Non-Adjacent Dependencies and Abstract Grammatical Representation in One-Year-Old Infants

Audrey-Anne Gilbert, Manuel Español-Echevarría, and Rushen Shi

1. Introduction

Grammatical dependencies, adjacent and non-adjacent, are a crucial part of the phrase structure in natural language. Dependencies are observable to some degree in the linear speech, acting as potential cues that can help the child acquire the underlying structure. In previous experimental studies infants aged 14 to 18 months showed evidence of tracking non-adjacent grammatical dependencies (Culbertson et al., 2016; Höhle et al., 2006; Soderstrom et al., 2007; Santelmann & Jusczyk, 1998; Van Heugten & Shi, 2010). In Santelmann and Jusczyk, English-learning 18-month-olds detected the non-adjacent dependency in sentences such as *Everybody is baking bread* and preferred such sentences over *Everybody can baking bread*, which violated the dependency. Culbertson et al. found that French-learning infants at 14 months of age recognized the non-adjacent agreement dependencies between the determiner of the subject phrase and the preverbal number-marking morpheme. They discriminated grammatical sentences such as *Le*$_{sg}$ *garçon il* /l/$_{sg}$*-apporte le vip* ("The boy, he brings the vip") from ungrammatical sentences (e.g., **Le*$_{sg}$ *garçon ils* /z/$_{pl}$*-apportent le vip* "The boy, they bring the vip"). Infants in these studies were impressive in detecting non-adjacent dependent elements involving bound morphemes such as *-ing* and /l/. This is unsurprising since infants aged 6 to 11 months are already capable of segmenting frequent bound morphemes and representing them as independent units (Kim & Sundara, 2021; Marquis & Shi, 2012).

These studies revealed babies' acute sensitivity to non-adjacent dependencies. However, the nature of their representation and processing of such dependencies during early acquisition remains unclear. The present study thus addressed two questions about this literature. Firstly, do infants just track the co-dependencies between elements because these items are typically frequent functional morphemes (which even babies below one year of age can perceive, e.g., Hallé, Durand & de Boysson-Bardies, 2008; Shi & Lepage, 2008; Shi, Marquis & Gauthier, 2006; Shi, Werker & Cutler, 2006; Shi et al., 2006), or do they

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understand and process more about the syntax of and around a dependency? To address this question, we hypothesized that infants use non-adjacent dependencies to categorize other words. It is known that infants around 14 months of age begin to use frequent functors such as determiners to categorize the following novel words as nouns (e.g., Babineau, Shi & Christophe, 2020; Höhle et al., 2004; Shi & Melançon, 2010). French-learning 14-month-olds also use the frequent verb suffix -/e/ in single-word imperatives (e.g., *Migé*!) to categorize the preceding novel root as verbs (Gilbert & Shi, 2024). Hence, infants might also be able to use both pieces of non-adjacent dependencies as frames for categorization, as proposed by Mintz (2003).

Our second question concerned how infants represent the elements of the non-adjacent dependency per se. In the grammar, dependencies are defined as between categories rather than between specific items. The dependencies examined in previous infant studies were between frequent items, typically functors. The results cannot tell us if the dependencies are represented as between categories or between specific items in infants. We thus addressed this question by testing infants' ability to generalize a dependency element to a novel item.

To understand the early development of non-adjacent dependencies in child language, we investigated two age groups, 14 and 19 months. The younger group can inform us of the nature of this knowledge when it emerges. The older group can help reveal whether the representation and use of non-adjacent dependencies begin late or gradually improve over time.

2. Experiment 1

2.1. Methods

2.1.1. Participants and stimuli

Participants were French-learning infants. The younger group consisted of 15 girls and 9 boys, with a mean age of 14 months 13 days (range: 13 months 25 days to 15 months 9 days). The data of three additional 14-month-olds were not retained due to parental interference (2) and software problem (1). The older group consisted of 10 girls and 14 boys, with a mean age of 18 months 21 days (range: 17 months 26 days to 20 months 21 days). Two additional infants in this age group did not complete the task due to fussiness.

The experimental materials included two pseudo-words (*mige*; *crale*) from our previous categorization studies (Shi & Melançon, 2010; Massicotte-Laforge & Shi, 2015, 2018). In those studies infants categorized them as nouns or verbs depending on the preceding function words and the prosodic phrasing. For the familiarization stimuli of the present experiment, we constructed sentences in French using these two pseudo-words in the compound past structure (passé composé). The sentences all started with a subject pronoun (*je* "I"; *il* "he"; *elle* "she"; *ils* "they$_{masculine}$"; *elles* "they$_{feminine}$"; *on* "someone, we"), followed by a present auxiliary AVOIR ("have") and a pseudo-word inflected with a verb suffix *-é* (a past participle suffix). The *-é* suffix is the most frequent past participle form in French (among various past participles alternatives), and it is inflected with

first-class verbs, the most dominant class. Multiple forms of auxiliaries were used, varying according to the subject pronoun, e.g., *J'ai migé* "I have miged / I miged"; *Il a cralé* "He has craled / He craled"[1]. Thus, in each sentence the root of the pseudo-word appeared inside a non-adjacent dependency between an auxiliary and the verb suffix (i.e., Aux …-*é*), i.e., inside frequent frames. A full list of the familiarization sentences is shown in Table 1.

The test utterances were identical to the those of our previous studies (Shi & Melançon, 2010; Massicotte-Laforge & Shi, 2015, 2018, 2020; Gilbert & Shi, 2024). As shown in Table 1, the pseudo-words *mige* and *crale* were used as nouns in Det+Noun phrases: *Le mige* "The mige"; *Le crale* "The crale". The two noun phrases were contrasted with two declarative sentences containing the same pseudo-words as verbs: *Tu miges* "You mige"; *Tu crales* "You crale". The verbs used were in their root forms, unlike their inflected versions in the familiarization.

The familiarization and test utterances were recorded by a female Quebec-French speaker in child-directed speech. Two exemplars with distinct intonations were selected for each of the 12 familiarization sentences, in total 24 exemplars, with a mean sentential duration of 1.327 seconds (SD = 0.064). These exemplars were strung together into two sound files, each containing the 12 sentences (half of the recorded exemplars) in a random order with the restriction that no more than two consecutive sentences with the same intonation may occur. Two other sound files were prepared, with the same exemplars in each of the two first files rearranged in a different random order. Within a file, any adjacent two sentences were separated by a pause of approximately 0.7 sec. The four files were uploaded to our experimental program as separate familiarization trial.

The test stimuli consisted of six exemplars for each of the four utterances, in total 12 exemplars of the Det+Noun phrases (mean = 1.251 sec; SD = 0.128) and 12 exemplars of the Pron+Verb sentences (mean = 1.249 sec; SD = 0.127). These exemplars were organized into two sound files, i.e., 12 for Det+Noun and 12 Pron+Verb. The utterances in each file were ordered randomly except that no more than two consecutive exemplars containing the same pseudo-word or the same intonation may occur. Once the order of the utterances in one of the files was decided, the utterances in the other file were arranged to match that order in terms of the pseudo-word and the intonation. For example, the Det+Noun sound file started with *Le mige* in a particular intonation, and the Pron+Verb file also started with *Tu miges* in the same intonation. The pause between any two utterances within a trial was about 0.7 sec. The two files were uploaded to the experimental program to be used for test trials.

An abstract kaleidoscopic animation was used for familiarization and test trials. The attention-getter was an animation of a moving star accompanied by the sound of chirping birds. An 'boing boing' electric sound and an animation of bouncing balls were the stimuli for the pre-experimental and post-test trials.

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[1] As shown in the examples, the compound past structure (i.e., present auxiliary + past participle) in French can give either a perfect interpretation (like the present perfect, e.g., *have written*) or a perfective interpretation (like the simple past, e.g., *wrote*) in English.

2.1.2. Procedure and design

The experiment was conducted in a visual fixation procedure. Each child was tested individually in an acoustic chamber. The parent was advised not to influence the child during the task. In the sound chamber the parent held the child on his or her lap, facing a display screen. Loudspeakers placed next to the left and right sides of the screen played auditory stimuli. The parent wore headphones to hear masking music. Hidden cameras, one below the central screen and another on the side wall, sent the video of the child simultaneously to a monitor in the adjacent room, where the researcher, who could not hear nor see the stimuli, coded the child's looking to the display screen in real time through the video. The experimental program, Habit2 (Oakes et al., 2019), controlled the trial presentations and the experimental phases in response to the child's looking to the screen, while recording and calculating the child's looking in all trials. During each trial auditory and visual stimuli were presented simultaneously. All trials in this study were determined by the child's looking. Specifically, a trial would start upon infant's looking to the display screen, and it would end if the child looked away from the display for at least two consecutive seconds or if he or she looked to the maximal length of the trial. The attention-getter was presented automatically between trials to attract the child back to the screen for the next trial.

The experimental session consisted of four consecutive phases: a pre-experimental trial, familiarization phase, test phase, and a post-test trial. The 5-second pre-experimental trial presenting bouncing balls on the display screen with the "boing boing" sound introduced the equipment setup to the child. Next, familiarization trials presented the sound files containing the compound past sentences (see Table 1). The maximal trial length was 24 sec. The familiarization criterion was 47 sec, ensuring that all the sentences were heard by each child.

Table 1: Speech Stimuli and Design of Experiment 1

Familiarization Phase (12 sentences)
J'$_{\text{Pron}}$ *ai*$_{\text{Aux}}$ *cralé/migé* ([kʁalẹ/miʒɛ]). "I HAVE.1SG craled/miged."
Il$_{\text{Pron}}$ *a*$_{\text{Aux}}$ *cralé/migé*. "he HAVE.3SG craled/miged."
Elle$_{\text{Pron}}$ *a*$_{\text{Aux}}$ *cralé/migé*. "she HAVE.3SG craled/miged."
On$_{\text{Pron}}$ *a*$_{\text{Aux}}$ *cralé/migé*. "someone/we HAVE.3SG craled/miged."
Ils$_{\text{Pron}}$ *ont*$_{\text{Aux}}$ *cralé/migé*. "they$_{\text{mas}}$ HAVE.3PL craled/miged."
Elles$_{\text{Pron}}$ *ont*$_{\text{Aux}}$ *cralé/migé*. "they$_{\text{fem}}$ HAVE.3PL craled/miged."
Test Phase
Grammatical (Pron+Verb):
Tu$_{\text{Pron}}$ *crales*/*miges* ([kʁal/miʒ]). "you crale/mige."
Ungrammatical (Det+Noun):
Le$_{\text{Det}}$ *crale*/*mige* ([kʁal/miʒ]). "the crale/mige."

Note: All the pseudo-words conform to French phonology. The *-s* ending in the spelling of the test words *crales* and *miges* (in the Pron+V structure) is phonetically mute.

In the test phase there were two types of trials: grammatical versus ungrammatical, as shown in Table 1. The grammatical trials presented the sound file containing the Pron+Verb sentences, in which the category of the pseudo-words was consistent with the verb status of these items in the familiarization sentences even though the exact word forms changes (inflected bisyllabic *cralé*/*migé* [kʁale/miʒe] in the familiarization versus the monosyllabic root forms *crale*/*mige* [kʁal/miʒ] in the test). The ungrammatical trials presented the sound file containing the pseudo-words as nouns in Det+Noun phrases, inconsistent with their familiarized category status. The two trial types were presented alternatingly, each six times for a total of 12 trials. The first test trial was either grammatical or ungrammatical, counterbalanced across infants. The child initiated each trial and could terminate it at any moment before the maximal trial duration (23.2 sec). The test phase was followed immediately by a post-test trial, which presented the audiovisual stimuli of the pre-experimental trial but with the same maximal trial duration as the test trials (23.2 sec). This post-test trial marked the end of the experiment. It also served to indicate if a child remained on task till the end, which should be revealed by a renewed interest (increased looking time) to the stimulus change after the last test trial.

This study followed a series of categorization experiments in our lab (Shi & Melançon, 2010; Massicotte-Laforge & Shi, 2015, 2018, 2020; Gilbert & Shi, 2024), using the same procedure and the same test stimuli. In our previous experiments, the earliest categorization of nouns and verbs was found in 14-month-olds, and whenever infants showed an effect, it was consistently a novelty preference (a surprisal effect), that is, longer looking (i.e., listening) to the ungrammatical trials than to grammatical trials. Thus, in the present study we predicted that if infants categorized the pseudo-words as verbs, they should show a novelty preference for the ungrammatical test trials. However, we did not know a priori the age at which infants begin to use non-adjacent dependencies for grammatical categorization. If this ability emerges early, then discrimination should be observed in 14-month-olds. If the ability develops gradually and improves over the two ages, the response patterns of the two groups should differ.

2.2. Results

We calculated each infant's responses to the two types of test trials. Specifically, the average looking time per trial was calculated for grammatical trials and for ungrammatical trials, respectively. The combined data of all infants were then analyzed in a mixed 2 x 2 analysis of variance, with Grammaticality as the within-subject factor (grammatical versus ungrammatical) and Age as the between-subject factor (14 months versus 19 months). The results showed no significant main effect of Age ($F(1,46) = 2.10$; $p = .154$). The effect of Grammaticality was significant ($F(1,46) = 8.85$; $p = .005$). There was no Grammaticality x Age interaction ($F(1,46) = 0.45$; $p = .508$), indicating that infants of both ages responded in the same fashion. In particular, as shown in Figure 1, the 14-month-olds looked longer when listening to ungrammatical trials

than when listening to grammatical trials ($t(23) = -2.34$, $p = 0.028$), so did the 19-month-olds ($t(23) = -2.094$, $p = 0.048$). All p values are two-tailed.

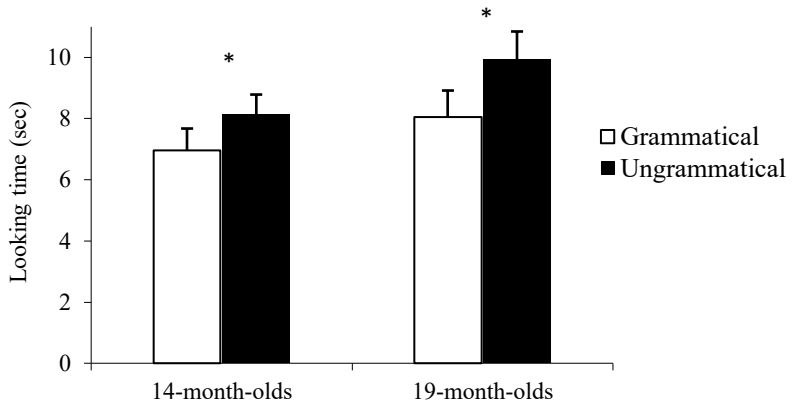

Figure 1. Looking times (means and standard errors) to grammatical versus ungrammatical test trials in Experiment 1. Both 14-month-olds and 19-month-olds discriminated the two types of test trials, showing evidence of verb categorization across different syntactic structures.

These results revealed that our infants categorized the pseudo-words as verbs, and that the performance of younger and older ages were equally successful. This ability is impressive given that the target verbs in the test sentences were root forms that varied morpho-phonologically from their inflected forms in the familiarization sentences. Our infants recognized the roots as independent units from the more complex inflected forms. We note that the same word forms (*mige*, *crale*) in the test stimuli were categorized as nouns by 14-month-olds in Shi and Melançon (2010) after infants were familiarized with the words in noun context. Thus, it is reasonable to interpret that the non-adjacent dependencies (Aux …-*é*) that surrounded the targets *mige* and *crale* in the familiarization sentences guided our infants in the present experiment to perceive the targets as verbs.

The discrimination suggests that infants can use the non-adjacent dependencies of "Aux …-*é*" (i.e., frequent frames) to assign the verb category to an intervening novel root. Having established that the ability is present by 14 months of age, we further investigated the nature of its acquisition at this age. In Experiment 2 we asked whether infants indeed required the two dependent pieces (i.e., Aux and -*é*) to succeed in the categorization, considering that the results of Experiment 1 could also be obtained if infants relied on one of the two pieces, for example, only Aux.

3. Experiment 2
3.1. Methods

Participants were a new group of French-learning 14-month-old infants (n=24; 13 girls and 11 boys; mean age: 14 months 17 day; range: 14 months 1 day to 15 months 2 days). The data of three additional infants were excluded due to fussiness (2) and ceiling looking (1).

We assessed if infants could categorize novel verbs using one of the co-dependent pieces. In particular, we tested the hypothesis that infants track highly frequent non-adjacent dependencies and use them for categorizing novel words. In the case of "Aux …-*é*", both Aux and -*é* are frequent functional morphemes. We therefore replaced the frequent past participle suffix -*é* with a nonsense suffix -*ou* (/u/) so as to examine if this had a detrimental effect on infants' performance. Similar to Experiment 1, there were 12 familiarization sentences, see Table 2.

Table 2: Speech Stimuli and Design of Experiments 2 and 3

Familiarization Phase (12 sentences)
J'$_{\text{Pron}}$ *ai*$_{\text{Aux}}$ *cralou/migeou* ([kʁalu/miʒu]). "I HAVE.1SG crale-ou/mige-ou."
Il$_{\text{Pron}}$ *a*$_{\text{Aux}}$ *cralou/migeou*. "he HAVE.3SG crale-ou/mige-ou."
Elle$_{\text{Pron}}$ *a*$_{\text{Aux}}$ *cralou/migeou*. "she HAVE.3SG crale-ou/mige-ou."
On$_{\text{Pron}}$ *a*$_{\text{Aux}}$ *cralou/migeou*. "someone/we HAVE.3SG crale-ou/mige-ou."
Ils$_{\text{Pron}}$ *ont*$_{\text{Aux}}$ *cralou/migeou*. "they$_{\text{mas}}$ HAVE.3PL crale-ou/mige-ou."
Elles$_{\text{Pron}}$ *ont*$_{\text{Aux}}$ *cralou/migeou*. "they$_{\text{fem}}$ HAVE.3PL crale-ou/mige-ou."
Test Phase
Grammatical (Pron+Verb):
Tu$_{\text{Pron}}$ *crales/miges* ([kʁal/miʒ]). "you crale/mige."
Ungrammatical (Det+Noun):
Le$_{\text{Det}}$ *crale/mige* ([kʁal/miʒ]). "the crale/mige."

The familiarization sentences were recorded by the same speaker, who mimicked the familiarization sentences of Experiment 1 but with the -*ou* suffix instead of -*é*. The final selected sample contained two exemplars with distinct intonations for each sentence. The mean duration per sentence was 1.269 seconds (SD = 0.066). The randomization and preparation of the sound files for the experimental program followed the same steps as in Experiment 1. The speech stimuli of test trials were those of Experiment 1, so were the visual stimuli for all phases of the experiment as well as the auditory stimuli for the attention-getter, the pre-experimental trial and the post-test trial. The procedure and all design parameters were identical to those of Experiment 1.

If the verb categorization in Experiment 1 was driven by the high frequency of occurrences of both elements of the non-adjacent dependences (i.e., Aux …-*é*), then infants in Experiment 2 should fail the task since only one piece, Aux, was

frequent, while the nonsense suffix *-ou*, with a 0 frequency as a past participle inflection, was unhelpful. If, on the contrary, Aux alone is sufficient for verb categorization, infants in Experiment 2 should also discriminate the test trials as in Experiment 1.

3.2. Results

For each child, the average looking time per trial was calculated for grammatical test trials and for ungrammatical trials, respectively. We then analyzed the group data in a paired t-test to compare the two types of test trials. As shown in Figure 2, looking times in grammatical trials versus ungrammatical trials did not differ ($t(23) = 0.296$, $p = 0.77$, two-sided), i.e., there was no evidence of verb categorization when the frequent past participle suffix *-é* was replaced by an unknown one; that is, Aux alone was not sufficient for the task. This result confirms that the successful verb categorization observed in Experiment 1 was based on the dependency between Aux and the non-adjacent *-é*.

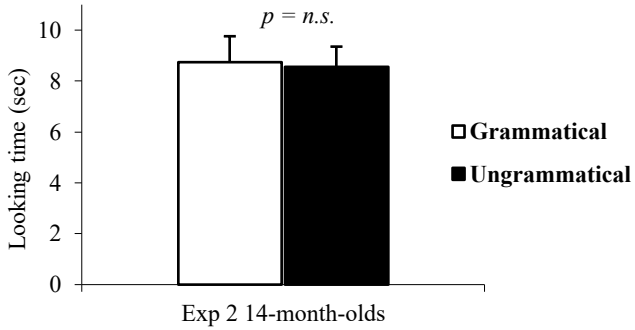

Figure 2. Looking times (means and standard errors) to grammatical versus ungrammatical test trials in Experiment 2. 14-month-olds did not discriminate the two types of test trials, showing no evidence of verb categorization.

The combined results of Experiments 1 and 2 indicate that 14-month-old French-learning infants rely on the frequent occurrences of the "Aux … *-é*" dependencies to categorize the intervening root as a verb. The absence of the co-occurring *-é* impeded their performance. In French, in addition to the frequent past participle suffix *-é*, there are less frequent past participle suffixes such as *-i* (/i/) and *-u* (/y/). The non-adjacent dependency is in fact between the class of Aux and the class of past participles, i.e., "Aux …-past participle", with each class containing multiple members. Children must ultimately learn the classes and the dependency relationship between classes. In Experiment 3 we tested the hypothesis that older infants, who have become more skilled at tracking multiple past participle suffixes (including less frequent ones) in the input, should be able to generalize past participles as a class, i.e., a more abstract representation. One

manifestation of this generalization would be the acceptance of a novel suffix (e.g., *-ou*) as a possible new member of the past participle class if it occurs in the position of familiar past participles. Moreover, we hypothesized that older infants can use non-adjacent class dependencies for grammatical categorization.

4. Experiment 3

4.1. Methods

Participants were a new group of 19-month-old French-learning infants (n = 24; 12 girls and 12 boys; mean: 18 months 29 days; range: 18 months 1 day to 20 months 10 days). Six additional infants participated in the experiment, but their data could not be retained due to fussiness (6).

The stimuli, procedure and design were identical to those of Experiment 2.

If 19-month-olds rely on the frequent occurrences of auxiliaries and the specific co-dependent *-é*, their looking responses to the test trials should resemble those of the 14-month-olds in Experiment 2, i.e., no discrimination of the test trials. If, however, the older group has advanced beyond the specific frequent participle *-é* and has acquired more abstract knowledge of the dependency between Aux and past participle suffix classes, their looking responses should differ from those of the 14-month-olds in Experiment 2 and resemble those in Experiment 1.

4.2. Results

As in Experiments 1 and 2, we calculated each infant's average looking time per trial in grammatical trials and in ungrammatical trials, respectively. The group data were then analyzed in a paired t-test. We found that infants discriminated the two types of test trials, looking significantly longer to ungrammatical trials than to grammatical trials ($t(23) = -2.242$, $p = 0.035$, 2-tailed), see Figure 3.

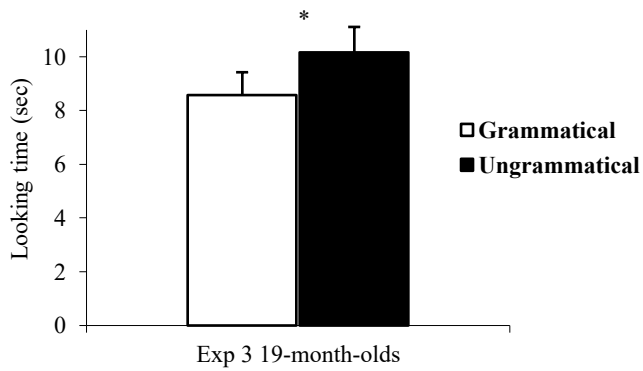

Figure 3. Looking times (means and standard errors) to grammatical versus ungrammatical test trials in Experiment 3. 19-month-olds discriminate the two types of test trials, showing evidence of verb categorization.

The result suggests that 19-month-olds processed the nonsense suffix *-ou* in the same way as they did for the frequent *-é*. The novelty preference in this experiment patterned with those of Experiment 1, indicating that 19-month-olds perceived past participle suffixes as an abstract class and used the class dependency "Aux …-past participle" to categorize an intervening novel root as a verb. The finding thus provides evidence that infants at this age have sophisticated syntactic representations.

5. General discussion

In three experiments we studied infants' representation and processing of non-adjacent grammatical dependencies at the earliest stage of syntactic acquisition, using the case of the "Aux …- past participle" dependency in French. We familiarized infants with compound past sentences containing target pseudo-words inside this dependency (Experiments 1-3). Following familiarization infants were tested with the targets as verbs in a different syntactic structure (present declarative: Pron+Verb) versus as a noun in a noun phrase (Det+Noun). In Experiment 1 infants aged 14 and 19 months were equally good at tracking the non-adjacent dependencies between auxiliaries and the verb past participle suffix *-é*, and at categorizing the intervening pseudo-root as a verb. Moreover, 14-month-olds failed to show evidence of verb categorization when *-é* was replaced by a nonsense suffix *-ou* (Experiment 2), suggesting that the familiar auxiliaries alone could not enable categorization - infants relied on the high frequency of occurrences of auxiliaries and the participle suffix -é to process the dependency. Their representation of the dependency is between specific auxiliaries and the specific *-é*, rather than between abstract classes of Aux and past participles. These results are consistent with the idea that functional morphemes serve as anchors that infants can use to bootstrap initial grammatical acquisition (e.g., Shi, 2014).

Furthermore, our study showed that 19-month-olds' representation of the dependencies has evolved to be between abstract classes, as shown in infants' acceptance of the nonsense *-ou* into the past participle class (Experiment 3). Infants relied on the dependency between the classes of Aux and past participle suffixes for verb categorization. Their responses revealed grammatical intuitions that likely arise from having observed that most verbs in French take a past participle suffix, either the highly frequent *-é* or other less frequent ones.

It is theoretically interesting to compare the results of the 14-month-olds in Experiment 1 with those of previous studies. In Shi and Melançon (2010) one group of French-learning 14-month-olds were familiarized with the pseudo-words *mige*/*crale* in the "Pron+Verb" structure (e.g., *Je mige* "I mige") and were tested with the novel word targets in "Pron+Verb" versus "Det+Noun" trials. Although the invariant sentential structure and pseudo-word forms throughout the experiment should be relatively easy for processing, infants did not discriminate the test trials. In contrast, another group of infants who were familiarized with the targets in the "Det+Noun" structure (e.g., *Mon mige* "my mige") categorized them as nouns. Using similar stimuli, Babineau et al (2020) also found that

categorization of verbs was much harder than that of nouns. In Höhle et al (2004), German infants who were familiarized and tested with sentences containing "Pron+Verb" versus "Det+Noun" structures categorized nouns, but not verbs. These results contrasted with the present study: The 14-month-olds in Experiment 1 succeeded in verb categorization in spite of a harder task (involving syntactic and morphological changes from familiarization to test). We suggest that these results across studies are in fact coherent if we take the structural relations of the stimuli into account. In particular, the "Aux …- past participle" dependency and the intervening verb root are in a tight relation in the phrase structure, with the participle being morphologically formed before entering syntax, and Aux being a head that select the projection headed by the verb as its complement. Likewise, Det and Noun are also in a head-complement relation. In contrast, Subject Pronoun and Verb are not in a head-complement relation, and are thus further apart in the phrase structure. The responses of 14-month-old infants across the prior and present studies indicate that they have some intuitions about the structural relations between grammatical categories.

In conclusion, the results of our experiments demonstrate that infants as young as 14 months of age are remarkable in their understanding and processing of non-adjacent grammatical dependencies. They start by tracking and representing the dependencies between frequent specific functional morphemes (e.g., between auxiliaries *ai*/*a*/*ont* and the past participle suffix *-é* in French), and they use them as anchors to categorize novel words. A few months later, around 1.5 years of age, their understanding of dependencies becomes more sophisticated. They no longer restrict themselves to specific dependency items. Rather, they represent abstract categories in dependent relations (e.g., Aux …- past participle). These results along with those from our previous studies demonstrate that infants' early syntactic acquisition is structurally rich, with rapidly developing representations that align with the adult grammar.

References

Babineau, Mireille, Shi, Rushen, & Christophe, Anne. (2020). 14-month-olds exploit verbs' syntactic contexts to build expectations about novel words. *Infancy*, *25*(5), 719-733.

Culbertson, Jennifer, Koulaguina, Elena, Gonzalez-Gomez, Nayeli, Legendre, Géraldine, & Nazzi, Thierry (2016). Developing knowledge of nonadjacent dependencies. *Developmental Psychology*, *52*(12), 2174-2183.

Gilbert, Audrey-Anne, & Shi, Rushen. (2024). Infants use inflectional morphology to categorize verbs in varying syntactic environment. *BUCLD 48*, *Vol. 1* (pp209-222). Boston, MA, USA: Cascadilla Press.

Hallé, Pierre A., Durand, Catherine, & de Boysson-Bardies, Bénédicte (2008). Do 11-month-old French infants process articles? *Language and Speech*, *51*(1-2), 23-44.

Höhle, Barbara, Schmitz, Michaela, Santelmann, Lynn M., & Weissenborn, Jürgen (2006). The recognition of discontinuous verbal dependencies by German 19-month-oldle: Evidence for lexical and structural influences on children's early processing capacities. *Language Learning and Development*, *2*(4), 277-300.

Höhle, Barbara, Weissenborn, Jürgen, Kiefer, Dorothea, Schulz, Antje, & Schmitz, Michaela (2004). Functional elements in infants' speech processing: The role of determiners in the syntactic categorization of lexical elements. *Infancy*, *5*(3), 341-353.

Kim, Yun Jung, & Sundara, Megha (2021). 6–month–olds are sensitive to English morphology. *Developmental Science*, *24*(4), e13089.

Marquis, Alexandra, & Shi, Rushen (2012). Initial morphological learning in preverbal infants. *Cognition*, *122*(1), 61-66.

Massicotte-Laforge, Sarah, & Shi, Rushen. (2020). Is prosody information alone sufficient for guiding early grammatical acquisition? *Journal of Acoustical Society of America, 147*(3)*,* EL295-300*.*

Massicotte-Laforge, Sarah, & Shi, Rushen (2018). Phrasal prosody and syntactic knowledge in infants below two years of age. *BUCLD 42, Vol. 2* (pp518-531). Boston, MA, USA: Cascadilla Press.

Massicotte-Laforge, Sarah, & Shi, Rushen (2015). The role of prosody in infants' early syntactic analysis and grammatical categorization. *Journal of the Acoustical Society of America*, *138*(4), EL441-EL446

Mintz, Toben H. (2003). Frequent frames as a cue for grammatical categories in child directed speech. *Cognition*, *90*(1), 91-117.

Oakes, Lisa M., Sperka, Daniel, DeBolt, Michaela C., & Cantrell, Lisa M. (2019). Habit2: A stand-alone software solution for presenting stimuli and recording infant looking times in order to study infant development. *Behavior Research Methods*, *51*(5), 1943-1952.

Santelmann, Lynn M., & Jusczyk, Peter W. (1998). Sensitivity to discontinuous dependencies in language learners: Evidence for limitations in processing space. *Cognition*, *69*(2), 105-134.

Shi, Rushen (2014). Functional morphemes and early language acquisition. *Child Development Perspectives*, *8*(1), 6-11.

Shi, Rushen, Cutler, Anne, Werker, Janet, & Cruickshank, Marisa (2006). Frequency and form as determinants of functor sensitivity in English-acquiring infants. *Journal of the Acoustical Society of America*, *119*(6), EL61-EL67.

Shi, Rushen, Marquis, Alexandra & Gauthier, Bruno (2006). Segmentation and representation of function words in preverbal French-learning infants. *BUCLD 30*, *Vol. 2* (pp. 549-560). Boston, MA, USA: Cascadilla Press.

Shi, Rushen, & Lepage, Mélanie (2008). The effect of functional morphemes on word segmentation in preverbal infants. *Developmental Science*, *11*(3), 407-413.

Shi, Rushen, & Melançon, Andréane (2010). Syntactic Categorization in French-Learning Infants. *Infancy*, *15*(5), 517-533.

Shi, Rushen, Werker, Janet F., & Cutler, Anne (2006). Recognition and representation of function words in English-learning infants. *Infancy*, *10*(2), 187-198.

Soderstrom, Melanie, White, Katherine S., Conwell, Erin, & Morgan, James L. (2007). Receptive grammatical knowledge of familiar content words and inflection in 16-month-olds. *Infancy*, *12*(1), 1-29.

Van Heugten, Marieke & Shi, Rushen (2010). Infants' sensitivity to non-adjacent dependencies across phonological phrase boundaries. *Journal of the Acoustical Society of America*, *128*(5), EL223-EL228.

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