic preferences between English- and -Spanish-speaking adults, however, to our knowledge, there are no studies that have directly examined cross-linguistic comparisons of PP attachment preferences in the absence and presence of a prime in children at earlier and later stages of development, and adults. Based on our previous findings from Studies 1 and 2 (Chapters, 2 and 3), we have found that English- and Spanish-speaking children and adults showed a preference for HA. However, we do not know whether the strength of the HA preference may differ significantly between the English- and Spanish-speaking participants of Studies 1 and 2. The current study addressed this question.

4.1 Introduction

Psycholinguistics researchers have attempted to address the question as to why people differ in their attachment preferences by proposing several accounts. One of them is the Tuning Hypothesis (e.g., Mitchell & Cuetos, 1991a; Cuetos, Mitchell, & Corley, 1996), which suggests that rather than having universal parsing strategies, the parser will choose an analysis based on its prior linguistic experience. That is, the decisions made by the parser from previous encounters with a particular syntactic ambiguity will guide the resolution when encountering the same kind of ambiguity in the future. Thus, the resolution of a syntactic ambiguity will be determined by prior exposure to the same structural ambiguities and the way they were resolved at that time. Resolution mechanisms may vary and adjust if the parser encounters new ambiguities and opts for new resolutions. If this is the case, the likelihood of choosing that new solution when encountering the same kind of syntactic ambiguity in the future will increase.

Therefore, attachment preferences will arise from an experience-based mechanism that will be driven by the statistical properties of the syntactic ambiguity in the language in question. (See Chapter 1, section 1.3.3 for a detailed description of this hypothesis).

The Tuning hypothesis highlights how extensive exposure to linguistic interpretations can shape individuals' attachment preferences. Another way to study the role of language experience in ambiguity resolution is by using a structural priming paradigm. Structural priming allows researchers to manipulate the language input and investigate how our syntactic choices may be affected. By studying structural priming effects, we can better understand how individuals represent language, the nature of such representations and the mechanisms involved that give rise to priming effects, which are argued to be linked with language acquisition.

Structural priming refers to an unconscious process whereby the processing of a particular structure (i.e., prime sentence) facilitates the processing of a subsequent structure (i.e., target sentence) (e.g., Branigan & Pickering, 2017). Evidence for existing abstract representations has been taken when priming effects occur in the absence of shared lexical content (e.g., verbs or nouns) between the prime and target sentence. Priming effects, however, may also be enhanced when there is lexical overlap between prime and target pairs (i.e., the lexical boost) (Pickering & Branigan, 1998).

The residual activation account (Pickering & Branigan, 1998) explains priming effects with a single and short-lived mechanism within the lemma stratum, whereby lexically-independent priming effects result from the residual activation of combinatorial nodes. Enhanced priming effects (lexical boost), on the other hand, will result from the activation of the lemma e.g., *give*, the e.g., NP,NP combinatorial node and the strengthened activation of these two. (See Chapter 1, section 1.4 for a detailed description of this account).

An error-driven implicit learning mechanism (e.g., Chang, Dell & Bock, 2006) has also been proposed to be responsible for priming effects under error-based learning accounts. Chang et al. suggest that learning takes place when the parser encounters a structure that does not match the predicted or expected structure (i.e., prediction error) leading the parser to adjust its weights on the structures to better predict the input. Enhanced priming effects, however, result from the explicit memory. Thus, the lexical boost will arise in adults but may or may not arise in young children, since their explicit memory skills are still underdeveloped. (See Chapter 1, section 1.4 for a detailed description of this account).

The current study

Differences in attachment preferences of RCs in many languages have been widely discussed for several years. They have been mostly studied in (bilingual) adults and by language without addressing cross-linguistic differences directly (Aranciba-Gutiérrez et al., 2015; Dussias & Sagarra, 2007; Felser, Marinis & Clahsen, 2003; Jegerski, Keating & VanPatten, 2016; De Vincenzi & Job, 1993). However, to our knowledge, there are no studies that have directly examined developmental cross-linguistic comparisons of PP attachment preferences in the absence and presence of a prime in children between the ages of 4 and 10. Therefore, the current study is aimed at investigating whether the English- and -Spanish-speaking participants of Studies 1 and 2 showed cross-linguistic differences in their PP preferences of globally ambiguous sentences.

We did not collect any further data or run any experiments for this study, instead we conducted analyses that made cross-linguistic comparisons between the data we had already collected for Study 1 (English-speaking participants, Chapter 2) and for Study 2 (Spanish-speaking participants, Chapter 3).

To examine cross-linguistic differences in PP attachment preferences, we first compared English- and Spanish-speaking children and adults in terms of how they interpreted globally ambiguous sentences in the baseline condition. We combined and analysed the data from the baseline experiments from Chapters 2 and 3 and examined whether the proportions of HA and LA responses differed between the two languages and across age groups.

In the next analysis, we combined and analysed the data from the experiments in the absence and presence of verb repetition between prime and experimental sentences from Chapters 2 and 3. We focused on analysing whether there were any differences in the priming effect and in the proportions of the HA responses between the two languages and across age groups when participants received frequent and mixed exposure to HA and LA primes.

In the baseline condition, Spanish-speaking adults were predicted to show a stronger preference for HA than LA in comparison to the English-speaking adults. This would be in line with previous research that has found an overall preference for HA in Spanish but in RC ambiguities (Cuetos & Mitchell, 1988; Carreiras & Clifton Jr., 1999). We are not sure whether

relevant differences may arise between English- and Spanish-speaking children, as there are no studies that have directly analysed cross-linguistic differences in PP attachment ambiguities in children who speak these two languages. However, based on previous studies that examine RC attachment preferences in English- and -Spanish-speaking adults (Cuetos & Mitchell, 1988; Carreiras & Clifton Jr., 1993; Carreiras & Clifton Jr., 1999; Aranciba-Gutiérrez et al., 2015), we predicted that Spanish-speaking children would show a stronger preference for HA in the baseline experiment than English-speaking children.

In the presence of a prime, English- and Spanish-speaking children and adults were predicted to be sensitive to the HA and LA primes in a similar way, however, since the HA analysis may be more strongly fixed in Spanish than in English, native speakers of Spanish might show weaker priming effects than the English-speaking participants.

4.2 Are there cross-linguistic differences in Baseline PP attachment preferences between Spanish- and English-speaking children and adults?

4.2.1 Methods

To investigate cross-linguistic differences in how Spanish- and English-speaking children and adults interpreted globally ambiguous sentences in the absence of a prime, we combined and analysed the data of the Baseline experiments from Chapters 2 and 3 (Experiments 1 and 4). For this study, we did not collect any new data, we only compared the Baseline experiments data of the English-speaking participants against the Baseline experiments data of the Spanish-speaking participants.

Participants

Combining the data of the Spanish- and -English-speaking participants from the Baseline experiments in Chapters 2 and 3, gave a total of 132 participants, of whom 65 were Spanish-speaking and 67 English-speaking. There were 40 native Spanish-speaking children (twenty 4- to 6-year-olds, mean age 5;5, 7 female, 13 male; twenty 8- to 10-year-old children, mean age 9;2, 12 female, 8 male), 47 native English-speaking children (twenty-seven 4- to 6-year-olds, mean age 5;8, 16 female, 11 male; twenty 8- to 10-year-old children, mean age 9;4, 8 female, 12 male), 25 adult native speakers of Spanish (aged 19 to 25; mean age 21, 14 female,

11 male) and 20 adult native speakers of English (18 to 27, mean age 20, 15 female, 5 male). We will refer to the 4- to 6-year-olds as the Younger group and the 8- to 10-year-olds as the Older group. Spanish-speaking children were recruited through social media groups for parents in Mexico, and the Spanish-speaking adults were recruited from the Anahuac University (North campus) Mexico. English-speaking children were recruited through social media groups for parents in the UK and through the Developmental Lab Facebook webpage from the University of Edinburgh. All the English-speaking adults were recruited from the University of Edinburgh.

Design

We used a 3 x 2 mixed design with Age Group (Adults vs. Older vs. Younger) and Language (Spanish vs. English) as between-participants factors.

Materials and Procedure

To conduct these analyses, no data were collected for this study. Instead, we made cross-linguistic comparisons between the data of the Baseline experiments between the English-and Spanish-speaking participants from Studies 1 and 2. (See Chapters 2 and 3, Experiment 1, for a detailed description of the materials and procedure).

Scoring and Data analysis

Once the datasets from the English- and Spanish-speaking participants were combined, our outcome variable was the responses to the experimental items. HA responses were coded as 1 and LA responses were coded as 0. Mixed-effects logistic regression models were built to analyse the data, which can be thought of as obtaining the probability (in log-odds) of choosing either a HA or a LA response (Jaeger, 2008). We analysed the data in the R programming environment (R version 3.5.2) and used the lme4 package and the glmer function to run the models. To construct the models, we started with a maximal random-effects structure, as suggested by Barr, Levy, Scheepers & Tily (2013). Our predictors were Age Group as a three-level categorical variable: Adults, Younger (4- to -6-year-old) and Older (8- to 10-year-old); and Language as a two-level categorical variable (Spanish and English). For the random-effect structure, we used the participants and items parameters as random intercepts and Language as a random slope if the model fit was significantly improved. Log-likelihood ratio tests were used to compare the models and the final model was the one that resulted in the best model fit

and could converge. For Age Group comparisons, the probability of HA responses for the adult group is represented in the intercept. The Age Group predictor was later relevelled so the intercept represented the probability of HA responses for the Younger group when comparing the two child groups against each other. Positive coefficients show that the HA responses were more likely to occur in the tested level of the predictor than the other.

4.2.2 Results

To test for cross-linguistic differences in Spanish- and -English-speaking children's and adults' baseline preferences for interpreting ambiguous PPs in the absence of a prime, we used the binomial outcome variable HA responses (with HA responses coded as 1, and LA responses coded as 0) and Language and Age Group as predictors. The random-effect structure of the best-fitting model involved participants and items as random intercepts with Language as a random slope. Figure 1 contains a summary of the participants' HA responses by age group and language. Table 1 shows a summary of results of Language and Age Group comparisons.

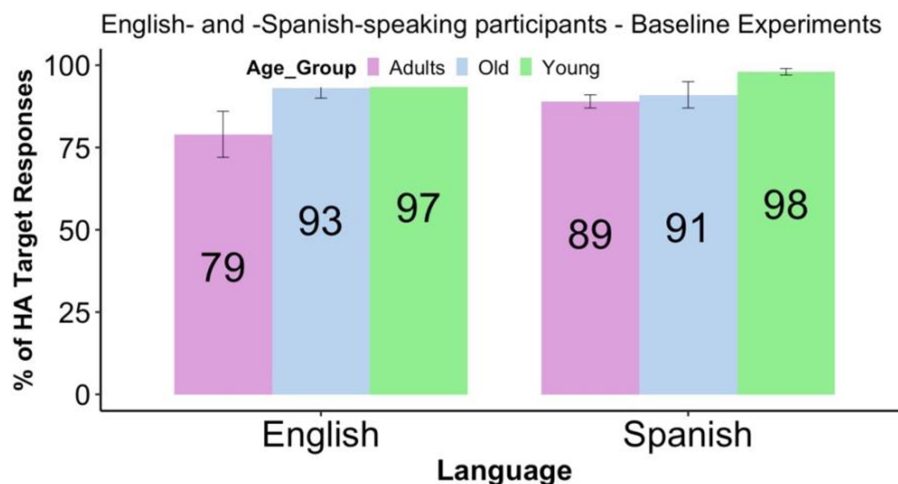

Figure 1. English- and Spanish-speaking participants: Proportion of HA responses by age group and language: Baseline experiments.

As shown in Figure 1, in the baseline condition, both Spanish- and -English-speaking children and adults have an overall preference for the HA analysis. We did not find a main

effect of Language. That is, Spanish and English-speaking participants did not differ in the number of their HA responses when being compared against each other. We only found an effect of Age Group between the Younger group and the adults ($p < .01$) and between the Older children and the adults ($p < .05$), suggesting that both the Younger and the Older Spanish- and -English-speaking children were more likely to choose HA responses than the adults. We found no significant interactions between Language and Age Group.

Experiments	Predictor	Coefficient	SE	Z value	p
Baseline experiments Cross-linguistic differences: Spanish vs. English	Intercept (English, Adults, HA, Young*)	2.63	0.61	4.28	**<.001**
	Language (Spanish vs. English)	0.32	0.73	0.44	.658
	Age Group (Young vs. Adults)	2.10	0.79	2.65	**<.01**
	Age Group (Old vs. Adults)	2.00	0.87	2.28	**<.05**
	Age Group (Old vs. Young*)	-0.09	0.85	-0.11	.909
	Language x Age Group (Young vs. Adults)	0.27	1.08	0.25	.800
	Language x Age Group (Old vs. Adults)	-0.88	1.11	-0.79	.425
	Language x Age Group (Old vs. Young*)	-1.15	1.16	-0.99	.319

Table 1. Cross-linguistic differences (Spanish vs. English) - Baseline experiments: Summary of mixed-effects logistic regression models with Language and Age Group as predictors

4.3 Are there cross-linguistic differences in priming effects between Spanish- and English-speaking children and adults?

4.3.1 Methods

To investigate cross-linguistic differences in how Spanish- and- English- speaking children and adults interpreted globally ambiguous sentences when exposed to HA and LA primes, we combined and analysed the data of the Non-Repeated Verb and Repeated Verb experiments from Chapters 2 and 3. We did not collect any new data, we only compared the data of the experiments in the presence of a prime (Non-Repeated Verb and Repeated Verb) from the English-speaking participants against the data of the experiments (Non-Repeated Verb and Repeated Verb) from the Spanish-speaking participants.

Participants

Combining the data for the Spanish- and -English-speaking participants from the Non-Repeated Verb and Repeated Verb experiments in Chapters 2 and 3, gave a total of 600 participants, of whom 300 were Spanish-speaking and 300 English-speaking. There were 200 native Spanish-speaking children (n =100, 4- to 6-year-olds, mean age 5;5, 50 female, 50 male; n =100, 8- to 10-year-old children, mean age 9;4, 48 female, 52 male), 200 native English-speaking children (n =100, 4- to 6-year-olds, mean age 5;6, 47 female, 53 male; n =100, 8- to 10-year-old children, mean age 9;1, 58 female, 42 male), 100 adult native speakers of Spanish (aged 18 to 29; mean age 20,) and 100 adult native speakers of English (aged 18 to 34, mean age 21).

All the Spanish-speaking participants resided in Mexico and had lived in Mexico most of their life. Spanish-speaking children were recruited through social media groups for parents in Mexico, and the adults were recruited from the Anahuac University (North campus) Mexico. English-speaking children were recruited through social media groups for parents in the UK and through the Developmental Lab Facebook webpage from the University of Edinburgh, and the adults were recruited from the University of Edinburgh.

Design

We used a 3 x 2 x 2 mixed design with Age Group (Adults vs. Older vs. Younger) and Language (Spanish vs. English) as between-participants factors and Prime condition (HA vs. LA) as a within-participants and -items factor.

Materials and Procedure

To conduct these analyses, no data were collected for this study. Instead, we made cross-linguistic comparisons of the data of the priming between English-and Spanish-speaking participants from Studies 1 and 2. In particular, we compared the data of the priming experiments (Non-Repeated Verb and Repeated Verb combined) from the English-speaking participants against the data of the priming experiments (Non-Repeated Verb and Repeated Verb combined) from the Spanish-speaking participants. (See Chapters 2 and 3, Experiments 2 and 3, for a detailed description of the materials and procedure).

Scoring and Data analysis

We followed the same Scoring and Data analysis procedures as in the previous section. Our predictors were Age Group as a three-level categorical variable: Adults, Younger (4- to 6-year-old) and Older (8- to 10-year-old), Language as a two-level categorical variable (Spanish and English) and Prime as a two-level categorical variable (HA, LA). For the random-effect structure, we used the participants and items parameters as random intercepts and Language as a random slope if the model fit was significantly improved. Log-likelihood ratio tests were used to compare the models and the final models were those that resulted in the best model fit and could converge. While constructing the first models, Experiment Type had also been included as a predictor, however, the models did not converge. Since we did not find significant differences between the Non-repeated Verb and Repeated Verb experiments in English- and Spanish-speaking children and adults from Chapters 2 and 3 i.e., we did not find evidence for a lexical boost, we decided to remove Experiment Type as a predictor for this analysis. For Age Group comparisons, the probability of HA responses for the adult group is represented in the intercept. The Age Group predictor was later relevelled so the intercept represented the probability of HA responses for the Younger group when comparing the two child groups against each other. Positive coefficients show that the HA responses were more likely to occur in the tested level of the predictor than the other.

4.3.2 Results

To analyse Spanish- and English-speaking children and adults' cross-linguistic differences in their preferences for interpreting ambiguous PPs in the presence of HA and LA primes, we used the binomial outcome variable HA responses (with HA responses coded as 1, and LA responses coded as 0), and Language, Age Group and Prime type as predictors. The random-effect structure of the best-fitting model involved participants and items as random intercepts with Language as a random slope. Figure 2 contains a summary of the participants' HA responses by Language, Age Group and Prime. Table 2 shows a summary of the results by Language, Age Group and Prime comparisons.

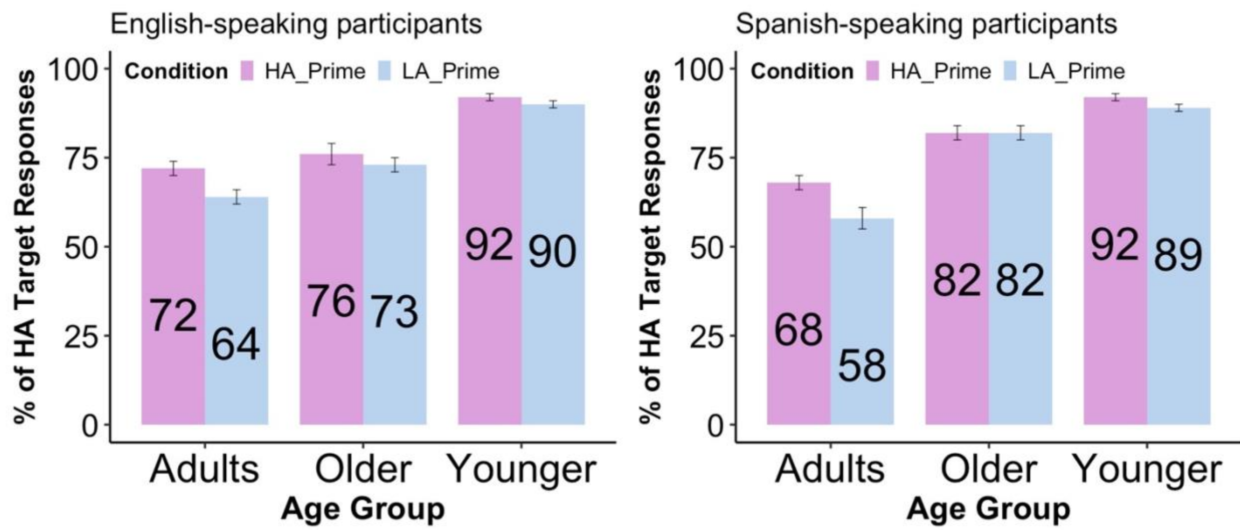

Figure 2. English- and Spanish-speaking participants: Proportion of HA responses by Language, Age Group and Prime: Non-Repeated Verb and Repeated Verb experiments (Combined).

	Experiments	Predictor	Coefficient	SE	Z value	p
Cross-linguistic differences Spanish vs. English	Non-repeated verb and Repeated Verb experiments Spanish vs. English	Intercept (English, Adults, HA, Young*)	1.29	0.18	7.09	**<.001**
		Language (Spanish vs. English)	-0.26	0.22	-1.15	.248
		Age Group (Old vs. Adults)	0.39	0.23	1.72	.085
		Age Group (Young vs. Adults)	1.86	0.24	7.52	**<.001**
		Age Group (Old vs. Young*)	-1.46	0.25	-5.85	**<.001**
		Prime (LA vs. HA)	-0.49	0.09	-5.06	**<.001**
		Language x Age Group (Old vs. Adults)	0.77	0.32	2.36	**<.05**
		Language x Age Group (Young vs. Adults)	0.28	0.34	0.81	.414
		Language x Age Group (Old vs. Young*)	0.49	0.35	1.37	.168
		Language x Prime (LA vs. HA)	-0.03	0.13	-0.23	.168
		Age Group (Old vs. Adults) x Prime (LA vs. HA)	0.23	0.14	1.61	.106
		Age Group (Young vs. Adults) x Prime (LA vs. HA)	0.28	0.18	1.60	.108
		Age Group (Old vs. Young*) x Prime (LA vs. HA)	-0.05	0.18	-0.27	.781
		Language x Age Group (Old vs. Adults) x Prime (LA vs. HA)	0.29	0.21	1.39	.161
		Language x Age Group (Young vs. Adults) x Prime (LA vs. HA)	-0.22	0.25	-0.87	.379
		Language x Age Group (Old vs. Young*) x Prime (LA vs. HA)	0.52	0.26	1.95	**.050**
	Adults	Intercept	1.27	0.17	7.13	**<.001**
		Language (Spanish vs. English)	-0.23	0.20	-1.14	.251
		Prime (LA vs. HA)	-0.49	0.09	-5.04	**<.001**
		Language x Prime (LA vs. HA)	-0.03	0.13	-0.25	.803
	Old	Intercept	1.77	0.21	8.24	**<.001**
		Language (Spanish vs. English)	0.57	0.28	2.01	**<.05**
		Prime (LA vs. HA)	-0.27	0.11	-2.47	**<.05**
		Language x Prime (LA vs. HA)	0.26	0.16	1.63	.102
	Young	Intercept	3.09	0.21	14.55	**<.001**
		Language (Spanish vs. English)	-0.06	0.28	-0.23	.813
		Prime (LA vs. HA)	-0.22	0.15	-1.42	.155
		Language x Prime (LA vs. HA)	-0.22	0.21	-1.02	.304

Table 2. Cross-linguistic differences – Non-Repeated Verb and Repeated Verb experiments (combined): Summary of mixed-effects logistic regression models with Language, Age Group and Prime as predictors (Spanish vs. English)

As shown in Table 2, when participants were exposed to HA and LA primes, we found a main effect of Prime ($p <.001$), indicating that when both languages and all age groups were considered together, participants were more likely to choose HA responses after an HA prime than after an LA prime. We also found an effect of Age Group between Younger children and adults ($p <.001$) and between the Older and the Younger children ($p <.001$) suggesting that overall, the Younger children chose more HA responses than the Older children and than the adults. We did not find a main effect of Language. However, we found an interaction between Language and Age Group (Old vs. Adults) ($p <.05$) and a marginal interaction between Language, Age Group (Old vs. Young) and Prime ($p = .050$).

To unpack these interactions, we examined the effects of Language and Prime for each age group separately. The adult group showed an effect of Prime ($p < .001$) and no interaction between Prime and Language, suggesting that Spanish- and -English-speaking adults were more likely to choose an HA response after an HA prime than after an LA prime. The Older children also showed an effect of Prime ($p < .05$), suggesting that Spanish- and -English-speaking older children chose more HA responses after an HA prime than after an LA prime. Additionally, they also showed an effect of Language ($p < .05$) indicating that the Older Spanish-speaking children were likely to choose more HA responses in comparison to the Older English-speaking children (Older Spanish $M = 82$; Older English $M = 74$). No interactions between Prime and Language were found in the Older children. The Younger children showed no effects of Language or Prime.

4.4 General discussion

The current study investigated cross-linguistic differences in the interpretation of globally ambiguous PP sentences in the absence and presence of HA and LA primes between English- and -Spanish-speaking children (4- to 6 and 8- to 10-year-olds) and adults.

To analyse cross-linguistic differences in the baseline condition, we examined and compared the combined data of the Baseline experiments of English- and Spanish-speaking children and adults from Chapters 2 and 3. Overall, we found a strong preference for HA that slightly decreased with age in both English- and Spanish-speaking participants. We did not

find a main effect of Language or and interaction between Language and Age Group. This suggests that when processing globally ambiguous sentences in the baseline condition (e.g., *The girl is touching the dog with the banana*), the preferred analysis for English- and Spanish speaking children and adults was HA with no significant differences in the proportion of their HA responses irrespective of language. These results are somewhat unexpected given the strong preference for HA (in ambiguous RCs) in Spanish and the slight preference for LA (in ambiguous RCs) in English that have been reported in previous studies (e.g., Cuetos & Mitchell, 1988; Carreiras & Clifton Jr., 1999). On the other hand, the fact that no differences were found in the proportion of the participants' PP attachment preferences for this kind of ambiguity may also support some studies that have found mixed results within the same language or when the syntactic ambiguities involved different prepositions e.g., *with* instead of *of* (De Vincenzi & Job, 1993; Baccino et al., 2000; Hemforth, Fernandez, Clifton, Frazier, Konieczny & Walter, 2015). Future research should further investigate whether the processing of syntactic ambiguities that include the preposition *with* differ in English and Spanish and if the patterns we found may be replicated in other languages.

The second analysis examined cross-linguistic differences in how recent language experience with HA and LA primes influenced the interpretation of globally ambiguous sentences in English and Spanish.

We continued to find the same pattern as in the baseline experiments, that is, for both English- and Spanish-speaking participants, there was a preference for HA responses and the number of HA responses decreased with age. Our model did not reveal a main effect of Language. This suggests that the proportion of HA responses for the English-speaking participants overall did not differ from those for the Spanish-speaking participants, when there was exposure to primes. However, Language interacted with Age Group, and with Age Group and Prime. When we unpacked these interactions by analysing the effects of Language and Prime in each age group separately, we found a significant effect of Language in the Older children that suggested that the Older Spanish-speaking children chose more HA responses in comparison to the Older English-speaking children. No effect of Language or an interaction between Language and Prime was found in the adult and Younger groups.

These findings may suggest that after manipulating the language input with frequent and mixed exposure to HA and LA primes, the Older English-speaking children in our study were more sensitive to the exposure to the LA primes, and therefore more accepting of the LA

analysis than the Older Spanish-speaking children. It may seem as if, at this point in their development, the Older Spanish-speaking children continued to show a strong HA preference even after being exposed to the primes, while the Older English-speaking children started to have access to the LA analysis more easily leading to an increase in the number of their LA responses and a decrease in the number of their HA responses. This cross-linguistic difference and developmental pattern is interesting as it may reflect how, exposure to the HA and LA analyses, between the ages of 4 and 6, English-and Spanish-speaking children do not seem to differ in their attachment preferences, however, by the time children are 8-10 years of age, the number of the HA responses in Spanish-speaking children has decreased, but not to the same extent as in the English-speaking children of this age range.

This pattern may suggest that, in English, by the age of 8 to 10, access to the LA analysis has become easier than in Spanish. However, by the time native speakers of Spanish reach adulthood, they show the same sensitivity to the LA primes as their English-speaking adult counterparts. The age at which Spanish-speaking children, or possibly adolescents, no longer show differences in the proportion of their HA responses compared to their English-speaking counterparts is still unknown and requires further research. Moreover, it would be useful if researchers could design a task that measures, not binary attachment preferences, but the levels or degrees of acceptance of one analysis over another. This kind of task may be more suitable to test cross-linguistic differences in attachment preferences between English and Spanish.

4.5 Conclusion

The current study examined cross-linguistic differences in attachment preferences for globally ambiguous sentences in English- and -Spanish-speaking children (4- to 6-and 8- to 10-year-olds) and adults in the absence and presence of priming.

We found that, when no prime was presented, English- and -Spanish-speaking children and adults processed globally ambiguous sentences in a similar way. While the 4- to 6-year-olds and the adult English-speaking participants seemed to show the same sensitivity to the HA and LA primes as their Spanish-speaking counterparts, the 8- to 10-year-old English-speaking children tended to choose fewer HA responses (and more LA responses) than the 8- to 10-year-old Spanish-speaking group. We suggest that by the age of 8, there may be easier access to the

LA analysis for globally ambiguous PP sentences in English than in Spanish. However, when native speakers of English and Spanish reach adulthood, recent language experience influences their interpretation of globally ambiguous PP sentences to the same extent.

5 Priming temporarily ambiguous sentences in language comprehension: evidence from the visual-world paradigm

5.1 Introduction

Research on sentence comprehension in adults has found that the adult parser starts processing language by building linguistic representations incrementally as the sentence unfolds and, on a moment-to-moment basis (e.g., Altmann & Steedman, 1988; MacDonald, Pearlmutter & Seidenberg, 1994; Woodard, Pozzan & Trueswell, 2016; Pozzan & Trueswell 2015). However, during language comprehension, the parser may occasionally misunderstand a sentence resulting in the need to employ other mechanisms so a new analysis can disambiguate the structure. When this happens, this is often referred to as the *garden-path effect*. For example, the parser may temporarily misanalyse the prepositional phrase (PP) (*on the sock*) upon hearing the sentence e.g., (1) '*Put the duck on the sock on the star*' and interpret it as a goal of the verb (*Put*) rather than as a modifier of the noun phrase (NP) (*the duck*). Once the parser realises that such interpretation no longer makes sense, recovery mechanisms will come into play, so the parser arrives at the correct interpretation. Various studies have examined what linguistic and non-linguistic factors are involved in the garden-path effect during language comprehension (e.g., prosodic cues, contextual information, lexical biases, development of cognitive control, etc). However, less is known about how prior exposure to syntactic repetition may modulate garden-path effects, and specifically influence how we process temporarily ambiguous sentences.

5.2 Ambiguity resolution and Structural priming

Serial or syntax-first models explain the garden-path effect by proposing a universal processing strategy named *Minimal Attachment* (e.g., Frazier, 1978). According to this principle, when interpreting a sentence, the parser uses the fewest tree structure nodes to select the simplest syntactic representation in an attempt to reduce memory demands. Preference for

this processing strategy is what makes readers and listeners be led down the garden-path in an initial syntactic stage, and later experience reanalysis mechanisms in a subsequent stage.

By contrast, interactive accounts, such as the constraint-based model (e.g., MacDonald et al., 1994; Trueswell, Sekerina, Hill, Logrip, 1999), suggests that, within a competitive parsing architecture, multiple analyses activate and are weighted in parallel based on the compatibility that they have with different constraints (e.g., contextual, plausibility, frequency information, etc). The level of activation of each analysis is what will determine which alternative analyses will be foregrounded or backgrounded. However, garden-path effects will occur when two or more analyses share the same level of activation and start competing with each other until the parser resolves the ambiguity. (See Chapter 1, section 1.3 for a detailed description of these accounts).

A growing body of language comprehension research has examined the processes involved in ambiguity resolution. Referential context (e.g., Trueswell et al., 1999; Weighall, 2008; Qi, Love, Fisher, Brown-Schmidt, 2020), lexical biases (e.g., Snedeker & Trueswell, 2004; Kidd, Stewart & Serratrice, 2010), prosody (e.g., Snedeker & Trueswell, 2003; Contemori, Pozzan, Galinsky, & Dussias, 2018) and cognitive control (e.g., Hsu & Novick, 2016; Woodard et al., 2016; Qi et al., 2020) are some of the factors that have been studied. However, not many studies have explored how structural priming may influence sentence processing mechanisms in the comprehension of temporarily ambiguous sentences.

Structural priming refers to when the processing of a sentence (i.e., prime sentence) facilitates the comprehension or production of a subsequent sentence (i.e., target sentence) that shares syntactic elements of the prime sentence (e.g., Branigan, Pickering, McLean, 2005; Traxler, 2008; Tooley, Pickering, 2019; Thothathiri & Snedeker, 2008). If priming effects occur when prime and target sentences do not share content words, such facilitation is referred to as lexically-independent priming effects or syntactic priming effects. If, however, such priming effects are enhanced as a result of the shared content words between prime and target sentences, this effect is known as the *lexical boost* (Pickering & Branigan, 1998). The rationale behind structural priming experiments, is that the processing of a sentence will activate the mental representation of that structure making the production of the following sentence more likely to occur or facilitating the comprehension of the subsequent sentence (Bock, 1986). For example, it is more likely for people to repeat a double object dative (e.g., *Sarah sent David a*

letter) after prior processing of a double object dative than after a prepositional dative (e.g., *Sarah sent a letter to David*).

Two main accounts explain structural priming effects. The error-based learning account (e.g., Chang, Dell & Bock, 2006) proposes that priming effects are the result of an error-driven implicit learning mechanism. When we listen to language input and encounter a sentence that does not match our expectations or predictions (i.e., prediction error), the parser will adjust the weighting for different structures to better predict the actual input leading to priming effects and long-term implicit learning. Learning is therefore predicted to be greater in less proficient speakers (e.g., children, second language learners) since they experience greater prediction error. Likewise, less frequent structures are also predicted to show greater priming effects (Fine & Jaeger, 2013). Under this account, the lexical boost is attributed to the explicit memory. Thus, since memory skills are not fully developed in childhood, only older children and adults are predicted to show a lexical boost, while children may or may not show it. (See Chapter 1, section 1.4 for a detailed description of this account).

The residual activation account (Pickering & Branigan, 1998) proposes that priming effects are the result of a single mechanisms within the lemma stratum. That is, priming effects arise from the residual activation of the lemma and combinatorial nodes and the links between these two. Thus, residual activation of a combinatorial node will give rise to lexically-independent priming effects when processing a sentence. If, however, the verb in the target sentence is the same as the one in the prime sentence (e.g., *give)*, enhanced priming effects (i.e., the lexical boost) will result from the residual activation of the pre-activated lemma (i.e., *give*), combinatorial node (i.e., NP,NP) and the strengthened link between these two. (See Chapter 1, section 1.4 for a detailed description of this account).

Priming studies in language comprehension have found that the prior processing of a temporarily ambiguous sentence can facilitate the comprehension of a subsequent temporarily ambiguous sentence with the same verb (e.g., Tooley & Traxler, 2018; Tooley, Traxler & Swaab, 2009; Tooley et al., 2019). For example, in an online reading comprehension study, Tooley et al. (2019) showed that a temporarily ambiguous target sentence (e.g., Reduced-relative: *The contestant selected by the judge did not deserve to win*) could be primed by another temporarily ambiguous prime sentence (e.g., Reduced-relative: *The customer selected by the security guard was not a thief*) and also by an unambiguous prime sentence with the

same verb (e.g., Full-relative: *The customer who was selected by the security guard was not a thief*).

At an abstract level of representation reduced-relative and full-relative clause sentences share the same sequence of syntactic structure (NP + RC), however, at a less abstract level, it is the RC of both structures that differs within its lexical elements (Full-relative = relativiser + auxiliary verb + verb + PP), (Reduced-relative = verb + PP). Thus, the fact that a full-relative primed a reduced-relative target sentence suggests that both structures may share some aspects of abstract form. Tooley et al.'s (2019) is the first language comprehension priming study that has demonstrated facilitated processing of reduced-relative clause sentences (ambiguous) after prior processing of full relative clause sentences (unambiguous). Additionally, these findings also suggest that facilitated structural processing is not contingent on garden-path recovery mechanisms of the temporarily ambiguous prime sentence (i.e., error signal), as it has been suggested by error-based learning accounts.

The current study

In the present study we aimed to investigate whether sentence processing mechanisms were affected by recent language experience during language comprehension in monolingual English-speaking adults. In particular, we focussed on answering the questions: are garden-path effects eliminated after exposure to an unambiguous prime sentence? and if not, is garden-path recovery facilitated by the prior processing of a prime sentence?

To do this, we used the visual-world paradigm and structural priming and analysed temporarily ambiguous target sentences such as (1) *Put the duck on the sock on the star* and unambiguous prime sentences such as (2) *Put the duck that is on the jacket on the blanket.*
For example, while listening to the ambiguous target sentence (1), participants could see on the computer screen a correct goal (CG) (*star*), incorrect goal (IG) (*sock*), distractor (*coin*), and a target entity (*duck*). After listening to the sentence, participants would need to move the target entity (*duck*) to the CG (*star*). We recorded participants' eye-movements on primes and targets and compared the fixation proportion on the CG against the IG on two time-windows. The first time-window (TW1) examined whether participants experienced a garden-path effect, it started from the onset of the noun of PP1 (i.e., *sock*) until the onset of the disambiguated noun of PP2 (i.e., …*star*). The second time-window (TW2) examined whether revision mechanisms were

facilitated or more difficult and started from the onset of the disambiguated noun of the PP2 (i.e., …*star*) until the start of the action period (i.e., when participants clicked on an object).

Temporarily ambiguous target sentences were preceded by two unambiguous primes, a modifier-disambiguated prime (Baseline) and a Goal-disambiguated prime (GP).

Sentence type		**Sentence**
Modifier-disambiguated prime	(Baseline)	*Put the duck that is on the jacket on the blanket*
Target preceded by a Modifier-disambiguated prime	(TMP)	*Put the duck on the sock on the star*
Goal-disambiguated prime	(GP)	*Put the duck on the blanket*
Target preceded by a Goal-disambiguated prime	(TGP)	*Put the duck on the sock on the star*

Sentence types: Baseline: Modifier-disambiguated prime; TMP: Target preceded by a Modifier-disambiguated prime; GP: Goal-disambiguated prime; TGP: Target preceded by a Goal-disambiguated prime.

TW1

In the unambiguous Baseline primes, participants did not experience garden-path effects. Therefore, to ensure that participants experienced garden-path effects in the target sentences, we compared the target sentences against the Baseline primes in TW1. That is, we compared the fixation proportion on the CG vs. IG in TW1 between the TMPs and Baseline primes, and between the TGPs and Baseline primes (i.e., TW1: TMP vs. Baseline; TGP vs. Baseline).

To examine whether the garden path effect was affected by the type of prime, we compared the target sentences preceded by a Baseline prime against the target sentences preceded by a GP in TW1. That is, we compared the fixation proportion on the CG vs. IG in TW1 between the TMPs and TGPs (i.e., TW1: TMPs vs. TGPs).

TW2

To ensure whether participants experienced garden-path recovery mechanisms in the target sentences, we compared the target sentences against the unambiguous Baseline primes in TW2. That is, we compared the fixation proportion on the CG vs. IG in TW2 between the TMPs and Baseline primes, and between the TGPs and Baseline primes (i.e., TW2: TMP vs. Baseline; TGP vs. Baseline).

To examine whether garden-path recovery was facilitated by the type of prime, we compared the target sentences preceded by a Baseline prime against the target sentences preceded by a GP in TW2. That is, we compared the fixation proportion on the CG vs. IG in TW2 between the TMPs and TGPs (i.e., TW2: TMPs vs. TGPs).

By answering our research questions, we also aimed to explore the level of abstractness of the representation of the structure being primed. That is, if the processing of an *unambiguous* prime (i.e., Baseline) helps eliminate garden-path effects or facilitates garden-path recovery of a temporarily *ambiguous* target sentence, this may suggest that the representation of the sentence being primed may be highly abstract to some extent, since there was no need for its constituent structure to have lexical information within the constituent phrases. In other words, at a highly abstract level, both the ambiguous and unambiguous sentences share the (NP + RC) syntactic sequence, whereas at a less abstract level, they do not. Thus, while both unambiguous Baseline primes and ambiguous target sentences share a modifier, it is only the unambiguous Baseline primes that contain a relativiser and an auxiliary verb.

We predicted that TMPs (ambiguous target sentences preceded by a Baseline prime), would not show garden-path effects in TW1, and if they did, then in TW2, garden-path recovery might be facilitated.

By contrast, in TW1 we predicted that TGPs (ambiguous target sentences preceded by a GP), would show stronger garden-path effects than the TMPs. Thus, in TW2, it would take them longer for the TGPs to recover from the garden-path effect than for the TMPs (assuming that for the TMPs, there was a garden-path effect and facilitated garden-path recovery in TW2).

If on TW1, the fixation proportions of the Baseline did not differ from those of the TMPs and TGPs, this would suggest that participants did not experience garden-path effects when processing the TMPs and TGPs and that they interpreted the first PP as a modifier of the target entity. If this is the case, then on TW2, the fixation proportions of both the TMPs and TGPs should not differ from those of the Baseline either, as the parser did not experience any garden-path effects and therefore no garden-path recovery. If, however, the parser experienced garden-path effects when processing the TMPs and TGPs, differences between the fixation proportions of the Baseline and TMPs as well as between the Baseline and TGPs should be reflected on TW1. Likewise, recovery mechanisms of the processing of the TMPs and TGPs should also be reflected on TW2.

Differences in the fixation proportions on TW1 between the TMPs and TGPs would indicate that the processing of a prime affected garden-path effects. Differences in the fixation proportions on TW2 between the TMPs and TGPs would indicate that recovery mechanisms were either facilitated or more difficult by the prior processing of a prime.

Response Times

Response times (RTs) between the TMPs and TGPs were also analysed to examine whether exposure to a prime sentence speeded or slowed the resolution of the ambiguity and whether these effects were also reflected on time measures. To do this, we compared the RTs of the TMPs against the ones of the TGPs starting from the onset of (Put) until the action period began. Participants were expected to show shorter RTs in the TMPs than in the TGPs.

5.3 Methods

Participants

We analysed the data of 23 monolingual English-speaking adult students (aged 18 to 28; mean age: 21, 14 female; 9 male) from the University of Edinburgh. None of the participants had a history of language disorders or learning disabilities. Participants provided their written consent before starting the experiment and they received course credits for their participation.

Design

We performed a growth curve analyses (Dink & Ferguson, 2015) using a mixed design with Prime type as a between-participants factor (Baseline vs. TGPs; Baseline vs TMPs) and with Target type as a between-participants factor (TMPs vs. TGPs) within items.

Materials

To investigate whether syntactic priming modulated garden-path effects, we followed the visual-world paradigm and used structural priming in an online language comprehension task. We designed 48 ambiguous target sentences (e.g., *Put the duck on the sock on the star*), 24 unambiguous Baseline primes (e.g., *Put the duck that is on the jacket on the blanket*), 24

unambiguous GPs (e.g., *Put the duck on the blanket)* and 72 filler sentences (e.g., *Find the cow)*.

Target sentences were always prepositional phrase (PP) ambiguities as e.g., *Put the duck on the sock on the star.* For each target trial, four images were displayed on a computer screen: a CG (*star*), IG (*sock*), distractor (*coin*) and a target entity (*duck on a sock*), see Figure 1.

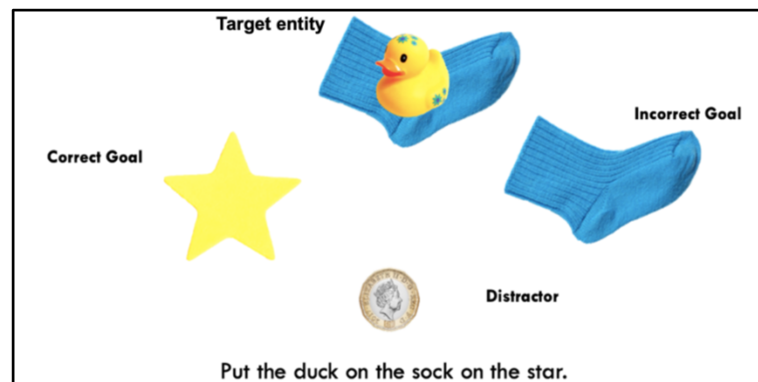

Figure 1: Example of the visual display for the ambiguous target sentences.

All ambiguous target sentences were always preceded by one type of prime, Baseline or GP. Baseline primes were unambiguous sentences with a relative clause as in (e.g., *Put the duck that is on the jacket on the blanket)*. For each Baseline trial, four images were displayed on a computer screen: a CG (*blanket*), IG (*jacket*), distractor (*boat*) and a target entity (*duck on a jacket*), see Figure 2.

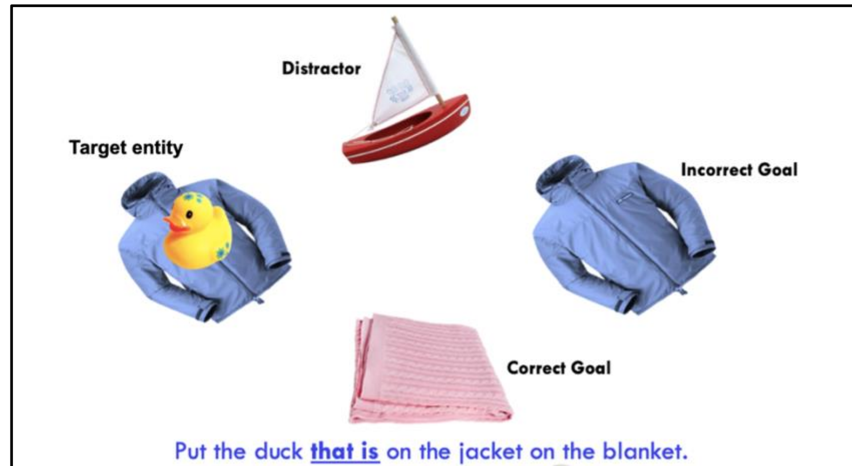

Figure 2: Example of the visual display for the Baseline primes (Baseline).

GPs were unambiguous prime sentences with one argument PP as in (e.g., *Put the duck on the blanket)*. For each GP trial, four images were displayed on a computer screen: a correct goal (*blanket*), distractor 1 (*jacket*), distractor 2 (*boat on a jacket*) and a target entity (*duck*), see Figure 3.

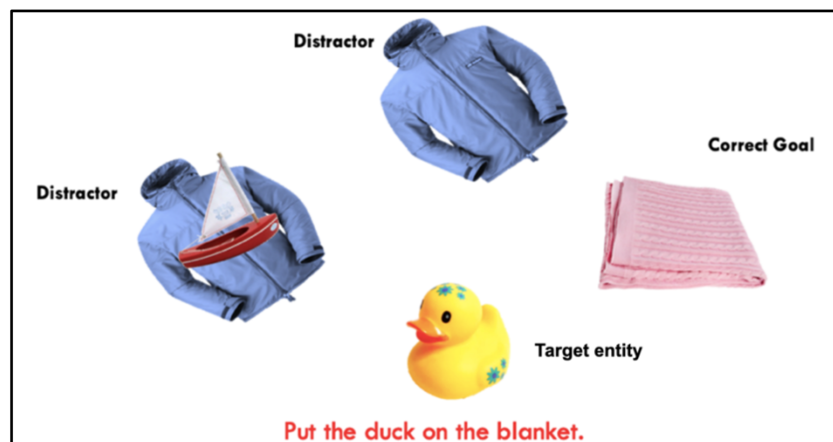

Figure 3: Example of the visual display for the goal-disambiguated primes (GPs).

To avoid additional priming effects on the GP primes, filler sentences always started with either the verb *click* or *find*, rather than the verb *put* (e.g., *Find the cow)*. Half of the filler sentences showed a target item (*cow*) and three different distractors (e.g., *plate*). The other half also showed a target entity and three distractors but with the constraint that one of the

distractors consisted of an object on a platform (e.g., *shoe on a blanket*) so participants could not notice the target trials, see Figure 4.

Figure 4: Example of the visual display for the filler sentences.

We used 12 different platform images (e.g., *plate, book, star*) and 48 different target images (animate and inanimate e.g., *duck, butterfly, spoon, banana*). The position of the item locations on the screen (CG, IG, distractor and target) were counterbalanced within trials and across conditions. The position of the dragging object and CG was never repeated between the prime and target pairs. Two different lists (A and B) were created. Primes, fillers and target sentences were pseudo-randomised, with the constraint that a prime would be followed by an target sentence, and that there would be at least one intervening filler after each target sentence. The Baseline primes that were used in list A, were used as GPs in list B, likewise, the GPs that were used in list A, were used as Baseline primes in list B. Thus, each target sentence was exposed to the two versions of the same prime sentence (Baseline and GP). All the primes and target sentences started with the same verb (i.e., *Put*), and shared the same target noun (e.g., *duck*) and preposition (i.e., *on*). Each participant was randomly allocated to one of the lists. Each sentence was considered as one individual trial.

To avoid biases towards the verb-attachment interpretation (i.e., *Put the duck on the jacket*) or noun-phrase interpretation (i.e., *…the duck on the jacket…*) on the target sentences, a native speaker of English trained in psycholinguistics pre-recorded fragments of the sentences. For example, for the Baseline and target sentences e.g., *Put the duck | (that is) on the jacket | on the blanket*, there were 4 different audios: one for (*Put the duck)*, another for

(*that is on the jacket)*, another one without the relative pronoun (i.e., *on the jacket)* and another one for (*on the blanket*). We later used the Audacity audio editor to combine the audios and form each trial sentence. Thus, there were 48 different audios for the *Put* + *target* fragments, 12 audios for the platforms (e.g., *on the jacket*) as well as 12 audios for the platforms but with the relativiser (e.g., *that is on the jacket*). For filler sentences such as e.g., *Click | on the cow*, we recorded 4 different audios for the verbs (i.e., *Click, Find, Now click, Now find*), 36 audios that started with the preposition (*on*) followed by (*the*) and a target (e.g., on the fish) so they could be combined with the verb (*click,* i.e., *click on the fish*) and another 36 audios with the target entities but without the preposition (*on)* (i.e., *the ball*) so they could be combined with the verb (*find*) as in e.g., *Find the cow*.

At the beginning and at the end of each sentence audio there were 100 ms of generated silence using the Audacity audio editor. There was no generated silence in between each sentence fragment. Participants answered 5 practice trials before the experiment started. Those practice trials consisted of 3 sentences similar to the fillers, 1 Baseline prime and 1 GP prime that were not part of the experiment.

Procedure

We used E-prime 2 Professional to design the comprehension task and the Tobii-TX 300 eye-tracker to record participants' eye-movements every 16 ms. Participants listened and carried out the pre-recorded spoken instructions on the computer screen from the Developmental Lab at the University of Edinburgh, while their eye-movements were being recorded. The eye-tracker was attached to the computer screen. Before the experiment began, participants answered 5 practice trials and then they followed the calibration process.

For each instruction, participants dragged and dropped the appropriate target entity around a visual scene on a computer display using a mouse. A visual display with a prime or an ambiguous target sentence appeared for 1000 ms. After that, participants heard the complete pre-recorded sentence. At the end of the recording the cursor appeared on the screen so participants could carry out the action using the mouse with no time pressure. After each participant's response, a beep would indicate the end of each trial (see Figure 5).

Each sentence audio started automatically, and participants could only listen to it once. Once participants had either clicked on a target entity or dragged and dropped a target entity on a destination, the slide would automatically change showing the following slide of the next trial sentence. Participants were not able to go back to the previous trial and change their answers. There were 3 breaks throughout the task and each break would start after a filler trial. Similarly, after each break, the first trial was always a filler sentence. The experiment lasted approximately 20 min.

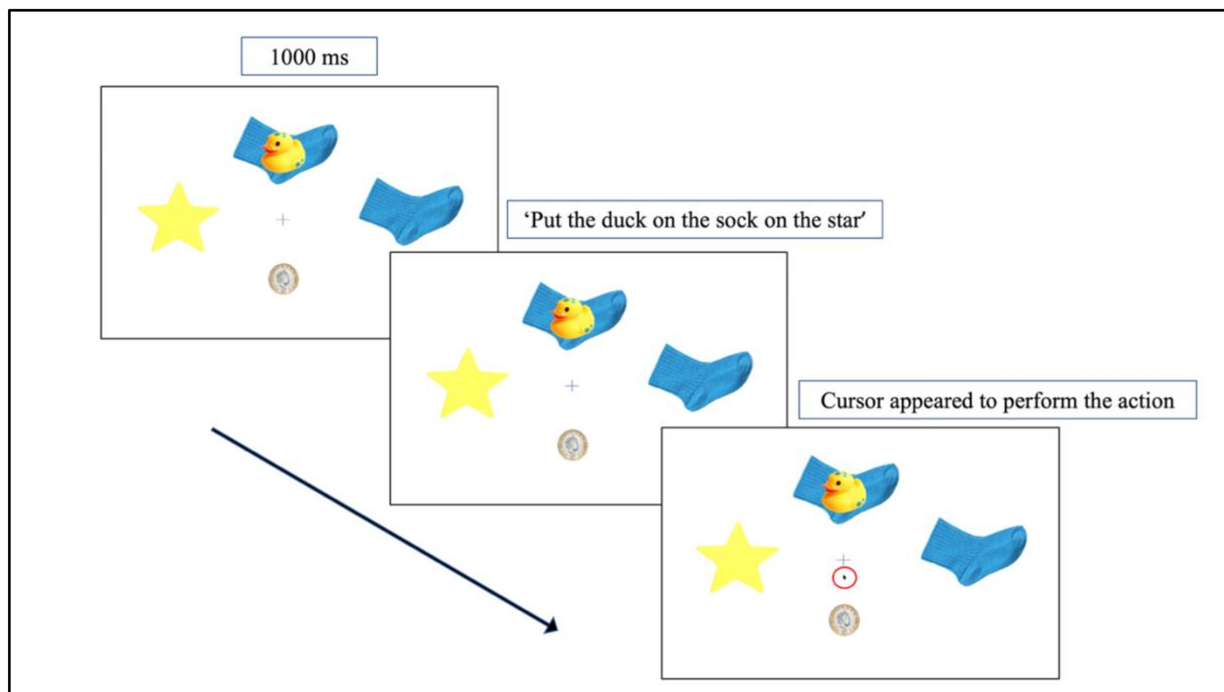

Figure 5: Example of the visual display sequence for one of the target sentences.

Scoring and data analysis

Each quadrant of the screen was considered as an area of interest (CG, IG, distractor, and target entity), so participants' fixations were labelled based on the area of interest and were recorded from the onset of (*Put*) until the action period began.

We analysed the proportion of fixations on the CG (coded as 1) and IG (coded as 0) of the target sentences and Baseline primes.

To check for early-processing commitments and whether participants considered the interpretation of the first PP as the CG, we examined TW1, that started from the onset of the noun of PP1 (i.e., *sock*) until the onset of the disambiguated noun of PP2 (i.e., …*star*) in the two ambiguous target sentences (TMPs and TGPs) and in the Baseline prime.

TW2 examined whether garden-path recovery was facilitated or more difficult, so we analysed the proportion of fixations from the onset of the disambiguated noun of the PP2 (i.e., …*star*) until the start of the action period (i.e., when participants clicked on an object) in the two ambiguous target sentences (TMPs and TGPs) and in the Baseline prime.

To analyse the eye-tracking data we used the R programming environment (R version 3.5.2) and performed growth curve analyses by building linear mixed effects models using the lme4 and EyetrackingR packages (Dink & Ferguson, 2015). The fixation proportion on the CG as well as its time course in each time-window was captured by the best-fitting models using the Baseline vs. Target predictor, Target type predictor, the linear, quadratic and cubic orthogonal polynomials as well as their interactions and a subject and Trial-by-condition random effect structure on all time terms.

We first compared whether the fixation proportions on the CG and IG from the Baseline prime differed from those of TMPs and TGPs on both time-windows. We later compared whether the fixation proportions on the CG and IG from the TMPs differed from those of the TGPs on both time-windows. Therefore, to analyse TW1, we built three models that compared the fixation proportions between (Baseline vs. TMPs), (Baseline vs. TGPs) and (TMPs vs. TGPs).

Likewise, to analyse TW2, we built three additional models that compared the fixation proportions between (Baseline vs. TMPs), (Baseline vs. TGPs) and (TMPs vs. TGPs). All the models shared the same outcome variable (Proportion: i.e., Fixation Proportion on the CG and IG). Depending on the model, the predictors were: Baseline vs. Target predictor (sum-coded as Baseline = 0.5, TMP = -0.5; Baseline = 0.5, TGP = -0.5), Target predictor (sum-coded as TMP = 0.5, TGP = -0.5).

We also compared the response times (RTs) of the TMPs and TGPs starting from the onset of (*Put*) until the action period began. To do this we built a linear regression model and used the RTs by trial as the outcome variable and Target Type predictor (TMP vs. TGP; TGP on the intercept). If significant differences were found between the RTs of the TMPs and TGPs,

this would indicate that the processing of a prime sentence affected the processing of a temporarily ambiguous sentence by either speeding or slowing the resolution of the ambiguity and that these differences were also reflected on the RTs.

5.3.1 Results

Eye-movements

To test whether the processing of a prime sentence affected the processing of a temporarily ambiguous sentence, we used the visual-world paradigm to analyse the proportion of fixations on the CG and IG of the prime and target sentences. Figure 6 shows the overall time course of the fixation proportions on the CG and IG of the Baseline primes, TMPs and TGPs from the onset of (*Put*) until the action period began.

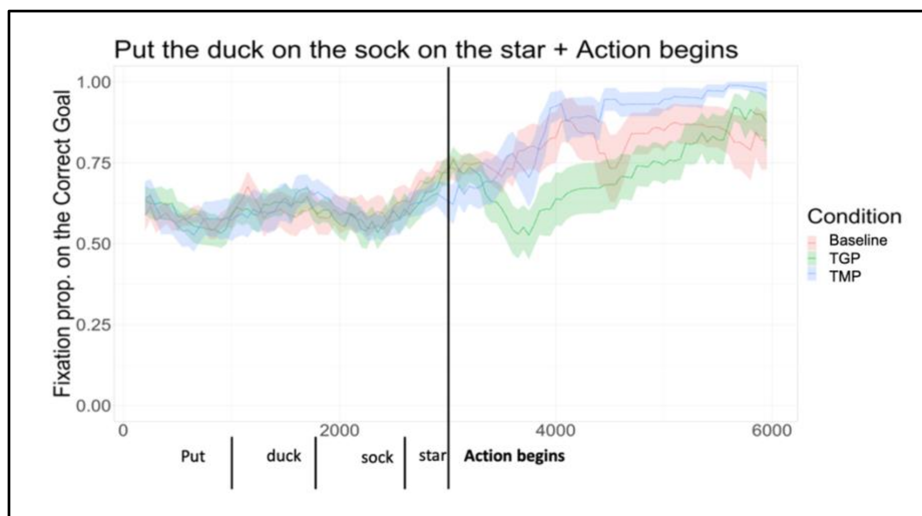

Figure 6: Fixation proportion on the CG from the onset of (*Put*) until the action period begins. (Baseline, TMPs and TGPs)

Time-Window 1 analyses

To test whether participants experienced garden-path effects, we examined the fixation proportions of the CG and IG on TW1 that started from the onset of the noun of PP1 (*sock)* until the onset of the noun of PP2 (*star*) of the Baseline primes against the ones of the TMPs,

and the ones of the Baseline primes against the ones of the TGPs (see Figure 7). Following previous eye-tracking studies, Trials whose trackloss proportion was greater than 25% were removed. For the comparison between the Baseline primes and TMPs we removed 8% of the trials. For the comparison between the Baseline primes and TGPs, we removed the 7% of the trials.

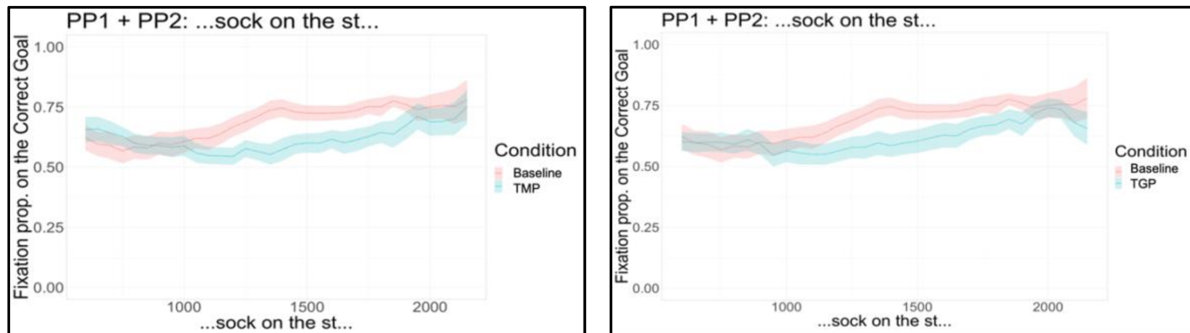

Figure 7: Time-window 1: Fixation proportion on the CG from the onset of the noun of PP1 (*sock*) until the onset of the noun of PP2 (*star*). Baseline primes vs. TMPs and Baseline primes vs. TGPs

When comparing the overall fixation proportions on the CG vs. IG between the Baseline primes and TMPs in TW1, the model revealed no significant differences ($p > .05$). However, there was a significant effect on the interaction between Baseline vs. TMPs and the quadratic orthogonal polynomial ($p < .05$). In the second model, when comparing the overall fixation proportions on the CG vs. IG between the Baseline primes and TGPs in TW1, we found a marginal effect ($p = .067$).

The results of these two models suggest that on TW1, there were more looks to the CG when processing the Baseline primes than when processing the TMPs and TGPs. Such effects suggest that participants experienced garden-path effects when they processed both the TMPs and TGPs (see Table 1).

Analysis	Term	Estimate	SE	Statistic	p
TW1 Baseline vs. TMPs	Intercept	0.68	0.02	26.64	
	Baseline vs Target	0.05	0.04	1.22	.223
	ot1	0.32	0.10	3.05	**<.01**
	ot2	0.13	0.09	1.40	.167
	ot3	-0.10	0.05	-1.79	.082
	Baseline vs Target x ot1	0.21	0.14	1.52	.132
	Baseline vs Target x ot2	-0.27	0.11	-2.41	**<.05**
	Baseline vs Target x ot3	-0.06	0.07	0.09	.360
Analysis	**Term**	**Estimate**	**SE**	**Statistic**	**p**
TW1 Baseline vs. TGPs	Intercept	0.66	0.02	23.07	
	Baseline vs Target	0.07	0.03	1.84	**.067**
	ot1	0.45	0.09	4.64	**<.001**
	ot2	0.08	0.08	1.03	.303
	ot3	-0.12	0.05	-2.28	**<.05**
	Baseline vs Target x ot1	0.00	0.14	0.03	.973
	Baseline vs Target x ot2	-1.15	0.13	-1.12	.263
	Baseline vs Target x ot3	-0.01	0.08	0.18	.856

Table 1. Time-Window 1: Summary of Growth Curve Analyses models with Baseline vs. Target as a predictor and with the linear, quadratic, and cubic orthogonal polynomials. Baseline primes vs. TMPs and Baseline primes vs. TGPs

To test whether the garden-path effect differed between the TMPs and TGPs on TW1, we also compared the fixation proportions on the CG and IG between the TMPs and TGPs. Trials whose trackloss proportion was greater than 25% were removed. On this TW and for this analysis we removed the 8% of the trials. The model revealed no significant differences in the fixation proportions on the CG and IG between the TMPs and TGPs and no interactions between Target type and the orthogonal polynomials ($p > .05$). These non-significant results suggest that on TW1, participants processed the TMPs and TGPs in a similar way (see Figure 8 and Table 2)

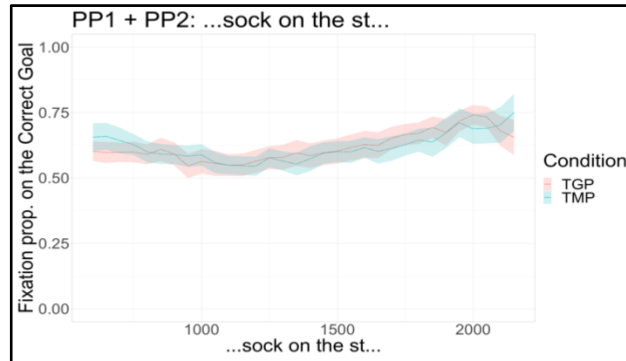

Figure 8: Time-window 1: Fixation proportion on the CG from the onset of the noun of PP1 (*sock*) until the onset of the noun of PP2 (*star*). TMPs vs. TGPs

Analysis	Term	Estimate	SE	Statistic	p
TW1 TMPs vs. TGPs	Intercept	0.63	0.03	19.69	
	Target Type	0.03	0.04	0.73	.461
	ot1	0.31	0.10	3.14	**<.01**
	ot2	0.22	0.08	2.74	**<.01**
	ot3	-0.06	0.06	-1.06	.296
	Target Type x ot1	-0.17	0.13	-1.26	.208
	Target Type x ot2	0.13	0.12	1.08	.279
	Target Type x ot3	0.04	0.08	0.52	.597

Table 2. Time-Window 1: Summary of Growth Curve Analyses models with Prime Type as a predictor and with the linear, quadratic, and cubic orthogonal polynomials. TMPs vs. TGPs

Time-Window 2 analyses

To test whether participants disengaged more easily from considering the incorrect analysis and recovered from garden-path more or less efficiently after processing a prime sentence, we examined the fixation proportions of the CG and IG on TW2 from the onset of the noun of PP2 (*star*) until the Action period began between the Baseline prime and TMPs, and between the Baseline prime and TGPs (see Figure 9). Trials whose trackloss proportion was greater than 25% were removed. For the comparison between the Baseline primes and TMPs we removed 5% of the trials. For the comparison between the Baseline primes and TGPs we removed 4% of the trials.

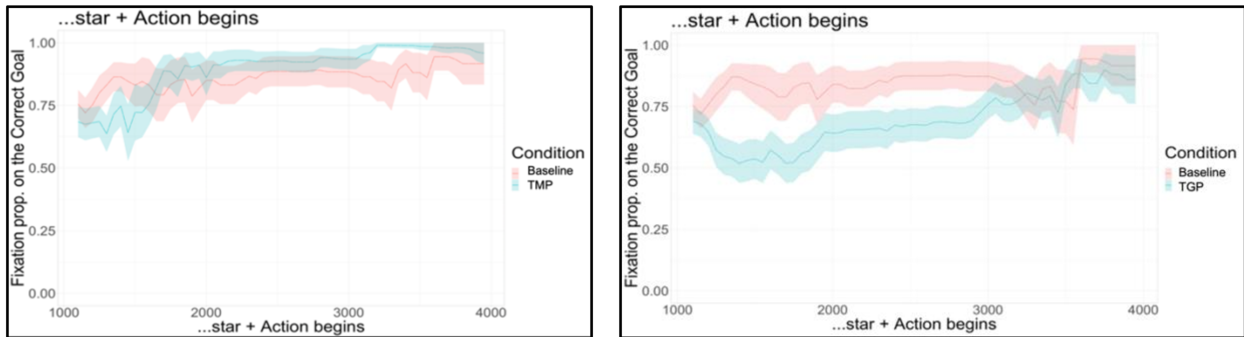

Figure 9: Time-window 2: Fixation proportion on the CG from the onset of the noun of PP2 (*star*) until Action period begins. Baseline prime vs. TMPs and Baseline prime vs. TGPs.

When comparing the fixation proportions on the CG and IG between the Baseline prime and TMPs on TW2, the model revealed no significant differences (p >.05). There were no interactions between the Baseline vs Target predictor and the orthogonal polynomials (p >.05). This suggests that when the parser processed a temporarily ambiguous sentence that was preceded by a Baseline prime, the parser did not experience difficulties (or at least not enough difficulties to show a significant difference) when recovering from garden-path effects.

By contrast, when comparing the fixation proportions on the CG and IG between the Baseline prime and TGPs on TW2, we found a significant difference (p <.05) indicating that, on TW2, there were more looks on the CG when processing a Baseline prime than when processing a TGP (see Table 3).

Analysis	Term	Estimate	SE	Statistic	p
TW2 Baseline vs. TMPs	Intercept	0.88	0.05	15.45	
	Baseline vs Target	-0.02	0.07	-0.32	.744
	ot1	0.59	0.09	5.03	**<.05**
	ot2	-0.10	0.15	-0.68	.497
	ot3	0.07	0.11	0.60	.549
	Baseline vs Target x ot1	-0.25	0.28	-0.89	.382
	Baseline vs Target x ot2	0.12	0.18	0.69	.498
	Baseline vs Target x ot3	-0.04	0.14	-0.32	.751
Analysis	**Term**	**Estimate**	**SE**	**Statistic**	**p**
TW2 Baseline vs. TGPs	Intercept	0.79	0.04	16.27	
	Baseline vs Target	0.16	0.07	2.29	**<.05**
	ot1	0.31	0.23	1.34	.191
	ot2	-0.10	0.20	-0.50	.622
	ot3	-0.06	0.08	-0.80	.436
	Baseline vs Target x ot1	0.13	0.28	0.48	.636
	Baseline vs Target x ot2	0.18	0.19	0.97	.344
	Baseline vs Target x ot3	0.13	0.12	1.05	.296

Table 3. Time-Window 2: Summary of Growth Curve Analyses models with Baseline vs Target as a predictor and with the linear, quadratic, and cubic orthogonal polynomials. Baseline prime vs. TMPs and Baseline prime vs. TGPs

To confirm whether garden-path recovery had been facilitated after a Baseline prime and less efficient after a GP prime, we compared the fixation proportions on the CG and IG between the TMPs and TGPs. Trials whose trackloss proportion was greater than 25% were removed. On this TW and for this analysis we removed 8% of the trials.

The model revealed a significant effect of Target type ($p < .05$) indicating that, on TW2, TMPs showed more looks to the CG than TGPs. This effect suggests that the parser experienced facilitated garden-path recovery mechanisms after processing a Baseline prime, compared to prior processing of a GP prime, which made garden-path recovery less efficient than the Baseline primes (see Figure 10 and Table 4).

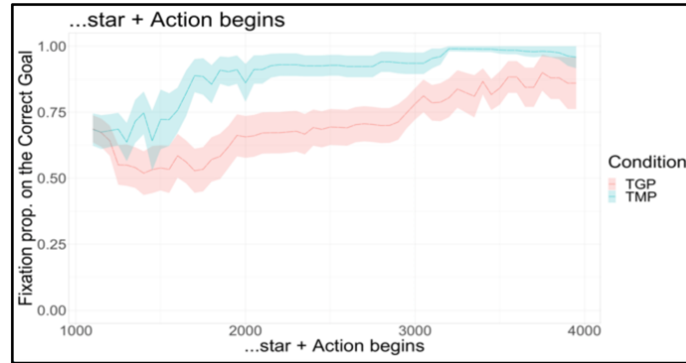

Figure 10: Time-window 2: Fixation proportion on the CG from the onset of the noun of PP2 (*star*) until Action period begins. TMPs vs. TGPs

Analysis	Term	Estimate	SE	Statistic	p
TW2 TMPs vs. TGPs	Intercept	0.76	0.05	13.09	
	Target Type	0.14	0.06	2.19	**<.05**
	ot1	0.40	0.17	2.36	**<.05**
	ot2	-0.09	0.17	-0.52	.611
	ot3	-0.13	0.10	-1.31	.196
	Target Type x ot1	0.01	0.22	0.06	.950
	Target Type x ot2	0.10	0.16	0.66	.515
	Target Type x ot3	0.13	0.14	0.92	.361

Table 4. Time-Window 2: Summary of Growth Curve Analyses models with Target Type as a predictor and with the linear, quadratic, and cubic orthogonal polynomials. TMPs vs. TGPs

Response Times

To test whether the processing of a prime facilitated or made the processing of a temporarily ambiguous sentence more difficult and whether these effects were also reflected on the RTs, we compared the RTs of the TMPs against the ones of the TGPs starting from the onset of (*Put*) until the action period began. The model revealed no significant effect of Prime type (*Estimate = 10.99, SE = 20.6, p > .05*), that is, the RTs of the ambiguous targets that were preceded by a Baseline prime did not differ from those that were preceded by a GP.

5.4 General discussion

To examine whether sentence processing mechanisms were influenced by recent language experience when processing a temporarily ambiguous sentence, we used the visual world paradigm in an online language comprehension task with English-speaking adults. In particular, we sought to investigate whether prior processing of an unambiguous prime sentence could eliminate the garden-path effect when processing a temporarily ambiguous target sentence. If this was not the outcome, we further examined whether revision mechanisms were facilitated in the resolution of an ambiguous target sentence after prior processing of an unambiguous prime sentence. RTs of the target sentences were also analysed to explore whether processing differences were also reflected on time measures.

By doing this, we aimed to examine whether the facilitated processing that occurred in the target sentences was not only dependent on garden-path revision mechanisms of an ambiguous prime sentence, as it has been shown in previous studies (e.g., Tooley et al., 2009), whereby the processing of a temporarily ambiguous prime sentence (reduced-relative) facilitated the processing of a subsequent temporarily ambiguous target sentence (reduced-relative). Thus, in the current study, we investigated whether prior processing of an unambiguous Baseline prime sentence (i.e., a structure that did not trigger reanalysis processes) could also facilitate the processing of an ambiguous target sentence. If such facilitated processing occurred between the Baseline prime and target sentences, this may reflect that both structures, share to some extent an abstract structure, even if the lexical/syntactic content differed within the RCs of both structures (Unambiguous prime RC = relativiser + auxiliary verb + PP; Ambiguous target RC = PP + PP)

To do this, we analysed participants' eye-movements while they listened to pre-recorded sentences and performed their actions on a computer screen. To look for evidence of whether participants experienced garden-path effects on TW1, we analysed the fixation proportion on the CG and IC between the Baseline primes and TMPs; Baseline primes and TGPs; and TMPs and TGPs.

Our results showed that, on TW1, participants experienced garden-path effects when they processed a target sentence (TMPs and TGPs). That is, when analysing the fixation

proportion to the CG vs. IG in TW1, participants did not process a target sentence in the same way as they processed a Baseline prime.

Similarly, in TW1 there were no differences between the processing of a target preceded by a Baseline prime and the processing of a target preceded by a GP prime, indicating that both TMPs and TGPs experienced garden-path effects to the same extent. This suggests that prior processing of a Baseline prime did not eliminate the garden-path effect when participants processed the ambiguous target sentences.

To look for evidence of facilitated reanalysis processes during ambiguity resolution, we analysed the fixation proportions on the CG vs. IG on TW2 between the Baseline primes and TMPs; Baseline primes and TGPs; and TMPs and TGPs. Our results showed that, prior processing of a Baseline prime, but not a GP prime, facilitated garden-path recovery in ambiguous target sentences.

The fact that in TW2 we did not find significant differences in the fixation proportions on the CG between the Baseline prime and TMPs, but we did find them between the Baseline prime and the TGPs, suggests that recovery processes were more efficient after prior processing of a Baseline prime than a GP prime. Moreover, the fact that on TW2 we also found significant differences in the fixation proportions on the CG between the TMPs and TGPs, confirmed that participants did not recover from the garden path in the same way when they processed a previous Baseline prime than when they processed a prior GP prime. Thus, the Baseline prime facilitated garden-path recovery in the target sentences, in fact, reanalysis processes were highly facilitated to the point that, participants adopted the correct analysis in the TMPs in a similar way as when they processed the Baseline primes. This was not the case when target sentences were preceded by a GP prime (i.e., TGPs), whereby participants experienced more difficulties with garden-path recovery than the TMPs.

Our results showed that prior processing of an unambiguous Baseline prime sentence facilitated garden-path recovery of an ambiguous target sentence when prime and target pairs shared the same verb (Put), same head noun (e.g., duck) and same preposition (on). These results may suggest that the unambiguous Baseline prime and the ambiguous target sentence may share some aspects of abstract form, even though the syntactic elements of the RC in the unambiguous Baseline prime differ from those of the RC in the ambiguous target sentence.

Such facilitated processing of the target sentences only emerged in TW2, during the stage where garden-path recovery mechanisms come into play. Thus, the fact that the facilitation took place only during TW2, may suggest that facilitated processing may be contingent on reanalysis processes of the ambiguous target sentences to some extent. In other words, for lexically-mediated priming effects to occur in this type of ambiguities (*Put the duck on the sock on the star*), it may be necessary to have 1) a shared abstract structure, a repeated verb and preposition between prime and target pairs as well as 2) syntactic reanalysis processes of the target sentence.

To some extent, these findings are consistent with Tooley et al.'s (2019), who found that facilitated processing of reduced-relatives is not only contingent on reanalysis mechanisms of the ambiguous prime sentences, as predicted by error-driven learning accounts (e.g., Chang et al., 2006). That is, the error signal could not be the only cause that gave rise to facilitated garden-path recovery, especially because in our experiment the Baseline prime was unambiguous, so no error signal was originated when the Baseline prime was processed. Therefore, Baseline prime sentence processing may have influenced sentence processing mechanisms, especially garden-path recovery, by weakening the adoption of the preferred analysis (i.e., verb-attachment interpretation) and favouring the adoption of the less preferred analysis (i.e., noun-phrase interpretation) in the target sentences. This may also suggest that some aspects of the representation of the unambiguous Baseline prime were pre-activated and that the parser was influenced by this pre-activation resulting in facilitated processing of the ambiguous target sentences. Thus, the fact that the parser was influenced by recent language experience, may also be compatible with interactive accounts, that suggest that other sources of information (not only syntactic) may influence sentence processing.

5.5 Limitations

Our results need to be interpreted with caution since, to our knowledge, this is the first study that explores priming effects during language comprehension with this type of ambiguity (i.e., *Put the duck on the sock on the star*). Although we intended to continue investigating priming effects with this type of ambiguity and with the visual world paradigm in adults and in children, due to the COVID-19 pandemic we were not able to continue with these studies. However, future research will have to replicate our results with adults and continue to explore

the influence of prime sentences on ambiguity resolution using the visual world paradigm in children and adults.

6 General discussion

Previous developmental language studies have addressed the questions about the nature and development of children's syntactic representations in comprehension. However, to this day, it is still unclear how children represent language, when their language representations start to become adult-like and whether their language representations are affected in the same way by language experience across languages.

Thus, the aim of this thesis was to better understand the role of recent language experience during language comprehension by investigating the nature and development of language representations in 4- to 6-year-old (Younger group) and 8- to 10-year-old (Older group) English- and Spanish-speaking children and adults. We specifically focussed on exploring the development of language representations of the high-attached (HA) and low-attached (LA) analyses of prepositional phrases (PPs) in globally ambiguous sentences in English and Spanish (e.g., English: *The girl is touching the dog with the banana;* Spanish: *La niña está tocando al perro con el plátano*) and examining the extent to which children were susceptible to cumulative language experience. To do this, we used a structural priming paradigm, which allowed us to manipulate language input in a series of six web-based language comprehension experiments in English and Spanish.

We also conducted a pilot study that used structural priming and the visual world paradigm to examine how recent language experience affected the processing of temporarily ambiguous sentences in English-speaking adults. As mentioned in Chapter 5, we started this PhD project with the aim of continuing to use the methodology described in Chapter 5 but with children, however, due to the COVID 19 pandemic, we were unable to continue with this approach, as it required in-person data collection**.**

In this chapter, we first provide an overview of the findings reported in this thesis. Then we discuss the implications and conclusions that can be drawn from these findings in relation to our research question, as well as highlighting how our findings contribute to knowledge in this field and the questions they raise for future research.

6.1 Summary of studies and findings

In this section, we summarise the findings from each of our four studies. The first three studies all investigated children's and adults' processing of globally ambiguous sentences. Study 1 was carried out with English-speaking children and adults (Experiments 1, 2 and 3 in Chapter 2), Study 2 was carried out with Spanish-speaking children and adults (Experiments 1, 2 and 3 in Chapter 3) and Study 3 (Chapter 4) involved cross-linguistic comparisons between English- and Spanish-speaking participants, based on the data collected for Studies 1 and 2. Finally, Study 4 (Chapter 5) was a pilot-study on English-speaking adults' processing of temporarily ambiguous sentences.

6.1.1 Study 1: English-speaking children and adults (Chapter 2, Experiments 1, 2, and 3)

Our first study investigated the nature and development of 4- to 6- and 8- to 10-year-old English-speaking children's (and adults as a control group) PP attachment preferences (HA vs. LA) by examining lexically-dependent and lexically-independent priming effects for globally ambiguous sentences during language comprehension. To do this, we used a forced-choice picture selection task and designed three experiments investigating the participants' comprehension preferences in contexts without an immediately preceding prime (Experiment 1, Baseline), with an immediately preceding prime that involved a different verb from the target sentence (Experiment 2, Non-Repeated Verb), and with an immediately preceding prime that shared the same verb as the target sentence (Experiment 3, Repeated-Verb).

In all three experiments in Study 1, an overall preference for HA over LA was found in language comprehension in English-speaking children and adults.

In the Baseline condition, the overall PP attachment preferences differed significantly between children and adults, but not between the Younger and Older children. That is, children tended to choose more HA responses than the adults. This may suggest that adults have relatively easy access to both the HA and LA interpretations when interpreting globally ambiguous sentences, whereas, for the Younger and Older children, the HA analysis may be more easily accessible than the LA analysis. Moreover, once children selected the HA

interpretation, their follow-up overall choices continued to reflect a strong preference for HA throughout the experiment.

When there was no lexical repetition between prime and target sentences (Non-Repeated Verb), English-speaking participants showed a main effect of priming. However, the fact that this priming effect was no longer reliable when only the children's data were analysed, may suggest that children's abstract representations of the LA analysis may be more fragile than the ones of adults'. However, these results may also reflect unstable abstract priming effects in children and therefore more power may be required to detect them.

When the verb was repeated between the prime and target sentences, English-speaking participants showed a reliable priming effect. The fact that children continued to show a reliable priming effect even after the adult data were removed from the analyses suggested that shared lexical content between the prime and target sentences facilitated processing of the HA and LA analyses of globally ambiguous sentences in children. No evidence of the lexical boost was found in any of the age groups. However, when participants were exposed to HA and LA structures within a session (Non-Repeated Verb and Repeated Verb), participants showed an overall decrease in their HA responses (and therefore an overall increase in their LA responses) compared to the Baseline condition.

Overall, in our first study participants showed reliable sensitivity to recent language experience that involved mixed exposure to the HA and LA primes. This reliable sensitivity was reflected both in the overall PP attachment preferences and in the priming effects in children and adults. Our results suggested that children's representations of the HA and LA analyses were partly syntactic in nature with a strong lexically-specific component.

6.1.2 Study 2: Spanish-speaking children and adults (Chapter 3, Experiments 1, 2, and 3)

Our second study also investigated the nature and development of PP attachment preferences (HA vs. LA) but in Spanish-speaking children (4- to 6 and 8- to 10-year-olds) and adults. We followed the same structural priming paradigm as in Study 1, but with the stimuli in Spanish.

In all three experiments in Study 2, an overall preference for HA over LA was found in language comprehension in Spanish-speaking children and adults. In the baseline condition, Spanish-speaking participants were more likely to choose a HA analysis than a LA analysis when interpreting globally ambiguous sentences. The Younger group was more likely to choose more HA responses than the adults. However, no differences in the overall PP preferences were found between the Younger and the Older groups or between the Older group and the adults. This suggested that the language experience to interpret globally ambiguous sentences did not differ between the Younger and Older children; and that the Older children may also be slowly progressing to acquire adult-like PP attachment preferences. Age in Months was not a predictor for children's overall PP attachment preferences in children when no prime was presented.

Participants also showed sensitivity to recent language experience that involved mixed exposure to the HA and LA primes. The findings of Experiment 2 (Non-Repeated Verb) indicated that Spanish-speaking participants showed a reliable effect of priming when there was no lexical repetition between prime and target sentences. The findings of Experiment 3 (Repeated Verb) showed that when there was shared lexical content between prime and target pairs, priming effects were only reliable in Spanish- speaking adults, but not in children. These results were very surprising, given the fact that priming effects in the absence of verb repetition were found in Experiment 2. Moreover, only the Older group showed cumulative effects of experience in the presence of verb overlap between prime and target pairs. No evidence of the lexical boost was found in any of the age groups. However, when participants were exposed to HA and LA structures within a session (Non-Repeated Verb and Repeated Verb), participants showed an overall decrease in their HA responses (and therefore and overall increase in their LA responses) compared to the Baseline condition.

Although these findings were very unexpected, our results still suggest that Spanish-speaking children and adults were sensitive to the language input to which they were exposed reflecting gradual changes in their syntactic choices in comprehension.

6.1.3 Study 3: Cross-linguistic comparisons (Chapter 4)

Our third study (Chapter 4) focussed on investigating cross-linguistic differences in PP attachment preferences for globally ambiguous sentences between English- and -Spanish-

speaking children (4- to 6 and 8- to 10-year-olds) and adults in the absence and presence of a prime. We did not collect any further data or run any experiments for this chapter, instead we conducted analyses that made cross-linguistic comparisons between the data we had already collected for Study 1 (English-speaking participants, Chapter 2) and for Study 2 (Spanish-speaking participants, Chapter 3).

We did not find any significant differences in the overall PP preferences between the English- and Spanish-speaking participants in the Baseline experiments. That is, when no prime was presented, English- and -Spanish-speaking children and adults processed globally ambiguous sentences in a similar way.

When participants were exposed to the primes (Non-Repeated Verb and Repeated verb combined), only the Older children showed a significant difference in their overall PP preferences by language. That is, in the presence of a prime, the Older Spanish-speaking children tended to choose more HA responses than the Older English-speaking children and this effect of language was not modulated by prime. English- versus -Spanish-speaking Younger children and adults did not show any significant differences in their overall PP preferences and in their priming effects.

6.1.4 Study 4: Priming temporarily ambiguous sentences in English-speaking adults (Chapter 5)

Our fourth study investigated whether prior exposure to an unambiguous modifier-disambiguated prime sentence (Baseline prime) (e.g., *Put the duck that is on the jacket on the blanket*) and an unambiguous goal-disambiguated prime sentence (GP prime) (e.g., *Put the duck on the blanket*) influenced subsequent processing of a temporarily ambiguous target sentence (e.g., *Put the duck on the sock on the star*) in monolingual English-speaking adults. By using a computer-based language comprehension task and the visual world paradigm, we specifically investigated whether the garden-path effect could be eliminated or whether revision mechanisms could be facilitated when processing a temporarily ambiguous sentence preceded by a Baseline prime.

To examine whether the garden-path effect was eliminated, we analysed the fixation proportion on the correct goal (CG) and incorrect goal (IG) from the onset of the noun of the first PP (*sock*) until the onset of the noun of the second PP (*star*) of the Baseline primes and

the ambiguous target sentences. To examine whether garden-path recovery was facilitated, we analysed the fixation proportion on the CG and IG from the onset of the noun of the second PP (*star*) until participants started to perform the action of the Baseline primes and the ambiguous target sentences. We also compared the fixation proportion on the CG and IC of the ambiguous target sentences that were preceded by a Baseline prime against the ambiguous target sentences that were preceded by a GP prime.

Overall, the findings of Study 4 showed that prior processing of a Baseline prime did not eliminate the garden-path effect when processing temporarily ambiguous target sentences. However, prior processing of a Baseline prime, but not a GP prime, facilitated garden-path recovery. Our results suggested that, for lexically-mediated priming effects to occur between an unambiguous prime and a temporarily ambiguous target sentence, a shared verb and a shared structure between the prime and target sentences as well as syntactic reanalysis processes in the ambiguous target sentence may be required. Moreover, the fact that facilitated processing of an ambiguous target sentence occurred after prior processing of a Baseline prime, may suggest that prime and target sentences (unambiguous baseline prime vs. ambiguous target sentence) may share the Noun Phrase + Relative Clause syntactic sequence, even if the lexical/syntactic content within the relative clauses of the Baseline prime and ambiguous target sentence differed.

6.2 Implications and conclusions

6.2.1 Developmental differences in PP attachment ambiguities

To have a better understanding about how structural priming influenced the way English- and -Spanish-speaking children processed globally ambiguous sentences, we first examined children’s PP attachment preferences but without the influence of a prime (Chapter 2, Baseline experiment 1, Chapter 3, Baseline experiment 1).

In the baseline condition, English-speaking children and adults showed a strong preference for HA over LA: 4- to 6-year-olds (97%), 8- to 10-year-olds (93%) and adults (79%). No significant age group differences in overall PP preferences were found between the Younger and Older children, or when Age in Months was used as a predictor to detect developmental differences in the children’s PP preferences. However, adults’ overall PP

preferences did differ significantly from the ones of children's, indicating that children were more likely to choose HA responses than adults. This suggested that, when no prime was presented, children between the ages of 4 and 10 may have a similar language experience for interpreting globally ambiguous sentences, and that adults may have easier access to the LA interpretation than children when processing globally ambiguous sentences.

Our results are consistent with previous developmental research that has found that when no prime was presented, English-speaking children (aged 4 - 6) tend to choose a VP attachment analysis to interpret globally ambiguous sentences (e.g., Snedeker & Trueswell, 2004; Qi, Yuan & Fisher 2011; Kidd & Bavin, 2005; Kidd, Stewart & Serratrice, 2010). This has been argued to be because children tend to over rely on bottom-up lexical cues such as frequency-based information of verbs and structures to guide their parsing commitments. By the age of 5, children have already experienced and tracked a lot of different syntactic/semantic scenarios in which familiar verbs may appear. This in turn, makes verb-specific information a highly reliable cue for language interpretation (Snedeker & Trueswell, 2004). Therefore, since the verbs in our language comprehension task were mostly instrumental verbs (*pat, push, poke, move, touch* and *tickle*), that is, verbs that favoured the HA analysis over the LA analysis, this may explain why children showed a strong preference for HA and had difficulties accessing the LA interpretation for the resolution of globally ambiguous sentences. This may also explain why the Older group showed more sensitivity to cumulative experience, that is, in the baseline condition, the Older group showed an increase in their HA responses as the experiment progressed within a session. This suggested that once the Older children adopted a HA analysis, they were unlikely to abandon it over the course of the experiment.

The fact that even at the age of 10, English-speaking children still continued to show similar PP attachment preferences to 4- to 6-year-olds is striking. This raises the question as to when the developing parser starts to interpret globally ambiguous sentences in the same way as adults when no prime is presented. Based on our findings, we predict that it is likely to be after the age of 10, presumably during adolescence. It is still unclear what factors give rise to these language processing changes in children, however, previous research has suggested that the development of cognitive control may be associated with the developmental stage at which children begin to consider alternative analyses to disambiguate a structure. According to Novick, Trueswell and Thompson (2005), the mechanisms involved in ambiguity resolution during sentence processing may also be associated with cognitive control. Novick et al.

suggested that attentional processes based on mechanisms located in the left inferior frontal gyrus may be responsible for conflict resolution. Therefore, since the left inferior gyrus is located in the prefrontal cortex, and the pre-frontal cortex is still underdeveloped and immature during childhood, children would not be expected to show adult-like recovery mechanisms.

Spanish-speaking children and adults also showed similar results to the English-speaking children and adults, that is, in the baseline condition, participants showed a stronger preference for HA than LA: 4- to 6-year-olds (98%), 8- to 10-year-olds (91%) and adults (89%). The Younger group was likely to choose more HA responses than the adults, however, we did not find significant differences in the overall PP preferences between the Older group and the Younger group, and between the Older group and the adults. These results suggested that the language experience between the Younger and the Older children did not differ with respect to how they interpreted globally ambiguous sentences in the baseline experiment. However, the fact that the overall PP preferences between the Older children and the adults did not differ either, may be suggestive that between the ages of 8 and 10, children have started to acquire adult-like PP attachment preferences.

Another possible explanation as to why we did not find a clear difference in the overall PP preferences between the Older children and the other two age groups in the baseline experiment, may be that all the participants may have shown ceiling effects, suggesting that in Spanish, the parser does not experience a relevant decrease in their HA preferences when transitioning from childhood to adulthood. Our findings with the Spanish-speaking participants are consistent with previous studies that have also found a strong preference for HA but with relative clause ambiguities (e.g., Cuetos & Mitchell, 1988; Carreiras & Clifton Jr., 1993,1999; Aranciba-Gutiérrez, Bizama Muñoz, Sáez Carrillo, 2015). Future research should examine whether Spanish-speaking children and adults show similar patterns of PP preferences for globally ambiguous sentences in the baseline condition to the ones we presented in Chapter 3.

Future research should also investigate at what age English-speaking children show adult-like PP attachment preferences in the absence of a prime and what other factors (e.g., further language experience, development of executive functions, children's reading comprehension skills) may be involved in this developmental change. Syntactic ambiguity detection, a component of syntactic awareness, has been reported to be associated with reading comprehension skills in second and third graders (Cairns, Waltzman & Schlisselberg, 2004).

Moreover, improved reading comprehension skills were also found to be linked to enhanced syntactic ambiguity awareness in 7- to 9-year-olds (Yuill, 2009; Zipke, Ehri & Cairns, 2009).

Our findings have shown that both English- and Spanish-speaking children and adults showed a strong preference for HA over LA when interpreting globally ambiguous sentences in the baseline condition. However, is there a statistically significant difference in the overall PP preferences between the English- and Spanish-speaking participants in our studies? Chapter 4 addressed this question. Our studies from Chapters 2 and 3 showed *numerical* differences: Preferences for HA in English: 4- to 6-year-olds (97%), 8- to 10-year-olds (93%) and adults (79%) vs. Preferences for HA in Spanish: 4- to 6-year-olds (98%), 8- to 10-year-olds (91%) and adults (89%). However, after combining the data of experiments 1 from Chapters 2 and 3 and analysing the overall effect of Language and the Language by Age Group interactions, we did not find statistically significant differences in the overall PP attachment preferences for globally ambiguous sentences between English- and Spanish-speaking participants in the baseline condition.

Our findings with PP attachment ambiguities in English differed from those with relative clause attachment ambiguities in English, where LA has been reported to be favoured over HA (e.g., Mitchell & Cuetos, 1991). This supports the idea that attachment preferences are not language-specific, and that such preferences within the same language may vary depending on various factors (prepositions, structures, noun modifications) (Gilboy, Sopena, Clifton & Frazier, 1995). Moreover, such a strong HA preference found in relative clause attachment ambiguities in Spanish may not be as great as previously thought. Grillo and Costa (2014) found that when pseudo-relatives are available, they will be preferred over relative clauses and therefore HA will be favoured, as pseudo-relatives only allow for HA (see Chapter 1, section 1.3.1).

Future research should continue to investigate whether both English- and Spanish-speaking children and adults do not significantly differ in their PP preferences when interpreting PP attachment ambiguities such as (*The girl is touching the dog with the banana*) when no prime is presented. More studies are needed in which researchers address this cross-linguistic difference directly, that is, the same experimental task should be used for the two groups of participants and analyses should be conducted to assess whether the PP attachment preferences between the two groups differ significantly, rather than focussing on only describing the PP attachment preferences by group and with populations who were given different tasks, especially since in English the LA preference in ambiguous relative clauses is

rather modest (see Carreiras & Clifton Jr., 1999). This area of research would also benefit from tasks designed to examine the levels or degrees of acceptance of one analysis over another (HA vs. LA), rather than examining binary attachment preferences.

6.2.2 The nature and development of children's language representations of HA and LA analyses: evidence from structural priming

Previous experimental research has explored the nature of adults' syntactic representations, and it has been suggested that their representations are abstract (Pickering, Branigan & Mclean, 2013). To prove this, researchers have employed structural priming paradigms, which have shown how adults tend to repeat abstract syntactic structure after hearing or reading unrelated sentences (Bock, 1986). These findings have raised some important questions in the field of language development such as, do children also show abstract representations, or do they develop over time? At what age do children start showing abstract representations? Researchers have addressed these questions by applying to children the same structural priming techniques used in adults and comparing the priming effects between these two groups.

Thus, the aim of this thesis was to investigate the nature and development of children's representations of language, in particular, we examined whether English- and Spanish-speaking children's PP attachment preferences (e.g., *The girl is pushing the teacher with the ball*) were affected during language comprehension by recent experience of a structure or a structure in association with a particular verb.

In the field of language development, usage-based lexicalist accounts have proposed that during the early stages of language development, children's linguistic knowledge may be governed by lexically-dependent representations (i.e., item-specific syntax), or representations that are lexically specified to some extent, and as children get older, their representations gradually become abstract due to the accumulated linguistic experience involving particular words (e.g., Tomasello, 2000; Savage, Lieven, Theakston, & Tomasello, 2003; Ninio, 2006). By contrast, early abstraction accounts have proposed that similarly to adults, young children already have higher-level linguistic categories (i.e., abstract syntactic representations) (e.g., Pinker, 1989; Fisher, 2001). That is, early abstraction accounts suggest that young children's language representations do not go through a strict lexically-based phase during the early stages

of language development, instead their language syntactic representations are specified in abstract categories rather than specific lexical content.

Developmental structural priming studies have been informative about the nature of children's representations of language, the age at which children start showing abstract representations and how these develop over time (e.g., Huttenlocher et al., 2004; Rowland et al., 2012). Structural priming effects occur when processing a prime sentence facilitates processing a subsequent target sentence with the same structure (e.g., Thothathiri & Snedeker, 2008; Branigan, Pickering & McLean, 2005). Evidence for existing abstract syntactic representations has been taken when priming effects occur in the absence of verb overlap between prime and target sentences (i.e., lexically-independent). Priming effects may be enhanced in the presence of verb repetition (i.e., lexically-dependent; the lexical boost) (Pickering & Branigan, 1998), which has been interpreted as evidence for a lexically-specific component in syntactic representations.

Therefore, if we link structural priming findings to language development accounts, the usage-based lexicalist account predicts that young children will show syntactic priming effects if and only if the verb is repeated between prime and target sentences. This is because, according to this account, young children are considered to have item-specific syntactic representations that become abstract gradually. Therefore, young children will only show priming effects if the target sentence *The boy is pushing the dog with the key* is preceded by the prime sentence *The girl is pushing the teacher with the ball*, but not if it is preceded by the prime sentence *The child is touching the sheep with the flower*. A more extreme position of this account would be that, during the earliest stages of language development, children's language representations are entirely lexically specified, that is, children only have knowledge of possible combinations of certain words, therefore priming effects would only occur if all the words are repeated. If there is a strong lexically specific component in young children's language representations, as suggested by the usage-based lexicalist accounts, then young children would also be predicted to show a stronger lexical boost than adults.

Early abstraction accounts, on the other hand, predict that young children will show priming effects regardless of the lexical content between prime and target pairs because, like adults, young children have abstract syntactic representations. Thus, according to this language development account, priming effects in young children are predicted to occur in the target sentence *The boy is pushing the dog with the key* even if this is preceded by a prime sentence

that does not share the same verb as the target e.g., *The child is touching the sheep with the flower.*

Two main models explain structural priming effects. The residual activation model (Pickering & Branigan, 1998), proposes that priming effects result from a single short-term mechanism within the lemma stratum. When processing a sentence, priming effects arise because there is residual activation of the combinatorial nodes previously used, and this is what facilitates their subsequent re-use. For example, after hearing the sentence *The girl is pushing the teacher with the ball* and having been primed with the picture with a HA interpretation, residual activation of the combinatorial node that specifies the presence of an instrument phrase, will facilitate subsequent sentence comprehension of that same combinatorial node. Priming may be enhanced when there is verb overlap between prime and target pairs because the link between the combinatorial node and the verb as well as the combinatorial node itself are being primed (i.e., lexical boost). Thus, according to this syntactic priming model, if there is verb-repetition between prime and target pairs, the lexical boost should arise irrespective of age.

The error-based learning model (e.g., Chang, Dell & Bock, 2006), aimed to account for language development and language processing explains priming effects with an error-driven implicit learning mechanism. When the parser encounters a structure that does not match the predicted structure (i.e., prediction error), the parser will have to adjust its weights on the structures to better predict the input. This will result in abstract syntactic priming and long-term implicit learning. The amount of the adjustment will depend on the probability of the actual input, that is, the greater the prediction error, the greater the adjustment for less probable input (i.e., high prime surprisal) giving rise to stronger priming effects for structures with high surprisal (Jaeger & Snider, 2006). Moreover, such priming effects will also accumulate throughout the experiment, making participants more likely to use the less probable input. Thus, this model predicts that Younger children will show stronger lexically-independent priming effects and cumulative effects than Older children and adults because of their high prediction error and high learning rates (Chang et al., 2006). Similarly, Older children will experience stronger lexically-independent priming effects and cumulative effects than adults. According to this model, the lexical boost originates in the explicit memory and decays quickly, therefore, since children have underdeveloped cognitive skills, children are predicted to show

no effects or inconsistent effects of a lexical boost, while adults are predicted to show a stronger lexical boost than children.

Our results showed that the English-speaking participants in our study (Chapter 2, Experiments 2 and 3) yielded a main effect of prime in the absence and presence of verb repetition between prime and target pairs. However, when prime and target pairs did not share lexical content, the priming effect was no longer reliable in children (although there was no evidence of a significant Prime and Age Group interaction).

When analysing the overall PP attachment preferences in the presence of a prime by age group, we also found that the Younger children were more likely to choose HA responses than the Older children and adults, and that no differences with respect to the number of HA responses were found between the Older children and the adults. These findings differed from experiment 1 (Baseline), whereby the Younger and the Older children's overall PP preferences did not differ significantly from each other, however, both child groups' responses did differ from the adults.

Unlike in experiment 1 (Baseline), we found that in the presence of a prime, Age in Months was a strong predictor for the children's overall PP attachment preferences. This suggested that, as children got older, they showed an increase in their overall number of LA responses and a decrease in their overall number of HA responses. After comparing the participants' overall PP preferences in the absence and presence of a prime, we found that participants were more likely to choose HA responses in the Baseline condition than in the presence of a prime irrespective of verb repetition.

The Spanish-speaking participants in our study (Chapter 3, Experiments 2 and 3) showed a main effect of prime in the absence of verb repetition, however, unlike the English-speaking children, this priming effect continued to be reliable after removing the adults' data from the analyses. This suggested that participants were less likely to choose an HA response after an LA prime than after an HA prime, even in the absence of shared lexical content between prime and target pairs.

When prime and target pairs shared the same verb, we found a main effect of prime and an interaction between Prime and Age Group that indicated that the effect of prime was only significant for the adults. This result continued to show after analysing only the children's data.

Only the Older group showed significant cumulative effects when there was verb repetition between prime and target pairs (i.e., we found a significant Trials by Age Group

interaction). That is, the Older group showed an effect of Trials, suggesting that their likelihood of choosing HA responses decreased and therefore the likelihood of choosing LA responses increased by the end of the experiment.

Also, their overall PP attachment preferences by age group differed significantly from each other in the presence of a prime with or without verb overlap. That is, the two child groups were more likely to choose HA responses than the adults, and the Younger group was more likely to choose HA responses than the Older group. These patterns were different from experiment 1 (Baseline), whereby, only the Younger group was more likely to choose HA responses than the adults, and the Older group's PP preferences did not differ from the Younger group and the adults. As for the overall proportion of HA versus LA responses between experiment 1 (Baseline) and the experiments in the presence of a prime, similarly to the English-speaking groups, the Spanish-speaking participants were more likely to choose HA responses in the baseline condition than in the Non-Repeated Verb and in the Repeated-Verb experiments.

Overall, based on the previous findings mentioned, the fact that both English and Spanish-speaking participants showed significant differences in their overall PP attachment preferences between the Baseline experiment (Experiment 1) and the priming experiments (Experiments 2 and 3); and that we did not find evidence of a significant interaction between Prime, Experiment and Age Group when comparing the Repeated-Verb against the Non-Repeated Verb experiments, this suggests that English- and Spanish-speaking participants were susceptible to the primes, even in the absence of verb repetition, reflecting existing abstract representations of the LA and HA analyses in children as young as 4. Although in the absence of verb repetition, priming effects may be weaker and more unstable in 4- to 10-year-old children, our results still showed evidence that children as young as 4 have existing abstract syntactic representations of the LA analysis and have a lexically specific component.

Our findings from Chapter 3 (Spanish-speaking participants) are somewhat unexpected. If we only consider the results from experiment 2 (Non-Repeated Verb), whereby lexical content was not shared between prime and target pairs, we could argue that Spanish-speaking children showed abstract priming effects that were reliable reflecting existing and stable abstract representations comparable to those of adults. These results would be compatible with early abstraction accounts, in that 4-year-old children show reliable abstract

priming effects. However, early abstraction accounts also predict priming effects when there is verb overlap between prime and target pairs, and such effects were not found in our study.

We cannot be certain whether verb repetition between prime and target sentences did *not* facilitate priming, as we did not find a significant interaction between Experiment and Prime; however, a plausible explanation as to why we got such results may be that children were not able to adopt the LA analysis when processing the LA primes. Therefore, their preferred analysis (i.e., HA) remained activated when they encountered the target sentence that shared the same verb as the prime sentence leading them to adopt the HA analysis again. We also hypothesised that the absence of verb repetition may have forced children to create new syntactic representations, one for the prime and another for the target sentence making the LA analysis more likely to be adopted.

This made us wonder what led Spanish-speaking children to choose the correct picture in the LA primes. A possible explanation for our results may be that when children heard a LA prime, they based their answers on the entities that were mentioned in the prime sentences. That is, for the LA prime *The girl is pushing the teacher with the ball*, children picked the picture that had a girl, a teacher, and a ball. Although this explanation is possible, it is perhaps unlikely, given the fact that children showed between 97% and 99% of accuracy in the filler trials. Specifically, one set of fillers had the agent and the patient reversed (e.g., *The queen is kissing the teacher* vs. *The teacher is kissing the queen*). Hence, to be able to choose the right picture for this filler trial, children were required to resolve the syntax accordingly. Therefore, the high accuracy of the filler trials is indicative that the children in our study were paying attention to the task and that they were understanding the sentences.

Another possible explanation may be that parents may have helped their children with their answers. Although parents were reminded that they could only offer their help for technical issues with the computer, we do not have evidence that they did not influence their children's answers, as this was a web-based experiment.

Future structural priming research should continue investigating whether similar patterns result from forced-choice picture selection tasks during the comprehension of PP attachment ambiguities in Spanish-speaking children (aged 4 to 10). Moreover, future research should also consider conducting the same experiment but with in-person testing.

Overall, our findings are not compatible with a strict item-specific and a strict item-independent accounts of language development, in which in the former, children's representations are entirely lexically-specified, while in the latter, children's syntactic

representations lack a lexical component. By contrast, our results are more compatible with early abstraction accounts, in which 4-year-old children's syntactic representations are abstract but still fragile and unstable and with a lexically specific component. However, we cannot rule out the possibility that children younger than 4 years-old may have representations that are lexically specified. Future research should continue to investigate the nature of language representations of PP attachment preferences in children younger than 4 years of age.

Taken together, our results are not fully compatible with neither of the two syntactic priming models mentioned above. That is, in one respect, the English- and Spanish-speaking participants in our studies were susceptible to the primes suggesting the existence of abstract syntactic representations of the HA and LA interpretations, although weaker and more unstable in children. These syntactic priming effects found in children and adults are consistent with both the residual activation and error-based learning models (Rowland et al., 2012; Peter et al., 2015; Branigan & McLean, 2016). However, neither of the age groups showed a lexical boost either in English or Spanish. This finding is not compatible with the residual activation account (Pickering & Branigan, 1998), which predicts enhanced priming effects when the verb is repeated between the prime and target pairs irrespective of age. These results are not compatible with the error-based learning model (Chang, Dell & Bock, 2006) either, since it predicts a lexical boost in adults and inconsistent or no effects of a lexical boost in young children. The fact that the adults in our study also did not show evidence of a lexical boost is surprising, given that in Pickering et al. (2012), adults were reported to show enhanced priming when there was verb repetition. However, it is possible that the lexical boost may not have arisen in our studies due to an overall weak priming effect found in both English- and Spanish-speaking participants. It has been suggested that priming effects in language comprehension are weaker than in language production (Thothathiri & Senedeker, 2008).

Although we found no effect of a lexical boost in studies 1 and 2, there was some suggestion that verb repetition may have facilitated language processing making our results more compatible with the error-based learning account. We found a significant interaction between Trials and Age Group, in which the Older Spanish-speaking children showed significant cumulative effects only when there was verb overlap between prime and target pairs. This may suggest that verb repetition facilitated the comprehension of the LA interpretation making the Older children more likely to adopt the less probable analysis (i.e., LA) by the end of the experiment. This finding would be consistent with the error-based

learning account that suggests cumulative effects may reflect implicit learning (Chang et al., 2006). Moreover, the fact that both English- and Spanish-speaking participants showed reliable sensitivity to the primes irrespective of verb repetition, this may also be compatible with the error-based learning account, which proposes that for priming effects to occur, the parser must have acquired and have some knowledge of the primed structure to be able to predict it.

Future research should continue to investigate the development of priming effects and the lexical boost with different structures in young and old children during language comprehension and in different languages.

If English- and Spanish-speaking participants showed sensitivity to the HA and LA primes irrespective of verb repetition, did they show significant cross-linguistic differences in attachment preferences when they were exposed to the primes? Chapter 4 addressed this question. We combined the data of the Repeated Verb and Non-Repeated verb experiments for the English- and Spanish-speaking participants and examined whether, in the presence of a prime, there were any significant differences in the overall proportion of HA versus LA responses by Age group and language, and by Age Group, Language and Prime.

Overall, we found that the Young and Adult English-speaking participants were similar to their Spanish-speaking counterparts in terms of susceptibility to the HA and LA primes. However, the Older children's PP preferences differed significantly by language. That is, the Older English-speaking children tended to choose fewer HA responses (and more LA responses) than the Older Spanish-speaking children. This developmentally mediated cross-linguistic difference suggested that in the presence of a prime, by the age of 8, it is easier for the English-speaking children to access the LA interpretation for globally ambiguous PP sentences than their Spanish-speaking counterparts. However, by the time English- and Spanish-speaking children reach adulthood, their interpretation of globally ambiguous sentences is influenced by recent language experience to the same extent. Future research should investigate whether this pattern of attachment ambiguities between English- and Spanish-speaking children (aged 4 to 10) can be replicated in further structural priming paradigms with PP attachment ambiguities.

Overall, the participants in studies 1 and 2 showed very high levels of high attachment in their sentence choices in the absence and presence of a prime with and without verb overlap.

We believe that the prevalence of instrumental verbs (*pat, push, poke, move, touch, and tickle*) used in our task, which favoured the HA interpretation of the ambiguous PP, may have led participants to show a strong preference for the HA analysis when interpreting the globally ambiguous sentences in our studies. Research in language acquisition has shown that children are sensitive to the distributional patterns presented by the linguistic input they are exposed to (Saffran, Newport & Aslin, 1996). They have the ability to track both verb-specific and verb-general statistical patterns, using this information to predict the behaviour of verbs. Children as young as five tend to rely on bottom-up cues, such as their comprehension of lexico-syntactic and semantic aspects of known verbs, in order to shape their parsing commitments (Snedeker & Trueswell, 2004; Kidd et al., 2010). Thus, they predominantly rely on verb biases during ambiguity resolution (Trueswell et al., 1999), and therefore exhibit a greater reluctance to adjust their initial parsing commitments compared to adults, even when presented with additional non-linguistic cues (Kidd & Bavin, 2005; Kidd, Stewart & Serratrice, 2011). As children accumulate more exposure to the various linguistic contexts in which familiar verbs are used, they gradually incorporate less reliable sources of information into their language interpretation strategies. However, the integration of these less-reliable cues into their parsing strategies is a process that develops over time. We suggest that the instrumental verbs used in our task (chapters 2 and 3) could have resulted in children displaying a tendency to favour the HA interpretation over the LA interpretation leading to weak priming effects. Future research should incorporate different modifier-biased verbs or only equi-biased verbs in the materials to better capture the influence of structural priming on the development of children's syntactic representations of PP attachment ambiguities.

Chapter 5 investigated whether prior exposure to an unambiguous modifier-disambiguated prime sentence (Baseline prime) (e.g., *Put the duck that is on the jacket on the blanket*) and an unambiguous goal-disambiguated prime sentence (GP prime) (e.g., *Put the duck on the blanket*) affected the processing of a subsequent temporarily ambiguous target sentence (e.g., *Put the duck on the sock on the star*) in monolingual English-speaking adults during language comprehension. We were specifically interested in whether the primes could eliminate the garden-path effect or facilitate revision mechanisms in temporarily ambiguous target sentences.

Our findings showed that prior processing of the primes did not eliminate the garden-path effect in the ambiguous target sentences, however, prior processing of a Baseline prime

facilitated garden-path recovery. This priming effect may reflect a strong lexical component given that for this experiment, prime and target pairs shared the same verb (*Put*), noun (e.g., *duck*), and preposition (e.g., *on*). Therefore, we cannot draw strong conclusions about the nature of the representations being primed. However, the fact that an unambiguous Baseline prime facilitated the processing of an ambiguous target sentence, gives rise to the interesting hypothesis that prime and target pairs may share the same Noun Phrase + Relative Clause syntactic sequence. Further studies are needed to investigate the extent to which the representations of these ambiguities are syntactically or lexically-based. However, this may be hard to determine given that this ambiguity always starts with the verb (*Put*). It is not clear what is causing the priming effect on these sentences. It could be the case that the hypothesised Noun Phrase + Relative Clause syntactic sequence shared between the prime and target pairs is what gave rise to the priming effects; or it could be a mixture of two elements, the Noun Phrase + Relative Clause syntactic sequence shared between the prime and target pairs as well as the reanalysis that occurred in the target sentences. Future studies should replicate our results and run the same experiment but with children, as we had originally intended.

If we assume that prime and target pairs share the same Noun Phrase + Relative Clause syntactic sequence and that this, along with the same shared verb, head noun and preposition between prime and target, were what gave rise to the priming effects, then our findings would be compatible with the residual activation account (Pickering & Branigan, 1998). That is, residual activation of the pre-activated lemma and combinatorial nodes and the links between these two, facilitated the processing of a subsequent ambiguous target sentence by weakening the garden-path effect and facilitating garden-path recovery. Moreover, the fact that priming effects occurred with the Baseline prime, but not with the goal-disambiguated prime, may also suggest that some aspects of the representation of the Baseline prime were activated and that the parser was influenced by this pre-activation resulting in facilitated processing of an ambiguous target sentence. Thus, these findings may also be compatible with interactive accounts, in that the parser employed other sources of information e.g., recent language experience (not only syntactic information) to resolve ambiguities more efficiently.

6.2.3 The developing parser and Prepositional-Phrase ambiguity resolution

Overall, studies 1 and 2 showed that adults were more likely to accept the LA interpretation in the absence and presence of a prime than children. This may be attributed to

differences between the mature and the developing parser. Previous studies have shown how adults exhibit a higher tendency compared to children to use other sources of information such as referential cues and plausibility when processing language (Kind & Bavin, 2005; Trueswell et al., 1999). Moreover, adults are more likely to disengage from an initial parse and recover from garden-path more efficiently than children (Trueswell et al., 1999; Snedeker & Trueswell, 2004). These differences may have played a role in children showing less acceptance towards the LA interpretation.

Due to the nature of the picture-selection task employed in studies 1 and 2 (i.e., forced-choice, HA vs. LA), we cannot be certain to what extent children considered the LA interpretation over the HA interpretation when a prime was presented. However, based on our findings, we know that participants showed sensitivity to the prime sentences, as they were more likely to choose a HA response in the absence of a prime than in the presence of a prime. This raises the question as to whether children between the ages of 4 and 10 show the same language processing mechanisms to disambiguate globally ambiguous sentences in the presence of a prime as adults. If we adopt a constraint-based approach for language comprehension (e.g., MacDonald et al., 1994; Trueswell, Sekerina, Hill, Logrip, 1999), then we would assume that while processing the globally ambiguous sentences in the presence of a prime, the developing parser activated both the HA and LA analyses in parallel and, based on the levels of activation of each alternative, the two analyses competed against each other and got ranked. Recent language experience (i.e., the priming effect) may have influenced the levels of activation of both the HA and LA alternatives (depending on the prime-type trial). However, when the developing parser weighted the two analyses based on the compatibility that they had with other constraints e.g., lexical biases, referential context, plausibility, etc, including recent language experience, we assume that the HA analysis showed an increased activation resulting in less activation for the LA analysis due to the fact that children tend to rely more on lexical information when processing language (Snedeker & Trueswell, 2004). That is, verb biases outweighed the effect of recent language experience (i.e., priming effect) leading to high levels of high-attachment in children's sentence choices.

To further explore whether children consider the two analyses in parallel and on a moment-to-moment basis even after selecting the HA interpretation as the final choice, future research should use eye-tracking methods to conduct the same priming experiment using the same task. If children show an important number of fixations on the LA pictures (as well as on the HA pictures) within the same time-window, this may suggest that the developing parser

considered both analyses in parallel and used different sources of information to guide their parsing commitments. If, on the target trials, there are more fixations on the LA pictures than the HA pictures after hearing a LA prime, and more fixations on the HA pictures than the LA pictures after hearing a HA prime, this would suggest that the developing parser used recent language experience as a cue to interpret language on a trial-by-trial basis, however this cue may not have been strong or reliable enough to make children change their final sentence choices. If this were the case, these findings would be compatible with the constraint-based model (e.g., MacDonald et al., 1994; Trueswell, Sekerina, Hill, Logrip, 1999). If, on the other hand, children showed an important number of fixations on both the HA and LA pictures after their corresponding primes, but the fixations on the LA pictures after a LA prime took place on a subsequent time-window, this might support serial processing (Garden-Path model, Frazier & Fodor, 1978; Frazier & Rayner, 1982; Frazier & Clifton, 1996), which suggests the existence of a second non-syntactic stage during language comprehension (see Chapter 1, section 1.3.1).

Future researchers should also consider incorporating different modifier-biased verbs or only equi-biased verbs in the experimental items to better capture the influence of recent language experience on PP ambiguity resolution processes in children. Moreover, using a task that measures, not binary attachment preferences, but the levels or degrees of acceptance of one analysis over another, may help us understand the human parser better and the mechanisms that are employed to solve PP attachment ambiguities.

6.3 Conclusion

The aim of this thesis was to gain a better understanding of the role of recent language experience in children's language representations during language comprehension. We specifically focussed on investigating the nature and development of language representations in 4- to 6 and 8- to 10-year-old English- and Spanish-speaking children and adults. We examined whether PP attachment preferences in children and adults were influenced by recent experience of a structure or a structure in association with a particular verb and whether children and adults showed cumulative priming effects.

Overall, our findings provided evidence that English- and Spanish-speaking children and adults showed reliable sensitivity to the language input to which they were exposed

reflecting changes in their syntactic choices during language comprehension. This reliable sensitivity was reflected on both in the overall PP attachment preferences and in the priming effects in children and adults. However, we did not find the same patterns of structural priming effects in English- and Spanish-speaking children. This suggests that to better understand language development, future research should continue to study cross-linguistic differences in structural priming paradigms in children.

Although we did not find evidence for a lexical boost, we found that shared lexical content between the prime and target sentences may have facilitated processing of the HA and LA analyses of globally ambiguous sentences and that children's abstract representations of the LA analysis may be more fragile than the ones of adults'.

We conclude that 4- to 6 and 8- to 10-year-old English- and Spanish-speaking children's abstract representations of the LA analysis may still be weakly represented and that more power may be needed to detect reliable lexically-independent priming effects.

7 References

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8 Appendix: Experimental materials

8.1 Materials used in Study 1 (Chapter 2)

Prime sentences

1. The man is patting the frog with the pencil.
2. The child is patting the lady with the flower.
3. The child is patting the cat with the banana.
4. The boy is patting the doctor with the feather.
5. The girl is pushing the teacher with the ball.
6. The king is pushing the frog with the banana.
7. The queen is pushing the clown with the brush.
8. The policeman is pushing the cat with the ball.
9. The girl is poking the cat with the stick.
10. The policeman is poking the kid with the key.
11. The queen is poking the monkey with the brush.
12. The king is poking the doctor with the pencil.
13. The girl is moving the lady with the ball.
14. The king is moving the cat with the banana.
15. The queen is moving the clown with the stick.
16. The policeman is moving the monkey with the key.
17. The man is touching the lady with the brush.
18. The woman is touching the frog with the ball.
19. The boy is touching the clown with the key.
20. The child is touching the sheep with the flower.
21. The man is tickling the monkey with the banana.
22. The boy is tickling the lady with the feather.
23. The woman is tickling the kid with the stick.
24. The woman is tickling the cat with the brush.

Target sentences

1. The policeman is patting the kid with the stick.
2. The queen is patting the monkey with the brush.
3. The king is patting the teacher with the book.
4. The girl is patting the dog with the feather.
5. The woman is pushing the sheep with the pencil.
6. The child is pushing the doctor with the book.
7. The boy is pushing the dog with the key.
8. The man is pushing the lady with the book.
9. The man is poking the clown with the stick.
10. The woman is poking the dog with the banana.
11. The child is poking the teacher with the flower.
12. The boy is poking the sheep with the pencil.
13. The child is moving the frog with the banana.
14. The boy is moving the doctor with the flower.
15. The man is moving the sheep with the book.
16. The woman is moving the kid with the book.
17. The girl is touching the dog with the banana
18. The policeman is touching the teacher with the stick.
19. The king is touching the monkey with the feather.
20. The queen is touching the kid with the key.
21. The policeman is tickling the dog with the flower.
22. The king is tickling the frog with the brush.
23. The queen is tickling the teacher with the flower.
24. The girl is tickling the clown with the feather.

Filler sentences

1. The girl is chasing the sheep.
2. The man is carrying the doctor.
3. The king is hugging the lady.
4. The woman is talking to the policeman.
5. The queen is kissing the teacher.
6. The child is smelling the dog.

7. The policeman is chasing the sheep.
8. The king is carrying the kid.
9. The girl is hugging the teacher.
10. The king is talking to the doctor.
11. The woman is kissing the clown.
12. The man is smelling the teacher.
13. The dog is chasing the cat.
14. The policeman is carrying the teacher.
15. The woman is hugging the monkey.
16. The child is talking to the teacher.
17. The girl is kissing the frog.
18. The dog is smelling the lady.
19. The girl is dancing.
20. The policeman is running.
21. The king is eating.
22. The woman is singing.
23. The boy is jumping.
24. The king is sleeping.

8.2 Materials used in Study 2 (Chapter 3)

Prime sentences

1. El hombre está acariciando a la rana con el lápiz.
2. El niño está acariciando a la señora con la flor.
3. El niño está acariciando al gato con el plátano.
4. El niño está acariciando al doctor con la pluma.
5. La niña está empujando al maestro con la pelota.
6. El rey está empujando a la rana con el plátano.
7. La reina está empujando al payaso con el cepillo.
8. El policía está empujando al gato con la pelota.
9. La niña está picando al gato con la rama.
10. El policía está picando al niño con la llave.

11. La reina está picando al mono con el cepillo.
12. El rey está picando a la doctora con el lápiz.
13. La niña está moviendo a la señora con la pelota.
14. El rey está moviendo al gato con el plátano.
15. La reina está moviendo al payaso con la rama.
16. El policía está moviendo al mono con la llave.
17. El hombre está tocando a la señora con el cepillo.
18. La mujer está tocando a la rana con la pelota.
19. El niño está tocando al payaso con la llave.
20. El niño está tocando a la oveja con la flor.
21. El hombre está haciendo reír al mono con el plátano.
22. El niño está haciendo reír a la señora con la pluma.
23. La mujer está haciendo reír al niño con la rama.
24. La mujer está haciendo reír al gato con el cepillo.

Target sentences

1. El policía está acariciando al niño con la rama.
2. La reina está acariciando al mono con el cepillo.
3. EL rey está acariciando al maestro con el libro.
4. La niña está acariciando al perro con la pluma.
5. La mujer está empujando a la oveja con el lápiz.
6. El niño está empujando al doctor con el libro.
7. El niño está empujando al perro con la llave.
8. El hombre está empujando a la señora con el libro.
9. El hombre está picando al payaso con la rama.
10. La mujer está picando al perro con el plátano.
11. El niño está picando a la maestra con la flor.
12. El niño está picando a la oveja con el lápiz.
13. El niño está moviendo a la rana con el plátano.
14. El niño está moviendo al doctor con la flor.
15. El hombre está moviendo a la oveja con el libro.
16. La mujer está moviendo al niño con el libro.
17. La niña está tocando al perro con el plátano.

18. El policía está tocando al maestro con la rama.
19. El rey está tocando al mono con la pluma.
20. La reina está tocando al niño con la llave.
21. El policía está haciendo reír al perro con la flor.
22. El rey está haciendo reír a la rana con el cepillo.
23. La reina está haciendo reír al maestro con la flor.
24. La niña está haciendo reír al payaso con la pluma.

Filler sentences

1. La niña está correteando a la oveja.
2. El hombre está cargando al doctor.
3. El rey está abrazando a la señora.
4. La mujer está hablando con el policía.
5. La reina está besando al maestro.
6. El niño está oliendo al perro.
7. El policía está correteando a la oveja.
8. El rey está cargando al niño.
9. La niña está abrazando a la maestra.
10. El rey está hablando con la doctora.
11. La mujer está besando al payaso.
12. El hombre está oliendo a la maestra.
13. El perro está correteando al gato.
14. El policía está cargando al maestro.
15. La mujer está abrazando al mono.
16. El niño está hablando con la maestra.
17. La niña está besando a la rana.
18. El perro está oliendo a la señora.
19. La niña está bailando.
20. El policía está corriendo.
21. El rey está comiendo.
22. La mujer está cantando.
23. El niño está saltando.
24. El rey está durmiendo.

8.3 Materials used in Study 4 (Chapter 5)

Modifier-disambiguated prime sentences

1. Put the duck that is on the jacket on the blanket.
2. Put the fish that is on the blanket on the sock.
3. Put the fork that is on the sock on the bread.
4. Put the apple that is on the bread on the plate.
5. Put the rabbit that is on the plate on the book.
6. Put the cow that is on the book on the pillow.
7. Put the key that is on the pillow on the towel.
8. Put the cat that is on the towel on the shirt.
9. Put the shoe that is on the shirt on the soap.
10. Put the spoon that is on the soap on the star.
11. Put the pencil that is on the star on the shorts.
12. Put the flower that is on the shorts on the jacket.
13. Put the chocolate that is on the blanket on the jacket.
14. Put the pig that is on the sock on the blanket.
15. Put the plant that is on the bread on the sock.
16. Put the dog that is on the plate on the bread.
17. Put the brush that is on the book on the plate.
18. Put the water bottle that is on the pillow on the book.
19. Put the ball that is on the towel on the pillow.
20. Put the banana that is on the shirt on the towel.
21. Put the egg that is on the on the soap on the shirt.
22. Put the tree that is on the star on the soap.
23. Put the butterfly that is on the shorts on the star.
24. Put the lollipop that is on the jacket on the shorts.
25. Put the coin that is on the jacket on the star.
26. Put the lion that is on the star on the jacket.
27. Put the baby that is on the jacket on the pillow.
28. Put the turtle that is on pillow on the jacket.

29. Put the colour that is on the blanket on the bread.
30. Put the toy that is on the bread on the blanket.
31. Put the carrot that is on the blanket on the shirt.
32. Put the rock that is on the shirt on the blanket.
33. Put the cake that is on the sock on the book.
34. Put the pear that is on the book on the sock.
35. Put the biscuit that is on the sock on the towel.
36. Put the monkey that is on the towel on the sock.
37. Put the horse that is on the soap on the bread.
38. Put the sheep that is on the bread on the soap.
39. Put the circle that is on the plate on the shorts.
40. Put the popcorn that is on the shorts on the plate.
41. Put the strawberry that is on the book on the shirt.
42. Put the orange that is on the shirt on the book.
43. Put the glasses that are on the pillow on the soap.
44. Put the tiger that is on the soap on the pillow.
45. Put the chicken that is on the towel on the plate.
46. Put the cup that is on the plate on the towel.
47. Put the hat that is on the star on the shorts.
48. Put the boat that is on the shorts on the star.

Goal-disambiguated prime sentences

1. Put the duck on the blanket.
2. Put the fish on the sock.
3. Put the fork on the bread.
4. Put the apple on the plate.
5. Put the rabbit on the book.
6. Put the cow on the pillow.
7. Put the key on the towel.
8. Put the cat on the shirt.
9. Put the shoe on the soap.
10. Put the spoon on the star.
11. Put the pencil on the shorts.

12. Put the flower on the jacket.
13. Put the chocolate on the jacket.
14. Put the pig on the blanket.
15. Put the plant on the sock.
16. Put the dog on the bread.
17. Put the brush on the plate.
18. Put the water bottle on the book.
19. Put the ball on the pillow.
20. Put the banana on the towel.
21. Put the egg on the shirt.
22. Put the tree on the soap.
23. Put the butterfly on the star.
24. Put the lollipop on the shorts.
25. Put the coin on the star.
26. Put the lion on the jacket.
27. Put the baby on the pillow.
28. Put the turtle on the jacket.
29. Put the colour on the bread.
30. Put the toy on the blanket.
31. Put the carrot on the shirt.
32. Put the rock on the blanket.
33. Put the cake on the book.
34. Put the pear on the sock.
35. Put the biscuit on the towel.
36. Put the monkey on the sock.
37. Put the horse on the bread.
38. Put the sheep on the soap.
39. Put the circle on the shorts.
40. Put the popcorn on the plate.
41. Put the strawberry on the shirt.
42. Put the orange on the book.
43. Put the glasses on the soap.
44. Put the tiger on the pillow.
45. Put the chicken on the plate.

46. Put the cup on the towel.
47. Put the hat on the shorts.
48. Put the boat on the star.

Target sentences

1. Put the duck on the sock on the star.
2. Put the fish on the bread on the shorts.
3. Put the fork on the star on the pillow.
4. Put the apple on the jacket on the shirt.
5. Put the rabbit on the towel on the bread.
6. Put the cow on the shirt on the plate.
7. Put the key on the blanket on the soap.
8. Put the cat on the soap on the book.
9. Put the shoe on the plate on the pillow.
10. Put the spoon on the shorts on the sock.
11. Put the pencil on the jacket on the towel.
12. Put the flower on the book on the blanket.
13. Put the chocolate on the star on the sock.
14. Put the pig on the shorts on the bread.
15. Put the plant on the pillow on the star.
16. Put the dog on the shirt on the jacket.
17. Put the brush on the bread on the towel.
18. Put the water bottle on the plate on the shirt.
19. Put the ball on the soap on the blanket.
20. Put the banana on the book on the soap.
21. Put the egg on the pillow on the plate.
22. Put the tree on the sock on the shorts.
23. Put the butterfly on the towel on the jacket.
24. Put the lollipop on the blanket on the book.
25. Put the coin on the pillow on the bread.
26. Put the lion on the sock on the plate.
27. Put the baby on the shirt on the shorts.
28. Put the turtle on the star on the towel.

29. Put the colour on the jacket on the soap.
30. Put the toy on the towel on the star.
31. Put the carrot on the soap on the jacket.
32. Put the rock on the star on the bread.
33. Put the cake on the bread on the pillow.
34. Put the pear on the soap on the towel
35. Put the biscuit on the shorts on the shirt.
36. Put the monkey on the bread on the star.
37. Put the horse on the plate on the sock.
38. Put the sheep on the jacket on the sock.
39. Put the circle on the sock on the jacket.
40. Put the popcorn on the blanket on the book.
41. Put the strawberry on the book on the blanket.
42. Put the orange on the plate on the blanket.
43. Put the glasses on the blanket on the plate.
44. Put the tiger on the shorts on the book.
45. Put the chicken on the book on the shorts.
46. Put the cup on the shirt on the pillow.
47. Put the hat on the pillow on the shirt.
48. Put the boat on the towel on the soap.

Filler sentences

1. Click on the plate.
2. Find the turtle.
3. Click on the green shirt.
4. Find the shirt.
5. Click on the green jacket.
6. Find the orange.
7. Click on the key.
8. Find the blue sock.
9. Click on the lion.
10. Find the cat.
11. Click on the yellow pillow.

12. Find the chicken.
13. Click on the red circle.
14. Find the red jacket.
15. Click on the sock.
16. Find the spoon.
17. Click on the shorts.
18. Find the boat.
19. Click on the horse.
20. Find the pear.
21. Click on the red book.
22. Find the biscuit.
23. Click on the ball.
24. Find the butterfly.
25. Click on the flower.
26. Find the monkey.
27. Click on the tiger.
28. Click on the star.
29. Find the blue shirt.
30. Click on the book.
31. Find the green sock.
32. Click on the lollipop.
33. Find the rabbit.
34. Click on the glasses.
35. Find the baby.
36. Click on the fish.
37. Find the carrot.
38. Click on the apple.
39. Find the ball.
40. Click on the towel.
41. Find the plant.
42. Click on the popcorn.
43. Find the strawberry.
44. Click on the sheep.
45. Find the duck.

46. Find the yellow soap.
47. Click on the rock.
48. Find the cow.
49. Click on the shoe.
50. Find the pink blanket.
51. Click on the banana.
52. Find the chocolate.
53. Click on the blue book.
54. Find the cup.
55. Click on the tree.
56. Find the pencil.
57. Find the fork.
58. Click on the soap.
59. Find the water bottle.
60. Click on the egg.
61. Find the colour.
62. Click on the blue pillow.
63. Find the bread.
64. Click on the brush.
65. Find the toy.
66. Click on the cake.
67. Find the jacket.
68. Click on the dog.
69. Find the coin.
70. Click on the green soap.
71. Find the pig.
72. Click on the pillow.