CellPress
OPEN ACCESS

Trends in
Cognitive Sciences

Review

# Learning word order: early beginnings

Irene de la Cruz-Pavía [1,2,3,*] Caterina Marino [4] and Judit Gervain [1,4]

**We examine the beginning of the acquisition of the relative order of function and content words, a fundamental but cross-linguistically highly variable aspect of grammar. A review of the existing empirical literature shows that infants as young as 8 months of age can distinguish between functors and content words, and have a rudimentary knowledge of the order of these two universal lexical categories in their native language. Furthermore, human adults and nonhuman animals such as rodents process the same linguistic information differently from infants, emphasizing the developmental relevance of bootstrapping function/content word order from surface cues available in the input. We discuss the implications of these findings for a synergistic view of language acquisition, considering how grammar acquisition interacts with word learning.**

## Highlights

By 7–8 months of age, infants already have a rudimentary but abstract representation of word order, specifically of the relative order of functors and content words in their native language.

Moreover, by 8–17 months of age infants are sensitive to *all* characteristics that universally distinguish between functors and content words, namely their differing prosodic, statistical, distributional, and functional properties.

The acquisition of grammar is thus intimately intertwined with lexical acquisition, supporting a model of language growth in which the different levels of language develop synergistically, bootstrapping learning interactively.

## Discovering the beginnings of word order: function and content words

Because speech unfolds over time, linguistic units need to be ordered sequentially. How languages linearize the order of words is one of the most fundamental but cross-linguistically variable aspects of **grammar** (see Glossary), which infants need to learn as they acquire their native language. The current paper argues that word order acquisition starts in the first year of life, as infants discover one of its most basic features, namely the relative order of **function words** (also known as functors) – words that indicate grammatical structure, such as *she*, *it*, *on*, *the*, *up*, etc., and **content words** – words that carry lexical meaning, such as *turtle*, *rainbow*, *run*, *beautiful*, etc.

The relative order of functors and content words varies across languages. In many languages such as English and Italian, most functors precede content words: for example, English: *in the house*; Italian: *nella casa*. In other languages such as Turkish or Basque, functors typically follow content words: for example, Basque: *etxean*, house.in 'in the house'; Turkish: *evde*, house.in 'in the house'. As the examples illustrate, whether the functor is free (i.e., independent words), for example, English *the house*, or bound (i.e., it is attached to another word as an **affix**), for example, Hungarian *ház* 'house' versus *házban*, house.in 'in the/a house', also varies. To correctly understand and produce multiword utterances, infants need to learn the order that characterizes their mother tongue. This is thus a crucial early step in acquiring their native language, and, because the relative order of functors and content words correlates with other word order phenomena (e.g., the order of verbs and objects, of the noun and its relative **clause**, or of the possessor and the possessed [1–3]), discovering their order may be a useful first cue to bootstrap other aspects of grammar.

When and how do infants achieve this? A growing body of empirical literature suggests that infants as young as 8 months of age distinguish the universal lexical categories of functors and content words, and have a rudimentary knowledge of their relative order in the native language [4–6]. Recent findings also indicate that adults represent the same linguistic information in slightly different ways, revealing a developmental change in how humans process new linguistic input [7,8]. Whereas infants capture the input by extracting broad generalizations, adults reproduce the word order inconsistencies of the native language. Interestingly, non-human animals (rodents)

[1]Department of Developmental and Social Psychology (DPSS), Università di Padova, Padua, Italy
[2]Department of Linguistics and Basque Studies, Universidad del País Vasco/ Euskal Herriko Unibertsitatea (UPV/ EHU), Vitoria-Gasteiz, Spain
[3]Ikerbasque – Basque Foundation for Science, Bilbao, Spain
[4]Integrative Neuroscience and Cognition Center (INCC), Centre National de la Recherche Scientifique (CNRS), Université de Paris, Paris, France

*Correspondence:
irene.delacruz@ehu.eus
(I. de la Cruz-Pavía).

are also sensitive to the surface cues, in other words the low-level cues that are available in the signal (e.g., frequency) that distinguish between functors and content words, but crucially do not map these onto structural representations – abstract representations of the structure of the input [9]. Adults and non-human animals thus process the same linguistic information differently from infants, emphasizing the developmentally unique learning situation for the acquisition of grammar.

We review here the relevant empirical studies in the three populations and discuss the implications of these findings for a synergistic view of language acquisition, showing that the acquisition of grammar starts early and proceeds hand in hand with word learning, specifically with the distinction between the two universal lexical classes.

## The differing properties of function words and content words

The distinction between content words and function words is found universally (S. Abney, PhD thesis, MIT 1987 and N. Fukui, PhD thesis, MIT, 1986) in all natural languages. Content words are words that carry lexical meaning such as nouns (*turtle*, *chocolate*, etc.), verbs (*run*, *feel*, etc.), or adjectives (*pretty*, *green*, etc.). Functors are morphemes that encode grammatical function such as prepositions (*up*, *in*, etc.), pronouns (*she*, *it*, etc.) and determiners (*this*, *a*, etc.). Functors may be free – independent words, or can be bound – attached to another word as an affix.

These two broad classes of words differ not only in their distributional properties (i.e., their relative order across languages) but also in their functional, prosodic, and statistical properties. Functors belong to small, closed categories: without major language change, it is not possible to add a new functor to the grammar of a language. Meanwhile, content words form open categories to which new items can be added, for example, *iPad*, *app*. This is masterfully illustrated in Lewis Carroll's *Jabberwocky* poem – content words can be replaced with nonsense words provided that the functors are preserved: '*Twas brillig, and the slithy toves / Did gyre and gimble in the wabe …*'. Functors are phonologically minimal, whereas content words are heavy [10]. The exact features in which they differ vary across languages, but functors are typically unstressed, have a simpler syllable structure, reduced vowels, shorter duration, etc. Content words, by contrast, receive lexical (and phrasal) stress, and have a greater number of and more complex syllables, etc. Statistically, individual function words are typically much more frequent than individual content words [4,11]. Indeed, the 20–50 most frequent words in a language are usually functors [4]. The statistical and prosodic features of functors might be related because, from an **information theory** perspective, highly frequent signals should be shorter than less frequent signals [12–15]. Importantly, the statistical and phonological differences between functors and content words are relevant for language acquisition because they are readily observable in the speech input, and thus offer cues for infants to distinguish between the two lexical categories.

## Prelexical infants' representation of the order of functors and content words

Infants begin to recognize the functors of their native language at around 6–8 months of age, starting with those that are most frequent [16–18]. Indeed, frequency may be one of the earliest cues to lexical category identity. Specifically, the frequency-based bootstrapping hypothesis [4,6,19] argues that infants categorize words as functors on the basis of their high frequency and start to use them as anchors to encode structure and learn the sequential position of other words with respect to them ([20–24] for a similar proposal with respect to older children). This hypothesis is supported by artificial language learning studies [4–6]. In these studies, infants are familiarized with a continuous speech stream in which frequent and infrequent words strictly alternate, mimicking functors and content words, respectively, in natural languages (Figure 1). The beginning and the end of the stream are ramped in amplitude, making it structurally

### Glossary of linguistic terms

**Affix:** a bound morpheme that is attached to the root. Suffixes are affixes that follow the root; prefixes are affixes that precede it.

**Backward transitional probabilities:** the probability ($P$) that one element (Y, e.g., the content word *turtle*) will be *preceded* by another element (X, e.g., the functor *the*): $P(X|Y)$ = frequency(XY)/ frequency(Y).

**Clause:** a constituent of the syntactic hierarchy, it consists of a subject and a predicate, and can stand alone (i.e., a main clause) or depend from another clause (i.e., a subordinate clause).

**Content words:** words that carry lexical meaning and form an open class to which new items can be added, such as nouns (*popcorn*, *owl*), verbs (*dance*, *cook*) or adjectives (*purple*, *big*). They are one of the two universal broad classes of words in natural languages.

**Forward transitional probabilities:** the probability ($P$) that one element (X, e.g., the functor *the*) will be *followed* by another element (Y, e.g., the content word *turtle*): $P(Y|X)$ = frequency(XY)/ frequency(X).

**Function words (or functors):** morphemes that belong to a small, closed class, and which signal grammatical relations such as determiners (*the*, *a*), prepositions (*of*, *from*), or pronouns (*they*, *us*). They can be bound (i.e., attached to a word as an affix) or free (i.e., independent words). Functors are one of the two universal broad classes of words in natural languages.

**Functor-directionality:** the relative order of functors and content words in natural languages. Functors can precede content words (functor-initial order), or follow them (functor-final order). This property varies cross-linguistically, and correlates with other word order phenomena (e.g., the order of verbs and objects), as well as with the location and realization of phrase-level prosodic prominence.

**Functor-final languages:** languages in which functors typically follow content words, such as Basque, Turkish, and Japanese.

**Functor-initial languages:** languages in which most functors precede content words, such as English, French, and Italian.

**Grammar:** the structural organization of a natural language.

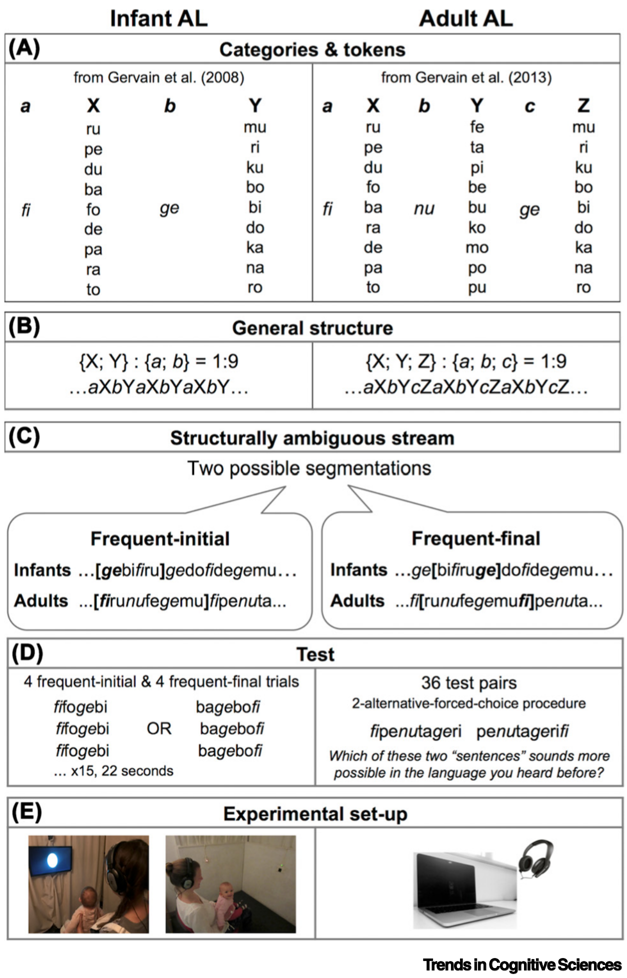


Figure 1. Shared structure of the artificial languages (ALs) designed to test infants (Gervain *et al.* 2008) [4] (left) and adults (Gervain *et al.* 2013) [7] (right). (A) The categories and tokens of the artificial languages. Half of the categories contained a single token each [infant artificial language (AL): categories *a*, *b*; adult AL: *a*, *b*, *c*], the remaining half contained nine tokens each (infant AL: categories X, Y; adult AL: X, Y, Z). These two types of categories were concatenated into a basic unit in strict alternation (infant AL: *aXbY*; adult AL: *aXbYcZ*). The basic unit was then concatenated into a constant stream and used for familiarization (B). As a result, tokens of single-token categories (*a*, *b*, and, for adults, *c*) occurred ninefold more frequently than tokens of multiple-token categories (X, Y, and, for adults, Z), mimicking the relative frequency of functors and content words in natural languages. Ramping the amplitude of the beginning and end of the familiarization streams rendered them structurally ambiguous (C). Thus, each stream allowed two possible parses: one in which frequent elements occurred at the initial position (i.e., frequent-initial order), and one in which they occurred in the final position (i.e., frequent-final order). After being familiarized with the ambiguous stream, infants and adults were tested on their preference for frequent-initial versus frequent-final sequences (D). For infants, looking times to the visual stimuli while listening to the two types of sequences were recorded and compared (headturn preference procedure). Adults expressed their preference by pressing keys on a keyboard (E).

ambiguous between a frequent-initial word order (a characteristic of **functor-initial languages**) or a frequent-final order (as in **functor-final languages**). In the test phase, infants are then presented with sequences four syllables in length that begin or end with a frequent element. Importantly, test items are always taken from the familiarization stream, so both frequent-word-initial and frequent-word-final test items are familiar. If infants show a preference for one word order over the other, this preference derives from knowledge the infants bring to the task. Therefore, these studies do not test learning of a structure or rule *during* the experiment, but whether infants already know the order of functors and content words in the native language, and generalize this knowledge to a new, structurally ambiguous, artificial language.

These experiments show that, by 7–8 months of age, infants track the frequency distribution of the elements in the linguistic input, and prefer to listen to test items that follow the word order of their native language. Specifically, Japanese (functor-final) learners prefer items with the frequent-final word order, whereas English, French, and Italian learners (all functor-initial) prefer the frequent-initial word order [4–6]. Infants show this preference whenever functors stand out

**Information theory:** the scientific study of how information is coded and transmitted. It argues that, to improve the efficiency of signal transmission, the most frequent elements in a communicative system (e.g., the most frequent words in a language) should be shortest.
**Morphology:** the set of rules that govern the internal structure of the words. It is part of the grammar of natural languages.
**Phonological phrase (PhP):** a constituent of the prosodic hierarchy, it comprises a content word – which receives prominence – and its related functors on the non-branching side. Syntactic and prosodic phrases are not isomorphic, but they must align at one of their edges. For example, '*dei pasticcini ripieni di cioccolata*' (some pastries filled with chocolate): (i) syntactic bracketing: [*dei pasticcini* [*ripieni di cioccolata*]$_{AP}$]$_{NP}$ (AP, Adjectival Phrase; NP, Noun Phrase); (ii) prosodic bracketing: [*dei pasticcini*]$_{PhP}$ [*ripieni*]$_{PhP}$ [*di cioccolata*]$_{PhP}$.
**Syntax:** the set of rules that govern how words are combined into bigger units such as phrases and sentences. It is part of the grammar of natural languages.
**Syntactic phrase:** a constituent of the syntactic hierarchy, it contains a head and its dependencies such as its complement.

as invariable anchor points in a sufficiently variable familiarization stream [25]. Furthermore, by 13 months of age, infants' knowledge of the **functor-directionality** of their native language impacts on the learning strategies they rely on to parse new input. English (functor-initial) learners rely on **backward transitional probabilities** to group 'words' into larger units, whereas Korean (functor-final) learners use **forward transitional probabilities** instead [26].

Although monolinguals can rely on the distribution of frequent words to establish the relative order of functors and content words, this cue is ambiguous for bilingual learners of a functor-initial and a functor-final language because they are exposed to frequent-initial *and* final structures in their input. How can they learn the order of functors and content words? Prosodic information might provide a relevant additional cue [27].

Functor-directionality correlates with the location and realization of phrase-level prosodic prominence in natural languages [27]. Because prominence is carried by the content words, it occurs phrase-finally in functor-initial languages, but phrase-initially in functor-final languages. Importantly, phrasal prominence is realized through increased duration in functor-initial languages (English: *in* ***Ro:****me*), but through increased pitch or intensity in functor-final languages (Japanese: ^***To****kyo ni*, Tokyo in) [5,27]. Thus the acoustic cues indicating prosodic prominence correlate with functor-directionality. Sensitivity to the position and acoustic realization of phrase-level prosody could thus provide an additional cue to identifying the order in their two languages.

Do infants perceive these cues? From birth, infants are sensitive to the acoustic correlates of **phonological phrase** boundaries [28] and the acoustic properties distinguishing between functors and content words [29]. By 6–12 weeks of age they discriminate sentences in languages with opposite word orders solely on the basis of phrasal prominence [30]. Most importantly, by 7–8 months mono- and bilingual infants can use phrase-level prosody as a direct cue to word order [5,19]: bilinguals exposed to one frequent-initial and one frequent-final language parse a prosodically enriched variant (Figure 2) of the earlier-described artificial language into frequent-initial units when presented with a durational contrast (with infrequent words lengthened), but into frequent-final units when the same language is presented with a pitch contrast instead (with infrequent words being higher in pitch). Furthermore, infants integrate the prosodic and word frequency information. Presenting the two in conflict (e.g., functor-final prosody to learners of a functor-initial language) or misaligned (e.g., prosodic prominence falling on the frequent word, i.e., the functor, and not on the infrequent word, i.e., the content word) disrupts the word order preference of monolingual infants [5,19,31]. In addition, at around 8 months of age infants begin to develop sensitivity to visual correlates of auditory prosody (i.e., head nods produced by an animated avatar, concurrent with phrasal prominence; Figure 2), although their influence is limited [32].

By this age, infants also show sensitivity to another distinctive feature of functors and content words – the extendibility of their categories. Content words form an open class [6], which accepts new members, whereas functors form a closed class, which does not. Thus, French 8-month-old infants, learners of a functor-initial language, who parse the structurally ambiguous artificial language in [4] into the predicted frequent-initial word order, maintain this word order preference when, in test, infrequent elements are replaced with new, previously unheard tokens, whereas frequent elements are preserved (Figure 2). Crucially, however, their word order preference is disrupted when frequent elements are replaced with new tokens, while preserving the infrequent elements (Figure 2) [6]. These results establish the sensitivity of infants to the functional properties of functors as anchors for structure, which form a closed class [23].

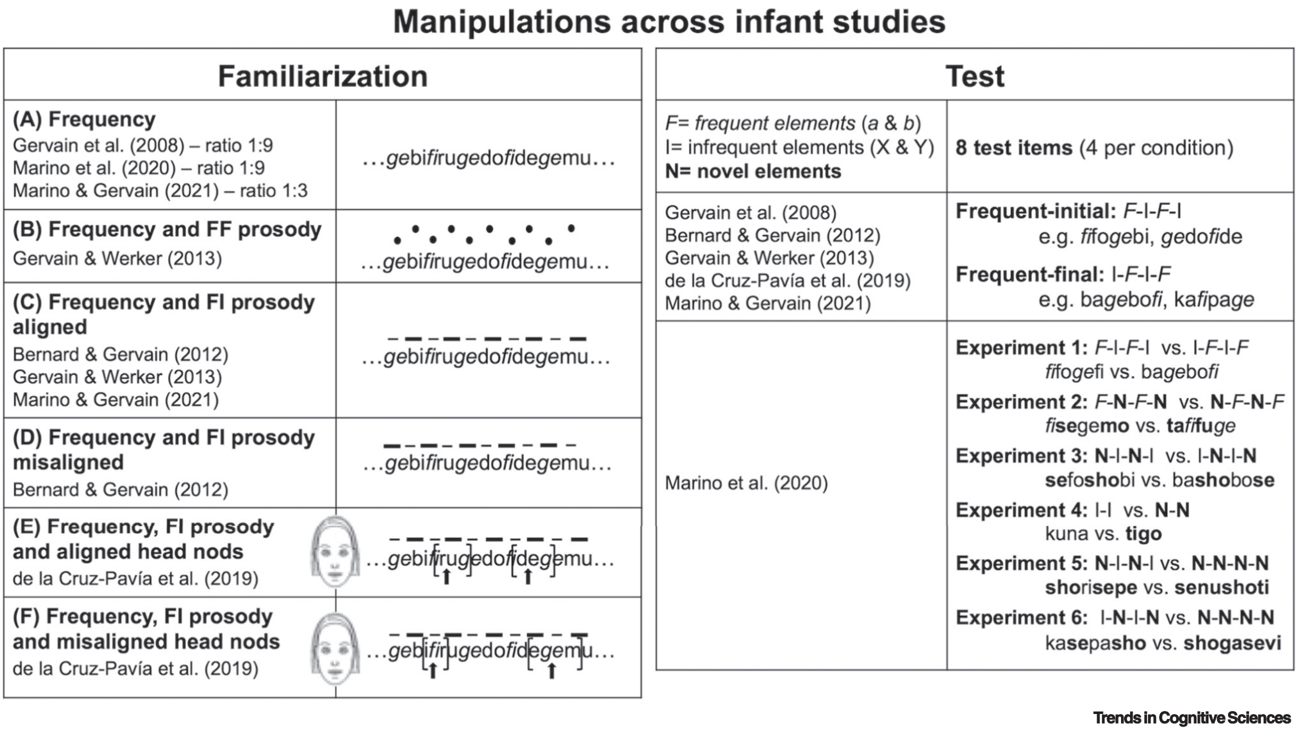


Figure 2. Graphical depiction of the manipulations of familiarization (left table) and test (right table) carried out across infant studies. All artificial languages consisted of a strict alternation of frequent (i.e., *ge*, *fi*) and infrequent elements (e.g., *bi*, *ru*, *do* …), mimicking functors and content words, respectively (panel A in left table). Frequent tokens were ninefold more frequent than infrequent tokens [4–6,19,32] in all but one study [25] in which they were only threefold more frequent (A). Some artificial languages additionally included the prosodic patterns marking phrasal prominence in natural languages: alternating elements with higher versus lower pitch (224 versus 200 Hz) [5], as in functor-final (FF) languages (B), or alternating short and long elements (120 versus 144 ms) [5,19,25], as in functor-initial (FI) languages (C,D). The frequency and prosodic cues could be aligned (C), thus providing convergent cues to word order, or misaligned (D), thus providing conflicting information. A final set of artificial languages also contained visual facial information [32] (E,F): specifically, head nods produced by an avatar, which again could be aligned (E) or misaligned (F) with the frequency and prosodic information. In the figure the brackets and arrows depict the duration of the head nods and the location of their peak, respectively. The test items (right table) in most studies were tetrasyllabic sequences of alternating frequent (F) and infrequent (I) elements (central panel), half starting with a frequent element (F-I-F-I), half with an infrequent one (I-F-I-F). They were all prosodically flat and had no visual information. In one study [6], novel items replaced frequent or infrequent elements (lower panel). Abbreviations: FF prosody, prosody of functor-final languages; FI prosody, prosody of functor-initial languages.

By 17 months of age, young children also recognize the functional properties of infrequent words – that they carry lexical meaning. Infants are more likely to treat infrequent elements than frequent elements as potential labels for objects [33,34]. After being familiarized with an artificial language with alternating frequent and infrequent words, infants were more likely to associate a novel object with the infrequent words than with the frequent words. These results, therefore, suggest that infants treated infrequent words as potential new content words.

In sum, infants are sensitive to *all* the distinctive features of functors and content words by 8–17 months (Table 1). They expect frequent words to be prosodically nonprominent, to come in a closed class, and to signal structure, whereas they expect infrequent words to be prosodically prominent, form an open class, and be associated with a referent. Furthermore, they know the relative order of the two categories in their native language, and when necessary use their characteristic prosody as a cue. These results argue for the existence of a representation of the relative order of functors and content words before a sizeable lexicon is in place, bootstrapped by surface cues – statistical and acoustic cues present in the speech input, such as frequency and prosody, that correlate with this abstract, structural property of language.

Table 1. Studies investigating infants' sensitivity to the different properties that distinguish between function and content words, and the age of the infants examined.

| Publication | Property examined | Age of infants (in months) | Refs |
|---|---|---|---|
| Shi, Cutler *et al.* (2006) | Statistical and distributional | 8, 11 | [17] |
| Shi, Marquis *et al.* (2006) | | 6, 8 | [18] |
| Gervain *et al.* (2008) | | 8 | [4] |
| Thiessen *et al.* (2019) | | 7, 13 | [26] |
| Marino and Gervain (2021) | | 8 | [25] |
| Shi, Werker, and Morgan (1999) | Prosodic | 0 (1–3 days) | [29] |
| Höhle and Weissenborn (2003) | | 6, 8 | [16] |
| de la Cruz-Pavía *et al.* (2019) | | 4, 8 | [32] |
| Bernard and Gervain (2012) | Statistical and prosodic | 8 | [19] |
| Gervain and Werker (2013) | | 7 | [5] |
| Marino *et al.* (2020) | Open versus closed classes | 8 | [6] |
| Hochmann *et al.* (2010) | Referentiality and lexical meaning | 17 | [34] |
| Hochmann (2013) | | 17 | [33] |

## Adults' knowledge of functor/content word order in artificial grammars

Do these bootstrapping mechanisms remain in place once language acquisition is complete? To answer this question, the infant artificial language studies [4] were adapted to adults by increasing the number of categories (three frequent and three infrequent; Figure 1) and using a two-alternative forced choice task to assess order preference.

Like prelexical infants, adult listeners rapidly compute the relative frequency and distribution of the elements in the artificial language but, importantly, their word order choices differ from those of infants. Adults follow more closely the input statistics of the native language [7,8]. Specifically, speakers of languages that are functor-initial in **syntax**, but functor-final in **morphology** (e.g., French: *nous mange**ons***, 'we eat', where the first person plural marker *-ons* follows the verb) display no word order preference [7], unlike the clear preferences of infant learners of these languages [4,6]. By contrast, adult speakers of languages with consistently functor-final order in syntax and morphology (i.e., Japanese, Basque) show strong functor-final word order preferences, like infants [7,8]. These results suggest that adults match the frequency distributions found in their native language more closely than infants, and take both syntax and morphology into account, whereas infants extract the most common pattern. Future research will need to test adult speakers of consistently functor-initial languages (syntactically and with prefixing morphology) to confirm adults' statistically driven behavior.

Adults also follow more closely the properties of their native language at the segmental level. The acoustic-phonetic properties of the artificial language modulate adults' word order preference. Thus Spanish–Basque bilinguals show a functor-initial preference typical of Spanish when the artificial language is synthesized with a Spanish voice, but a functor-final preference for a German, non-native voice [35].

These studies therefore reveal a developmental change in the use of bootstrapping strategies for word order. The finding that, unlike adults, infants exposed to different orders in syntax and morphology generalize the statistically more predominant syntactic order adds to the body of research showing that children impose systematicity on variable, nondeterministic linguistic input, regularizing it and generating consistent output. This evidence aligns with the 'less is more' hypothesis [36–40] which argues that infants, because of their limited information processing abilities, can best capture the input by extracting generalizations rather than rote-learning item-based information. By contrast, adults reproduce inconsistent linguistic input because their fully developed cognitive abilities allow them to better memorize item-specific knowledge.

A further difference between adult and infant processing of functors and content words is the extent to which they rely on phrasal prosody. Both are able to use native-like phrasal prosody. Specifically, the durational contrast typical of functor-initial languages has been shown to contribute to native-like order preferences in both adults and infants [5,8,19]. However, they process non-native prosody differently: adults weigh this cue more strongly than word frequency [8], whereas infants weigh both equally [5]. When exposed to an artificial language with a prosody characteristic of functor-final languages (i.e., a pitch contrast; Figure 2), adult speakers of English show a frequent-final word order preference, overriding their native frequent-initial preference. English-learning infants, by contrast, show no preference, possibly because of the conflict between prosody and frequency. We hypothesize that this difference may be related to the superior abilities of adults to process multiple cues simultaneously [41,42], added to developmental changes in the weight attributed to prosodic cues.

This hypothesis is supported by empirical differences between how monolingual and bilingual adults process multiple cues to word order. Adult bilinguals appear to benefit more than monolinguals from word frequency, phrasal prosody, and the visual correlates of prosody present in the signal, in other words they exhibit stronger word order preferences in artificial languages containing multiple cues [8]. The language in which bilinguals receive instructions before the study also modulates (but does not reverse) their word order preference [35,43]. This contextual factor might help bilinguals to inhibit the non-target language [8].

Taken together, these results suggest that an abstract representation of the relative order of functors and content words is also operational in adults when they face new linguistic material. However, whereas adults – with their more powerful cognitive abilities – match closely the properties of their native language, infants generalize the order that is statistically more predominant in the input. Regularizing inconsistent input to the most predominant pattern could be a useful strategy for infants to discover the rules of the native language.

## Non-human animals encode word frequency, but not order

Infants and adults use multiple cues to establish functors, content words, and their order. However, are these biases linguistic in nature? How does a species with no language process these artificial grammar streams?

To answer this question, rats were trained to respond to streams in which frequent and infrequent words strictly alternated, but to avoid responding to sequences in which the same words appeared in random order [9]. They were then tested on strictly alternating sequences that either started with a frequent word or an infrequent word (Figure 1), just like infants and adults [4,7]. Rats systematically chose the test items starting with a frequent word. Crucially, however, when rats were tested on sequences that either contained only frequent words or only infrequent words, in other words there was no alternating structure, rats chose the former, suggesting that they did not pay attention to the structure of the test items, only to the presence of a frequent element in initial position. Furthermore, when trained to ignore the alternating stream and respond to the random stream, rats still preferred the frequent-initial test items, irrespective of whether those had an alternating structure or were only composed of words of the same frequency. Rats maintained their frequent-initial choice even in the face of prosodic cues to the opposite.

In sum, rats are sensitive to frequency, but do not map this onto structural representations. This illustrates well the basic mechanism of bootstrapping as a mapping between surface cues and a structural representation. The sensitivity to surface cues is not sufficient in itself to successfully learn grammar – the ability to represent structure is also necessary, showing how learning is different in human infants and non-human animals.

## Concluding remarks

The findings reviewed above show that, at 7–8 months of age, infants already have a rudimentary representation of the relative order of functors and content words in their native language. The acquisition of word order has been found to start well before infants have compiled a sizeable lexicon, and this knowledge is sufficiently abstract to carry over from the native language to a newly encountered artificial grammar. Consequently, this body of work does not support item-based accounts of grammar acquisition [44,45], according to which infants' word order representation is initially not abstract, but piecemeal. According to these accounts, infants initially memorize frequently encountered chunks of the input (e.g., *eat a cake*, *eat your dinner*), and discover similarities between them to derive semi-abstract constructions (e.g., *eat X*) over which they gradually generalize. Under this view, developing a general representation of the relative order of functors and content words requires considerable lexical knowledge, something that 7–8-month-old infants do not yet have.

The findings reviewed here instead support representation-based accounts of grammar acquisition which claim that infants have an early representation of the two universal lexical categories of functors and content words and their relative order [4,46–49], and that this representation is generalizable across lexical items because it contains linguistically relevant (proto-)categories.

The universal distinction between the two lexical classes has reliable perceptual correlates in the signal that allow infants to infer an abstract and fundamental aspect of the grammar of their native language. The evidence presented here shows that prelexical infants are sensitive to the prosodic, statistical, and distributional characteristics that set the two broad categories of function and content words apart, and have a representation of their relative order in the native language. Importantly, to exploit these cues infants need only minimal lexical knowledge of the most frequent functional elements, which they begin to acquire at around 6 months of age [16,18]. At this same age infants begin to use the acoustic correlates marking the boundaries of syntactic units, such as clauses and phrases, to segment continuous speech [50,51]. Locating the boundaries of units bigger than the word allows infants to determine whether the familiar frequent functional elements appear in initial or final position within the **syntactic phrase** or clause. Furthermore, from birth, infants distinguish between the two lexical classes on the basis of their acoustic differences [29]. This ability in turn allows them to track whether the phonologically minimal elements (i.e., the functors) appear in initial or final position in the utterance. Corpus analysis of child-directed speech across typologically different languages shows that functor-directionality correlates with utterance position [4,5]. These findings thus add to the body of work showing that functors play a key role in early language acquisition [52].

Because the relative order of functors and content words correlates with a large number of other word order phenomena [1–3], its discovery could help infants to acquire other aspects of the grammar of their native language. Thus, functor-final languages tend to have an Object-Verb (OV) order, for example, Japanese: *ringo-wo taberu*, [apple.acc]$_{\text{Object}}$ eat$_{\text{Verb}}$ 'eat an apple' (the functor *wo*, an accusative case marker, follows the noun *ringo*, which in turn precedes the verb *taberu*). By contrast, functor-initial languages predominantly have a Verb-Object (VO) order, for

## Outstanding questions

When in development does the switch occur from generalizing the statistically more predominant word order towards a statistically based, more accurate representation of the variable input word order distributions? In other words, when do we stop regularizing the word order inconsistencies of the native language and begin to represent them?

Is this developmental shift related to an increase in memory capacity, attention, or other general cognitive processes, or is it a switch in linguistic representations?

When do infants discover other word order phenomena in their native language that strongly correlate with the relative order of functors and content words, for example, the order of verbs and objects?

How do cross-linguistic differences in typology and word order impact on this developmental trajectory in spoken languages? Do learners of sign languages follow a similar trajectory of acquisition of the differing properties and relative order of functors and content words?

example, *eat an apple* (the determiner *an* precedes the noun *apple*, which in turn follows the verb *eat*). Adpositions provide another example. Although the majority of VO languages have prepositions (91.57%), OV languages are overwhelmingly (97.12%) postpositional (WALS: https://wals.info/).

Importantly, in particular for learners of languages with complex morphologies (e.g., agglutinative languages), word order at the syntactic level also correlates with order at the morphological level [1,2,12]. Indeed, two principles guide morpheme order: a general tendency in languages to prefer suffixation over prefixation, and the functor-directionality of any specific language. Consequently, syntactically functor-final (OV) languages have heavy suffixation (e.g., Turkish and Basque) and show functor-finality in both syntax and morphology. By contrast, languages with functor-initial (VO) syntax tend to have prefixing (functor-initial) morphologies, but may also be suffixing (functor-final), due to the general suffixation preference [3].

As a result of this correlation between functor-directionality in syntax and morphology, establishing the basic functor-content word order of the native language also supports the acquisition of morphology and consequently of the lexicon. Indeed, the evidence reviewed here shows that the acquisition of functor-content word order begins at the developmental time when infants start to learn the first associations between objects and word forms [53,54]. Considering the architecture of language, this is not surprising. Functors not only provide structural anchors for sequential order but also the cues that distinguish between the different categories of content words, such as verbs, nouns, etc. [20,22,23,55]. Each lexical category has its own characteristic set of functors, for example, determiners for nouns (e.g., *the book*, *this turtle*), or auxiliaries for verbs (e.g., *is eating*, *has gone*, etc.). Indeed, high-frequency functors have been shown to aid the extraction of the following content word at 11 months [17], and by 14 months infants use them (e.g., determiners) to categorize adjacent content words (e.g., as nouns) [56,57] This link between morphosyntax and the lexicon is even more obvious in morphologically rich languages, where most word forms are prefixed or suffixed. Learning the word stems, namely the lexical entries, thus cannot proceed without an appropriate morphosyntactic decomposition of the morphologically complex word forms [58–60].

Future research (see Outstanding questions) will uncover the details of these interactions, and address exactly which other word order phenomena infants bootstrap from the relative order of functors and content words, and how this may be modulated by cross-linguistic differences. The exact developmental trajectory of this bootstrapping and the switch from more general representations to more precise statistical knowledge of the native language word order co-occurrence also needs to be explored.

In sum, the acquisition of grammar is intimately intertwined with lexical acquisition, supporting a model of language growth in which the different levels of language develop synergistically, bootstrapping learning interactively.

### Acknowledgements

This work was supported by the Agence Nationale de la Recherche (French Investissements d'Avenir – Labex Empirical Foundations of Linguistics (EFL) Program ANR-10-LABX-0083, ANR-15-CE37-0009-01 'SpeechCode'), the Basque Foundation for Science Ikerbasque, the Spanish Ministry of Science and Innovation (PID2019-105100RJ-I00), and the European Research Council (consolidator grant 773202 ERC-2017-COG 'BabyRhythm').

### Declaration of interests

The authors have no interests to declare.

## References


1. Dryer, M.S. (1992) The Greenbergian word order correlations. *Language* 68, 81–138
2. Greenberg, J.H. (1978) *Universals of Human Language*, Stanford University Press
3. Dryer, M.S. (2013) Prefixing vs. suffixing in inflectional morphology. In *The World Atlas of Language Structures Online Max Planck Digital Library* (Dryer, M.S. and Haspelmath, M., eds), Max Planck Institute for Evolutionary Anthropology
4. Gervain, J. *et al.* (2008) Bootstrapping word order in prelexical infants: a Japanese–Italian cross-linguistic study. *Cognit. Psychol.* 57, 56–74
5. Gervain, J. and Werker, J.F. (2013) Prosody cues word order in 7-month-old bilingual infants. *Nat. Commun.* 4, 1490
6. Marino, C. *et al.* (2020) Word frequency is a cue to lexical category for 8-month-old infants. *Curr. Biol.* 30, 1380–1386
7. Gervain, J. *et al.* (2013) Word frequency cues word order in adults: cross-linguistic evidence. *Front. Psychol.* 4, 689
8. de la Cruz-Pavía, I. *et al.* (2019) Finding phrases: the interplay of word frequency, phrasal prosody and co-speech visual information in chunking speech by monolingual and bilingual adults. *Lang. Speech* 63, 264–291
9. Toro, J.M. *et al.* (2016) Frequency-based organization of speech sequences in a nonhuman animal. *Cognition* 146, 1–7
10. Morgan, J.L. *et al.* (1996) Perceptual bases of rudimentary grammatical categories: toward a broader conceptualization of bootstrapping. In *Signal to Syntax: Bootstrapping From Speech to Grammar in Early Acquisition* (Morgan, J.L. and Demuth, K., eds), pp. 263–283, Lawrence Erlbaum Associates
11. Kucera, H. and Francis, W.N. (1967) *Computational Analysis of Present-Day American English*, Brown University Press
12. Fenk-Oczlon, G. and Fenk, A. (2005) Crosslinguistic correlations between size of syllables, number of cases, and adposition order. In *Sprache und Natürlichkeit: Gedenkband für Willi Mayerthaler* (Fenk-Oczlon, G. and Winkler, C., eds), pp. 75–86, Gunther Narr Verlag
13. Bar-Hillel, Y. (1955) An examination of information theory. *Philos. Sci.* 22, 86–105
14. Ferrer i Cancho, R. and Sole, R.V. (2003) Least effort and the origins of scaling in human language. *Proc. Natl. Acad. Sci.* 100, 788–791
15. Zipf, G.K. (1935) *The Psychobiology of Language*, Houghton Mifflin
16. Höhle, B. and Weissenborn, J. (2003) German-learning infants' ability to detect unstressed closed-class elements in continuous speech. *Dev. Sci.* 6, 122–127
17. Shi, R. *et al.* (2006) Frequency and form as determinants of functor sensitivity in English-acquiring infants. *J. Acoust. Soc. Am.* 119, EL61
18. Shi, R. *et al.* (2006) Segmentation and representation of function words in preverbal French-learning infants. In *Proceedings of the 30th Annual Boston University Conference on Language Development 2* (Bamman, D. *et al.*, eds), pp. 549–560, Cascadilla Press
19. Bernard, C. and Gervain, J. (2012) Prosodic cues to word order: what level of representation? *Front. Psychol.* 3, 451
20. Braine, M.D. (1966) Learning the positions of words relative to a marker element. *J. Exp. Psychol.* 72, 532–540
21. Braine, M.D.S. (1963) On learning the grammatical order of words. *Psychol. Rev.* 70, 323–348
22. Green, T. (1979) The necessity of syntax markers. *J. Verbal Learn. Verbal Behav.* 18, 481–496
23. Valian, V. and Coulson, S. (1988) Anchor points in language learning: the role of marker frequency. *J. Mem. Lang.* 27, 71–86
24. Valian, V. and Levitt, A. (1996) Prosody and adults' learning of syntactic structure. *J. Mem. Lang.* 35, 497–516
25. Marino, C. and Gervain, J. (2021) 8-month-old infants' ability to process word order is shaped by the amount of exposure. *Cognition* 213, 104717
26. Thiessen, E.D. *et al.* (2019) Early developing syntactic knowledge influences sequential statistical learning in infancy. *J. Exp. Child Psychol.* 177, 211–221
27. Nespor, M. *et al.* (2008) Different phrasal prominence realization in VO and OV languages. *Lingue E Linguaggio* 7, 1–28
28. Christophe, A. *et al.* (2001) Perception of prosodic boundary correlates by newborn infants. *Infancy* 2, 385–394
29. Shi, R. *et al.* (1999) Newborn infants' sensitivity to perceptual cues to lexical and grammatical words. *Cognition* 72, B11–B21
30. Christophe, A. *et al.* (2003) Prosodic structure and syntactic acquisition: the case of the head-direction parameter. *Dev. Sci.* 6, 211–220
31. Bion, R.A.H. *et al.* (2007) The role of prosody on the perception of word-order differences by 14-month-old German infants. In *Proceedings of the 16th International Congress of Phonetic Sciences* (Trouvain, J. and Barry, W.J., eds), pp. 1537–1540, Universität des Saarlandes
32. de la Cruz-Pavía, I. *et al.* (2019) Finding phrases: on the role of co-verbal facial information in learning word order in infancy. *PLoS One* 14, e0224786
33. Hochmann, J.-R. (2013) Word frequency, function words and the second gavagai problem. *Cognition* 128, 13–25
34. Hochmann, J.-R. *et al.* (2010) Word frequency as a cue for identifying function words in infancy. *Cognition* 115, 444–457
35. de la Cruz-Pavía, I. *et al.* (2020) Segmental information drives adult bilingual phrase segmentation preference. *Int. J. Biling. Educ. Biling.* Published online January 22, 2020. https://doi.org/10.1080/13670050.2020.1713045
36. Newport, E.L. (1990) Maturational constraints on language learning. *Cogn. Sci.* 14, 11–28
37. Culbertson, J. and Newport, E.L. (2015) Harmonic biases in child learners: in support of language universals. *Cognition* 139, 71–82
38. Culbertson, J. and Newport, E.L. (2017) Innovation of word order harmony across development. *Open Mind* 1, 91–100
39. Hudson Kam, C.L. and Newport, E.L. (2009) Getting it right by getting it wrong: when learners change languages. *Cognit. Psychol.* 59, 30–66
40. Hudson Kam, C.L. and Newport, E.L. (2005) Regularizing unpredictable variation: the roles of adult and child learners in language formation and change. *Lang. Learn. Dev.* 1, 151–195
41. Morgan, J.L. and Saffran, J.R. (1995) Emerging integration of sequential and suprasegmental information in preverbal speech segmentation. *Child Dev.* 66, 911–936
42. Lavi-Rotbain, O. and Arnon, I. (2018) Developmental differences between children and adults in the use of visual cues for segmentation. *Cogn. Sci.* 42, 606–620
43. de la Cruz-Pavía, I. *et al.* (2015) On the role of frequency-based cues in the segmentation strategies of adult OV-VO bilinguals. *Int. J. Biling. Educ. Biling.* 18, 225–241
44. Tomasello, M. (2000) Do young children have adult syntactic competence? *Cognition* 74, 209–253
45. McCauley, S.M. and Christiansen, M.H. (2019) Language learning as language use: a cross-linguistic model of child language development. *Psychol. Rev.* 126, 1–51
46. Guasti, M.T. (2002) *Language Acquisition: The Growth of Grammar*, MIT Press
47. Mazuka, R. (1996) Can a grammatical parameter be set before the first word? Prosodic contributions to early setting of a grammatical parameter. In *Signal to Syntax: Bootstrapping From Speech to Grammar in Early Acquisition* (Morgan, J.L. and Demuth, K., eds), pp. 313–330, Lawrence Erlbaum Associates
48. Pinker, S. (1984) *Language Learnability and Language Development*, Harvard University Press
49. Westergaard, M.R. (2009) *The Acquisition of Word Order: Micro-Cues, Information Structure, and Economy*, John Benjamins Publishing
50. Soderstrom, M. *et al.* (2003) The prosodic bootstrapping of phrases: evidence from prelinguistic infants. *J. Mem. Lang.* 49, 249–267
51. Jusczyk, P.W. *et al.* (1992) Perception of acoustic correlates of major phrasal units by young infants. *Cognit. Psychol.* 24, 252–293
52. Shi, R. (2014) Functional morphemes and early language acquisition. *Child Dev. Perspect.* 8, 6–11

53. Bergelson, E. and Swingley, D. (2012) At 6–9 months, human infants know the meanings of many common nouns. *Proc. Natl. Acad. Sci.* 109, 3253–3258
54. Tincoff, R. and Jusczyk, P.W. (1999) Some beginnings of word comprehension in 6-month-olds. *Psychol. Sci.* 10, 172–175
55. Morgan, J.L. and Newport, E.L. (1981) The role of constituent structure in the induction of an artificial language. *J. Verbal Learn. Verbal Behav.* 20, 67–85
56. Shi, R. and Melançon, A. (2010) Syntactic categorization in French-learning Infants: syntactic categorization in infants. *Infancy* 15, 517–533
57. Höhle, B. *et al.* (2004) Functional elements in infants' speech processing: the role of determiners in the syntactic categorization of lexical elements. *Infancy* 5, 341–353
58. Ladányi, E. *et al.* (2020) How 15-month-old infants process morphologically complex forms in an agglutinative language? *Infancy* 25, 190–204
59. Marquis, A. and Shi, R. (2012) Initial morphological learning in preverbal infants. *Cognition* 122, 61–66
60. Mintz, T.H. (2013) The segmentation of sub-lexical morphemes in English-learning 15-month-olds. *Front. Psychol.* 4, 24