Acquisition of morphosyntax: A pattern-learning approach

Natural languages contain complex grammatical patterns. For example, in German, embedded clauses have subjects first and verbs final, while main clauses have the verb second and allow any topicalized constituent to be first (V2 word order). Children acquire V2 patterns remarkably early, motivating claims that they fully represent the abstract structure of their language (e.g. Poeppel & Wexler, 1993). However, in order to represent patterns in an abstract way, learners must first notice the patterns, raising the possibility that these patterns are—at least initially—all the learner knows. I explore the possibility that learners begin acquiring morphosyntax by identifying and correlating concrete surface patterns. On this account, statistical patterns—not abstract tree structures—are the main content of learners' early morphosyntactic representations. I use a miniature language paradigm, where learners' knowledge can be carefully probed to distinguish different types of representations. In Experiment 1, I show that adults easily learn V2 patterns without representing the language's full structure, refuting claims that V2 patterns are too complex to learn and demonstrating that knowledge of patterns is possible without abstract structural representations. In Experiments 2-4, I explore constraints on this pattern-learning mechanism by manipulating the miniature language's morphology and measuring changes in learning of V2 patterns. V2 patterns were learned only when the language had V2 morphology, a universal property of natural V2 languages. Taken together, these results suggest that adults have access to a robust pattern-learning mechanism that operates quickly, does not require full linguistic representations, and is most effective under typologically natural conditions. This mechanism has the right properties to play an important role in the early stages of child language acquisition.

Keywords: learnability; language acquisition; V2 word order; morphology; syntax

Introduction

Natural languages use patterns of word order and inflection to mark grammatical structure. Often these grammatical patterns appear to be linked. For example, in German, embedded clauses have SOV word order while main clauses always have the verb second and allow any topicalized constituent (either subjects or non-subjects) to be first (fronted). This is called V2 word order. In addition, the verb's inflection varies with its position: verbs that are morphologically inflected for finiteness generally occur second in main clauses (V2), while nonfinite verbs are last (Vfinal).[1] Each of these individual patterns—fronting, a verb placement alternation, and morphological finiteness—could in principle occur without the others, but in V2 languages they correlate, clustering together across different constructions in the language.

The clustering of grammatical patterns can be elegantly represented with the linguistic notation of functional projections. These are abstract representations of the grammatical structure of different parts of the sentence, notably the clause (CP), the verb phrase (IP/TP) and the noun phrase (DP). For example, V2 word order is traditionally captured with the functional projection CP. On a traditional analysis of German, the underlying word order is SOV, and V2 sentences are generated from that structure via two movement operations. One operation (Fronting) moves any topicalized constituent to first position, and a second operation (Verb Movement) raises the verb from final to second position. The contingency among these patterns is captured by positing the representation CP, which (when the clause is finite) has a set of features that trigger both movement operations. Functional projections like CP effectively link patterns together in an abstract way, ensuring that patterns will correlate across different constructions.

[1] This form/position contingency is not perfect. Finite verbs can also occur last (as in subordinate clauses) or first (imperatives and questions). In the literature on the acquisition of V2 languages, however, sentence-final finite verbs in the speech of young children (~ age <3) are generally interpreted as verb placement errors. This interpretation reflects the assumption that children have not yet acquired embedded clauses (there is no other evidence that they have acquired embedded clauses by this point; they do not produce complementizers, for example). Furthermore, these "errors" are extremely rare (see below), suggesting that children learning V2 languages treat second position as the location for finite verbs—despite occasional exposure to sentences where the finite verb is elsewhere.

Impressively, children appear to know remarkably early that V2 patterns are linked. For example, toddlers learning German and other V2 languages correctly place finite verbs second and non-finite verbs last, use either V2 or Vfinal when subjects are first, and use only V2 when objects or adverbs are first (Boser 1992, Poeppel and Wexler 1993, Haegeman 1995). Based on this evidence, many linguists have concluded that toddlers represent an abstract, adultlike grammar in which V2 patterns are linked by the functional projection CP. Note, however, that the actual data comprises statistical contingencies among surface patterns (verb form, verb position, and the category of the first word in the sentence), while the inference is that toddlers represent these patterns in an abstract way.

Suppose toddlers do use abstract functional projections to represent sentence properties such as verb placement. How do they learn that sentences in their language have these particular properties in the first place? Poeppel and Wexler (1993) noted that this question was unanswered, and twenty-five years later this is still true. Children cannot be, for example, setting the value of an innate parameter: V2 patterns manifest variably in different languages, and learners of languages like Norwegian—where V2 works differently with certain lexical items—do not overgeneralize, the way a parameter-setting account would predict (Westergaard, 2009). Instead, children use input-driven learning procedures to learn, step by step, how V2 works in their particular language.

What is the nature of these input-driven learning procedures? At some level, learning must involve attending to patterns involving linguistic elements, such as how these elements are grouped into categories, how they are ordered, and how they are marked morphologically. The predominating view in the generative acquisition literature is that children use such patterns to make inferences about the abstract structure of their language (Lidz & Gagliardi, 2015). For example, Legate and Yang (2007) argue for a learner who uses the presence of verbal morphology to determine whether a language expresses an abstract tense feature. On this type of account, children notice surface patterns, but they *learn* (represent) abstract grammatical structures or rules. I will refer to this type of proposal as a STRUCTURE-LEARNING approach.

Although the structure-learning approach is assumed (implicitly or explicitly) by most generative models of language acquisition, there is another possibility for how learning might work. Children must first notice that certain patterns exist in their language in order to represent them in an abstract way. This raises the possibility that perhaps these superficial patterns are—at least initially—all the child knows. That is, rather than making inferences about abstract grammars based on surface patterns, children might begin by simply learning and representing the patterns. This would allow them to produce sentences that are adultlike in certain ways without fully representing the language's grammar. These concrete representations could then gradually become more abstract, structured, and detailed as children gain more experience with the language. I will refer to this proposal as the PATTERN-LEARNING approach since concrete patterns—not abstract structures—are what is being learned.

Both structure-learning and pattern-learning proposals acknowledge that learning a language requires attending to surface patterns. Both types of proposals also can account for children's production of sentences that are adultlike in certain ways. The proposals differ in the claims they make about the knowledge that underlies this performance. Under a structure-learning proposal, children are assumed to represent patterns in an abstract, adultlike way as soon as those patterns are productive in their speech. For example, when a German-learning child produces an overlapping set of verbs in second and final position, marking second-position verbs with a different set of morphemes than final-position verbs, he is assumed to understand that the

V2 morphemes encode the syntactic feature ‘finiteness’ and that verbs occur in 2nd position as a result of a movement operation triggered by that syntactic feature. A pattern-learning proposal would account for that child’s performance quite differently. He would know a set of concrete facts about how sentences are organized in German: that verbs may be second or final, and that second-position verbs take one set of endings, while final-position verbs take a different set. Note that a pattern-learning child need not actually know what the patterns *mean* (e.g., that the verb endings encode the notions of ‘finiteness’ or ‘non-finiteness’) in order to place words in the correct position, nor does the child need to represent an underlying structure with movement operations. In other words, it is possible in principle to know the basic patterns of German sentence structure without actually representing those patterns in an abstract way.

Note that the pattern-learning approach is different in important ways from a constructivist one (e.g., Freudenthal, Pine, Aguado-Orea, et al., 2007). Constructivist learning models posit that children memorize sentence templates but do not acquire any independent knowledge of the patterns inside them. In contrast, the pattern-learning account proposes that the child does learn patterns, but does not initially represent them in an adultlike way.

Thus the pattern-learning proposal, like the structure-learning proposal, can account for the presence of systematic patterns in children’s speech, but it makes a much more modest claim about the nature of children’s linguistic representations: that they contain information about concrete linguistic patterns, and not an adultlike generative grammar. This possibility has not been seriously considered in the generative literature. To the contrary, a widespread assumption is that patterns are simply not learnable without full linguistic representations. Poeppel and Wexler (1993), for example, note that “it is extremely difficult to see how such complex syntactic computations could be learned,” concluding not only that children represent an abstract, movement-based grammar but that the components of this grammar (e.g., verb movement) must be innate. However, the learnability of complex syntactic patterns is an empirical issue. Before concluding that syntactic patterns cannot be learned without full representations, one would first need to construct and test alternative hypotheses. That is the contribution of the present paper.

In a series of experiments, I explore the possibility that learners begin acquiring morphosyntax by learning concrete surface patterns, without representing them in an abstract way. To explore this possibility, I use a miniature language paradigm with adults, where learners' knowledge can be carefully probed to distinguish different types of representations. In Experiment 1, I test the basic prediction of the pattern-learning account: that linguistic patterns can be learned without full representations of the language's structure. Then, in Experiments 2-4, I begin to explore the constraints on this pattern learning mechanism, asking whether learning of V2 patterns is affected by the presence of closed-class morphology on V2. The results of all four experiments suggest that—contrary to widespread assumptions in the generative literature—learners can indeed learn language patterns without full representations, indicating that a pattern-learning mechanism is empirically viable. Furthermore, this mechanism is constrained in ways that make it well-suited to acquiring natural languages. In the Discussion, I consider implications of these results for theories of child language acquisition.

Experiment 1: Miniature V2 language with closed-class morphology

The goal of Experiment 1 was to ask empirically whether a pattern-learning approach is viable. On this approach, learners begin acquiring morphosyntax by identifying and correlating concrete patterns of word order and word form. This procedure would allow learners to acquire properties of basic sentence structure without representing an abstract grammar—a feat that Poeppel and Wexler (1993), among many others, assume is impossible. Thus, for a pattern-learning approach to be empirically viable, one would need to demonstrate that a complex cluster of patterns can be learned without full linguistic representations. Experiment 1 was designed to test this prediction.

All of the experiments in this paper used a miniature V2 language. The phenomenon of V2 word order was investigated for two reasons. First, this is a classic example of a set of patterns that cluster together across different constructions—the kind of phenomenon that abstract functional projections were proposed to account for. Second, these are the particular patterns that Poeppel and Wexler (1993), among others, cite as too complex to learn without innate representations. For these reasons, V2 word order served as an ideal test case for the pattern-learning approach. Of course, future research should examine learning of additional kinds of language patterns.

Experiment 1 method

Participants

Eight students at Georgetown University (age 18-20, mean 18.6) received $10 to participate in this study. Potential participants were screened via email. Individuals who reported exposure to any V2 language, or reported having taken a course on language acquisition or language structure (e.g., Syntax), were not invited to participate.

Description of the language

The syntax of the language, summarized in Table 1, was the same for all four experiments in this paper. The basic sentence structure was S-Adv-O-V. Complex sentences were formed by applying two rules: (1) front a non-verb (S, Adv, or O) and (2) place the verb 2nd. These constraints allow sentences with initial Subjects to have either Vfinal or V2, while sentences with initial Objects or Adverbs require V2.

While the syntax of this language includes the fundamental characteristics of a natural V2 language, it is kept simple for learning in large part because of the small vocabulary used in the language. The lexical items in the language's tiny vocabulary (Table 2) included three nouns, two verbs, and two adverbs. Each lexical category included a mixture of mono- and bisyllabic words, all bearing initial stress and ending with a closed final syllable. The distribution of lexical categories in sentences is determined by the syntax of the language and was the same for all experiments in this chapter. The language also contains a meaningless verb inflection. The distribution and class type of the inflection category varied across experiments (Table 3). In Experiment 1, the inflection category was closed class: it contained a single short, unstressed, prosodically weak form ("ka"). This form occurred as a suffix on second-position verbs only and did not occur on final-position verbs. In this experiment, the inflection is analogous to finite morphology in German and other V2 languages, where finite verbs are generally second in main clauses (this miniature language does not have embedded clauses, which is the context where V2 languages allow finite verbs to be final). Experiment 1 therefore asked whether people can learn V2 word order patterns under typologically natural conditions: when there is closed-class morphology on V2.

	"Moved" words		"Unmoved" words				Types
Basic structures (12)			S	Adv	O	V	6
			S		O	V	6
Complex structures (26)	S	V		Adv	O		4
	S	V			O		4
	O	V	S	Adv			5
	O	V	S				5
	Adv	V	S		O		8

Table 1. Syntax of the miniature V2 language used in Experiments 1-4. The basic sentence structure was S-Adv-O-V; adverbs were optional. Complex sentences were derived by moving a Subject, Adverb, or Object 1st ("topicalization") and placing the verb 2nd ("verb movement"), as in real V2 languages. These constraints allow sentences with initial Subjects to have either Vfinal or V2, while sentences with initial Objects or Adverbs require V2. The morphology of the language depended on the experiment (see Table 3).

Category	Word	Meaning
Noun	flugit daffin mawg	bee giraffe lion
Verb	zemper nim	hug head-butt
Adverb	spad lapal	slowly twice
Inflection	*see Table 3*	*none*

Table 2. Vocabulary of the miniature V2 language used in Experiments 1-4.

Experiment		V2	Vfinal	Description
1	V2+CC	"zemperka"	"zemper"	V2 is marked with the suffix *ka*
2	V2+OC	"zemper klidum"	"zemper"	V2 is followed by *klidum*, *jentif*, or *roy*
3	V2-ø	"zemper"	"zemper"	No inflection
4	Vfinal+CC	"zemper"	"zemperka"	Vfinal is marked with the suffix *ka*

Table 3. Morphology of the miniature V2 language used in Experiments 1-4. Across four experiments, the inflection differed in class type (closed or open) and position (V2 or Vfinal). Class type was defined by the number of words in the category and the phonological properties of those words. In Experiment 1 (V2+CC), verbs in second position (V2) had the suffix *ka* while verbs in final position (VFinal) were uninflected. The inflection is short, high frequency, and prosodically weak, all properties of closed-class items in real languages. This language is most like natural V2 languages. In Experiment 2 (V2+OC), V2 was followed by *klidum*, *jentif* or *roy* while Vfinal was uninflected. The inflections are similar in length and frequency to the open-class words in the language. In Experiment 3 (V2-ø), neither V2 nor Vfinal had any inflection. In Experiment 4 (Vfinal+CC), Vfinal was followed by *ka*. The languages in Experiments 2-4 are unlike natural V2 languages.

Materials

A 38-sentence exposure set was generated by selecting 4 to 8 sentence types for each of the seven sentence structures in Table 1. Twenty-six of these sentences (68%) were complex (V2) sentences, while the remaining 32% (12/38) had basic sentence structure (Vfinal). Subject-initial sentences were a slight majority (53%).[2] When selecting sentences, care was taken to ensure that lexical items were distributed evenly across and within sentence structures. For each sentence structure, half of the sentence types used one verb and half used the other; each of the three nouns appeared as subject and object at least once with each verb; and, for sentences containing adverbs, each adverb occurred equally often with each verb. Care was also taken to ensure that the exposure set did not contain duplicate sentence strings. (The full set of SVO sentence types is identical to the full set of OVS sentence types, but there was no overlap in the sentence types exposed as SVO and OVS.) The exposure set for Experiment 1 is provided in the Appendix. Sentence sound files were synthesized in MacInTalk using a female voice from InfoVox iVox (Sharon). Words were separated by 150 msec of silence.

During exposure, each sentence was paired with a video from an existing corpus of miniature language stimuli (Austin, 2010). In each video, one puppet approached a second puppet and performed a transitive action (Figure 1). The Agent and Patient of the action were always the syntactic subject and object of the sentence, respectively. The miniature language contained adverbs, so modified versions of the videos were created in which the action took

2 In preliminary pilot studies, participants failed to acquire a generalized Fronting pattern (either allowing fronted Objects but not Adverbs, or not acquiring a fronting rule at all) when all structures were equally frequent. The frequency of V2 structures was therefore adjusted. This exposure set more closely resembles the exposure of children learning real V2 languages, who hear many more V2 sentences than Vfinal (e.g. see quantitative data for Dutch in Wijnen, 2001).

place “twice” or “slowly”. The “twice” videos were created by applying iMovie’s Rewind function and then repeating the original video, such that the Agent appeared to perform the action, return to a standing position, and then re-perform the action. The “slow” videos were created by applying iMovie’s “slow motion” function (25% slower).

Figure 1. Videos used for language exposure in Experiments 1-4. Participants listened to sentences while watching movies of two puppets participating in a transitive action. Here, the giraffe approaches the bee, hugs the bee once, and then stands back up (videos are from a lab corpus; Austin 2010).

Procedure

The procedures were adapted from Austin (2010). Participants were told that they would be learning a made-up language called SillySpeak by playing a computer game. The game was programmed in PsiTurk, a platform for conducting online experiments through Mechanical Turk (Gureckis et al., 2016) because preliminary pilot testing was done through Mechanical Turk. Written instructions were provided on the screen. The experimenter was not present for any portion of the exposure or test phase. The entire experiment took approximately 40 minutes. Audio was recorded but not analyzed.

The experiment began with a Vocabulary Training Phase which provided explicit training of noun names. An image of one puppet was displayed on the screen. Written instructions prompted participants to click the picture to hear the puppet's name and to repeat it aloud. At the end of this and all subsequent blocks, a "refresher" screen displayed images of all three puppets. Participants were invited to listen to and repeat the puppets' names again if they could not remember them.

Next, participants entered the four-block Exposure Phase. On each trial, participants listened to a sentence from the language and were instructed to repeat it. Each sentence was accompanied by a video of two puppets participating in a transitive action (e.g., "lion headbutts bee slowly"). In the first block, only Basic sentences were presented.[3] Of the 12 Basic sentence types, half occurred once and half occurred twice in this block (in random order), such that participants heard a total of 18 Basic sentences in the first block. In subsequent blocks, a mixture of six Basic and 30 Complex sentences were presented, such that each sentence type occurred a total of three times across the entire exposure phase. The order of sentences was randomized within each block for each participant. Each exposure block concluded with the "refresher" screen to ensure that participants had ample opportunities to review the three puppets' names. The exposure phase took approximately 30 minutes.

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[3] Preliminary pilot testing on Mechanical Turk suggested that beginning exposure with a block of Basic structures led to better learning overall. This may help by providing a stable word order to aid in learning vocabulary and categorizing lexical items. Without a stable word order, accomplishing these tasks may require more exposure than was provided in this short experiment.

Finally, participants entered the Test Phase (see below). Participants were informed that there would be two new puppets, a Dog and an Elephant, who would each try to say what was happening in the video. The participant's job was to decide who said the best sentence in SillySpeak. The Test Phase appeared identical to the Exposure Phase except that images of the two new puppets appeared below the movie, and a star appeared underneath each of the two images. Participants clicked each image to hear the two sentence alternatives. They indicated their choice by clicking the star underneath the puppet who said the best sentence.

Test

A two-alternative forced-choice (2AFC) test was designed to measure knowledge of the language's V2 patterns and, separately, knowledge of the language's generative rules (Table 4). The target choice on each of 58 trials was always a grammatical sentence. The alternative was identical to the target except for a single error (see below). Care was taken to ensure that, as in the exposure set, lexical items were distributed evenly within and across sentence structures. The grammatical choice occurred first or second equally often, in random order. Accuracy was measured as the proportion of times participants chose the grammatical sentence.

Almost all of the sentences on the test were novel (50/58 grammatical choices and 55/58 foils). It was not possible to test exclusively novel sentence strings due to the language's small vocabulary and the fact that a single sentence string could have multiple structures (e.g., the SVO sentence strings are the same as the OVS strings). When it was necessary to test sentence strings that had occurred in learners' exposure, the string had a different structure on the test than it did during exposure. For example, several OVS test strings occurred in learners' exposure as SVO structures and vice versa, but no OVS test strings occurred as OVS sentences in learners' exposure and no SVO test strings occurred as SVO sentences during exposure. The three “familiar” ungrammatical items occurred as grammatical sentences during exposure (e.g., two *SVOA sentences occurred in learners’ exposure as OVSA sentences). The full set of test sentences for Experiment 1 is provided in the Appendix.

To measure knowledge of V2 patterns, three types of ungrammatical sentences were created. On the Verb Position items, the ungrammatical sentence contained a verb in 1st or 3rd position, while the grammatical choice contained a verb that was 2nd or final. The verb in the ungrammatical sentence always had the same inflection as the grammatical alternative (i.e., if the grammatical choice was a V2 sentence, both choices had inflected verbs; if the grammatical choice was a Vfinal sentence, both choices had uninflected verbs). On items testing Inflection, ungrammatical sentences contained an incorrectly inflected verb. In Experiment 1, V2 always had the suffix *ka* and Vfinal did not have a suffix, so ungrammatical sentences with this type of error either had V2 without *ka*, or Vfinal with *ka*. On items testing the Fronting Restriction, ungrammatical sentences had an Object or Adverb first and Vfinal without *ka*. Rejecting these sentences requires knowing that even though the verb is correctly inflected for its position, the sentence is ungrammatical because initial Objects and Adverbs require V2.

	Example sentences	
	Foil	Target
Patterns		
Verb position (16)	*Vka-S-Adv-O	S-Vka-Adv-O
	*Vø-S-O	S-O-Vø
Inflection (28)	*S-Vø-O	S-O-Vø
	*S-Adv-O-Vka	S-Adv-O-Vø
	*O-Vø-S	O-Vka-S
	*Adv-S-O-Vka	Adv-Vka-S-O
Fronting (6)	*O-S-Vø	O-Vka-S
	*Adv-S-O-Vka	Adv-Vka-S-O

Rules (8)	*S-O-Adv-Vø *Adv-Vka-O-S	S-Adv-O-Vø Adv-Vka-S-O

Table 4. The four types of items on the 2AFC test. Numbers in parentheses indicate the number of trials of each type. On each trial, the two alternatives were identical except for a single error in the ungrammatical sentence. Example pairs of sentence structures are provided for Experiment 1 (V2+CC). In Experiments 2 (V2+OC) and 4 (Vfinal+CC), test sentences were the same except that the morphology was altered to reflect the exposure language. In Experiment 3 (V2-ø), 22 test sentences were removed because, without morphology, the alternatives were either both grammatical (e.g., the first Inflection example in the table) or identical (e.g., the second and third Inflection examples). In all four experiments each structure contrast (e.g. *Vka-S-O vs. S-Vka-O) was tested twice, once with each of the two verbs. The full set of test sentences for Experiment 1 is provided in the Appendix.

Good performance on the Verb Position, Inflection, and Fronting item types would be evidence that learners successfully acquired the language's V2 patterns. In the literature on child language, evidence for children's knowledge of these patterns is often interpreted as evidence that children represent an abstract grammar. That is, children are assumed to represent a basic (underlying) sentence structure and two movement rules via which complex sentences are derived. However, as noted earlier, this does not necessarily follow. Learners first need to notice that patterns exist in order to represent them abstractly, so there may be a stage at which learners know the patterns but not the underlying grammar.

To measure knowledge of the language's grammar separately from the V2 patterns, a fourth type of test item was created. On the Rules items, ungrammatical sentences had all of the correct V2 patterns: verbs were either second or final, correctly inflected for their position, and if an Object or Adverb was first, the verb was second. The error in these sentences was that two of the words were the wrong order. For example, participants chose between the ungrammatical structure *S-O-Adv-Vø and the correct basic structure S-Adv-O-Vø. The ungrammatical sentence has the Object and the Adverb in the wrong order. This structure cannot be generated by the language's grammar: Adverbs precede Objects in the basic structure, and there is no operation which can change the order of Objects and Adverbs while keeping the verb in final position. (The only way for either of these to move is through the fronting operation, which requires also moving the verb 2nd.) On other trials, participants chose between the ungrammatical structure *Adv-Vka-O-S and the correct structure Adv-Vka-S-O. Here, the ungrammatical sentence has the Subject and Object in the wrong order. This structure cannot be generated by the language's grammar: the language has only two movement operations, Fronting and Verb Movement, and both have already applied (the Adverb is first and the verb is second). There are no additional operations that could have changed the order of the Subject and the Object.

There are a variety of ways to succeed on the Rules items. If participants fully represent the language's grammar, they should recognize that the ungrammatical structures cannot be generated by the rules of the language. However, there is other, less abstract knowledge that they could also draw on. Participants could succeed by rejecting unattested bigrams, since each of the ungrammatical sentences contained a sequence of categories that never appeared in their input (e.g. *O-Adv or *O-S). Participants could also succeed by simply memorizing the seven sentence structures as unique constructions. Because there are multiple ways to do well on this test, success would not reveal what kinds of representations are required to learn V2 patterns. However, failure on this test—if it accompanies successful learning of the V2 patterns—would be informative: this would reveal that V2 patterns are learnable without full linguistic representations.

Experiment 1 results

Experiment 1 was designed to answer two questions. First, could learners acquire the V2 patterns of a miniature language in the laboratory, with relatively little exposure? Results in Figure 2 indicate that the answer is clearly yes: participants preferred sentences with the correct V2 patterns over sentences with errors in V2 patterns 74% of the time. To find out whether learners acquired the full set of V2 patterns, results were analyzed for each of the V2 patterns (Table 5), and performance on items testing each pattern was compared to chance in a series of one-tailed t-tests. Participants reliably chose grammatical V2 or Vfinal sentences over sentences where the verb occurred 1st or 3rd (Verb position pattern: $M = .69$, $t(7) = 2.14$, $p = .03$). Learners also reliably preferred sentences where the verb was correctly inflected for its position (i.e., second and inflected or final and bare; Inflection pattern, $M = .77$, $t(7) = 3.61$, $p = .004$). Finally, participants also preferred sentences with initial Objects or Adverbs to have inflected V2 rather than bare Vfinal (Fronting pattern: $M = .73$, $t(7) = 2.76$, $p = .01$). In sum, all three V2 patterns were learnable after only 30 minutes of exposure to the language.

	V2+CC (Exp. 1)	V2+OC (Exp. 2)	V2-ø (Exp. 3)	Vfinal+CC (Exp. 4)
Patterns				
Verb position	.69 (.25)*	.68 (.14)*	.70 (.13)*	.76 (.16)*
Inflection	.77 (.21)*	.68 (.14)*	na	.83 (.16)*
Fronting	.73 (.23)*	.60 (.15)*	.54 (.29)	.48 (.21)
Rules	.48 (.19)	.56 (.20)	.58* (.11)	.44 (.18)

Table 5. Results for the 2AFC test for all four experiments. Means (standard deviations) reflect choice of target item on items testing knowledge of the three V2 patterns and the language's abstract rules. Only learners of languages with V2 morphology (V2+CC and V2+OC) acquired the full set of V2 patterns. When the language did not have V2 morphology (V2-ø and Vfinal+CC), learners struggled to acquire the critical Fronting pattern. In contrast to results for

V2 patterns, only learners of the language without any morphology (V2-ø) performed above chance on items testing the language's rules (likely by rejecting ungrammatical bigrams; see text). *significantly different from chance, $p < .05$, one-tailed.

The second question was whether knowledge of V2 patterns requires abstract representations of the language's grammar. As described above, knowledge of the language's rules was tested with a set of carefully constructed test items on which both alternatives had the correct V2 patterns, but only one could be generated by the language's grammar. In stark contrast to the results for V2 patterns, participants performed quite poorly on these test items: they did not prefer sentences that could be generated by the language's grammar over sentences that could not (48% correct; Figure 2). These results indicate that participants did not acquire full representations of the language. The important implication is that such representations are not required for successful learning of V2 patterns, supporting the pattern-learning proposal for acquiring morphosyntax.

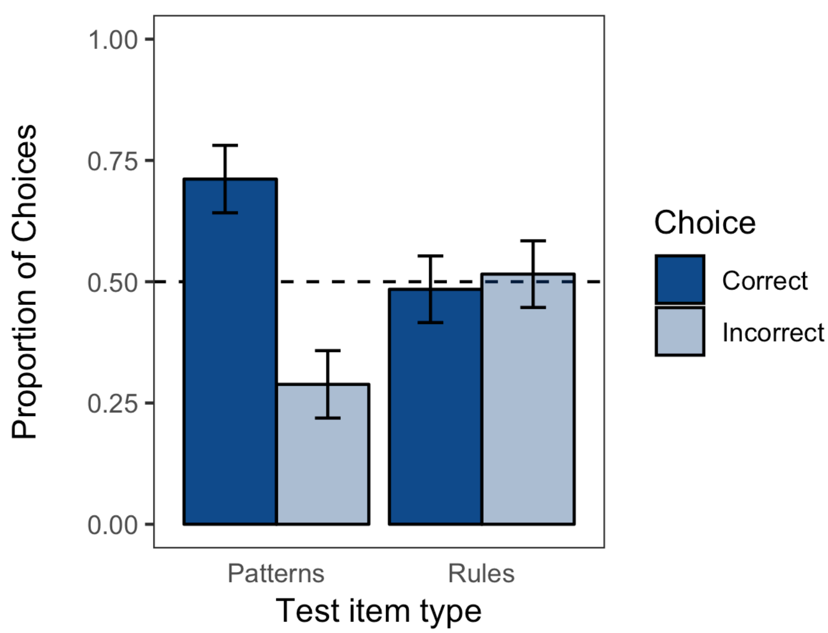

Figure 2. Results of Experiment 1. Adult participants readily acquired V2 patterns but not the language's generative rules.

Is it possible that participants did represent the language with an abstract grammar, just not the grammar intended? For example, learners might in principle be representing an abstract grammar with the wrong basic sentence structure. If so, their grammar would generate a slightly different set of sentences, leading to poor (but systematic) performance on the Rules test. To examine this possibility, participants were divided into subgroups based on their responses for the two items testing the basic sentence structure (S-Adv-O-Vø vs. *S-O-Adv-Vø). Three participants preferred S-Adv-O-Vø on both trials, three participants preferred *S-O-Adv-Vø on both trials, and two participants split their responses between the two structures. For the six participants who consistently preferred one structure, responses on the remaining test items were re-scored so that accuracy was defined in terms of a grammar with their preferred basic structure. That is, for participants who preferred *S-O-Adv-Vø as the basic structure, a preference for *S-V-O-Adv over S-V-Adv-O was now considered correct. When response accuracy was re-scored in terms of participants' preferred basic structure, participants still did not perform better than chance on the remaining Rules items ($M = .58$, $t(5) = 1.46$, $p = .20$). These results suggest that participants performed poorly on the Rules test not because they represented an incorrect abstract grammar, but because they did not represent an abstract grammar at all.

Experiment 1 discussion

After approximately 30 minutes of exposure to a miniature V2 language, adult participants acquired the distributional patterns of V2 word order. In children, this accomplishment has been argued to require knowledge of the full abstract structure of the language. However, careful testing revealed that participants did not represent the language's generative rules. When asked to choose between two sentences that both had correct V2 patterns, but only one of which had a word order that could be generated by the language's grammar, participants were at chance.

These results demonstrate that it is possible to learn V2 patterns without full linguistic representations, confirming the basic prediction of the pattern-learning account.

These results have important implications for theories of child language acquisition, which I consider in the Discussion. The results also raise questions about the nature of a pattern-learning mechanism. For example, do learners identify and correlate all possible patterns in a language? Though possible in principle, this approach would seem at odds with the relatively limited variation in natural languages. For example, languages with V2 word order always have closed-class morphology on V2, suggesting that morphology may be a necessary cue for learning of V2 word order. Supporting this possibility, there is diachronic evidence that the loss of verbal morphology leads to the loss of V2 word order historically (Lightfoot, 2006). Rather than searching for patterns in an unconstrained way, learners may "anchor" their search to closed-class items, which are distinctive across languages due to their high frequency and phonological properties (Shi, Morgan, & Allopenna, 1998); this idea is called the Anchoring Hypothesis (Braine, 1963; Morgan, Meier & Newport, 1987; Valian & Coulson, 1988; Shi & Lepage, 2008).

Three follow-up experiments were designed to ask whether learning of V2 patterns is affected by the language's morphology. Adults were exposed to a version of the miniature V2 language where the language's morphology was less distinctive (Experiment 2), absent (Experiment 3) or occurred on Vfinal rather than V2 (Experiment 4). All of these are unlike natural V2 languages to varying degrees. If learners can still acquire the other V2 patterns under these conditions, this would suggest that pattern learning is relatively unconstrained. Such a mechanism would seem ill-suited to the task of natural language acquisition. Alternatively, if learners struggle to acquire V2 patterns in some of these experiments, this would indicate that pattern learning is constrained in ways that mirror typological patterns. That kind of pattern-learning mechanism would be well-suited to acquiring natural languages.

Experiments 2-4: Miniature V2 language with altered morphology

Experiments 2-4 method

Participants

Three groups of 8 adults age 18-26 from the Georgetown University community received $10 in exchange for participating in one of these experiments. The experiments were run sequentially in the order presented in this paper.

Description of the miniature V2 languages

In the previous experiment, second-position verbs were marked with a closed-class verbal inflection (V2+CC). That language was like natural V2 languages, which always have at least some closed-class morphology on V2 (i.e., these languages always have at least one finite morpheme[4] which is high frequency and phonologically distinctive relative to the open-class words in the language). Thus, the results of Experiment 1 indicated that V2 patterns can be learned under typologically natural conditions. In Experiments 2-4, the morphology of the

[4] Many V2 languages have much more morphology than this, motivating claims that "rich" morphology is a syntactic requirement for certain types of movement and perhaps a learning requirement as well (e.g., Rohrbacher, 1999). However, Bentzen (2004) points out that this generalization does not hold for Norwegian, which has V2 word order but relatively "impoverished" morphology (e.g., each verb class has a single present tense morpheme for all persons and numbers). A generalization that to my knowledge does hold, even considering Norwegian, is that V2 languages always have at least one finite morpheme.

language was altered to be less typologically natural (Table 3). The question was whether this would affect learning of the other V2 patterns.

Open-class inflection on V2 (V2+OC). In Experiment 2, the V2 inflection was made less distinctive and more like an open class (V2+OC). The inflection category contained three phonologically heavy items (*klidum*, *jentif*, and *roy*). Because the inflection category contains three items instead of one, each inflection is relatively low frequency. Inflections were pronounced as a separate word, rather than as a suffix (the inflection was prosodically independent of the verb). The design of this language allowed us to ask whether learning V2 patterns requires morphology that is distinctive (closed-class).

No inflection (V2-ø). In Experiment 3, there was no inflection in the language. As a result, there was no morphological pattern that correlated with the syntactic V2 patterns (verb placement and fronting). This language therefore has fewer patterns than the others, which might in principle make it easier to learn. However, natural V2 languages always have V2 morphology. The design of this language allowed us to ask whether learning V2 patterns requires such morphology.

Closed-class inflection on Vfinal (Vfinal+CC). In Experiment 4, the language contained distinctive closed-class verbal morphology as in Experiment 1, except that the inflection appeared on verbs in final position rather than on V2. At an abstract structural level, this language is like natural V2 languages since the verb's morphology correlates with its position. However, at a surface level, this language is unlike natural V2 languages since V2 is unmarked. If learners "anchor" to closed-class morphology and search nearby portions of the sentence for patterns, they will focus on the end of the sentence (near Vfinal) rather than the middle (near V2). The design of this language allowed us to ask whether learning V2 patterns requires closed-class morphology on V2.

Test

The design of the test was the same as in Experiment 1. Test strings were altered to reflect the language's morphology. In Experiment 2 (V2+OC) and Experiment 4 (Vfinal+CC), test items were exactly the same except that the morphology was altered to reflect the exposure language. In Experiment 3 (V2-ø), 22 test items were removed because, without morphology, the alternatives were either identical or both grammatical (see Table 4). Most, but not all, of the items testing the Inflection pattern were removed for this reason. Items testing the Inflection pattern that were not removed for Experiment 3 had Objects or Adverbs first. In the other experiments, the foils for these items had the verb last with V2 inflection (e.g., *Adv-O-S-Vka in Experiment 1). These foils are still ungrammatical in Experiment 3 since they violate the Fronting pattern. To keep the test maximally similar across experiments, these items were included in the test for Experiment 3 but not analyzed.

Materials and Procedure

Except for the class type and distribution of V2 morphology as described above, the materials and procedures were identical to Experiment 1.

Experiments 2-4 results

In Experiments 2-4, the language's morphology was altered, and the question was whether this would affect learning of the other V2 patterns. Because Experiments 1-4 were designed and run in sequence, rather than as contrasting conditions in a single experiment, results for the different experiments are not directly compared statistically. Rather, performance in each experiment was analyzed in a series of one-tailed t-tests which tested, for each V2 pattern, whether performance was significantly above chance (.50). Results are presented in Figure 3 and Table 5. Results for Experiment 1 are included in Figure 3, Table 5, and the text below to facilitate comparison.

Verb position. Learners in all four experiments acquired the verb placement pattern, preferring V2 and Vfinal sentences over V1 and V3 sentences. Performance was virtually identical for languages with closed-class V2 morphology (V2+CC: $M = .69$, $t(7) = 2.14$, $p = .03$), open-class V2 morphology (V2+OC: $M = .68$, $t(7) = 3.66$, $p = .004$) and no morphology (V2-ø: $M = .70$, $t(7) = 4.33$, $p = .002$), and slightly numerically higher in the language with closed-class morphology on Vfinal ($M = .76$, $t(7) = 4.61$, $p = .001$). These results indicate that learners were able to acquire the verb position pattern in all four experiments, regardless of the type of morphology in the language.

Verb inflection. In all three experiments with morphology, learners acquired the language's inflection pattern, either preferring V2 to be inflected and Vfinal to be uninflected (V2+CC, V2+OC) or preferring the reverse (Vfinal+CC), depending on the language they had listened to. Accuracy was numerically higher with closed-class morphology (V2+CC: $M = .77$, $t(7) = 3.61$, $p = .004$; Vfinal+CC: $M = .83$, $t(7) = 5.60$, $p < .001$) than with open-class morphology (V2+OC: $M = .68$, $t(7) = 3.82$, $p = .003$), but learning was excellent in all three experiments. These results indicate that adults learned the verb's inflection pattern whether the inflection was highly distinctive or less distinctive, and whether the marked verb was second or final.

Fronting. The complex Fronting pattern—in which sentences with initial Objects or Adverbs must be V2, while sentences with initial Subjects may be V2 or Vfinal—defines V2 languages. Technically, this pattern is independent of the language's morphology: it could in principle be learned by tracking the position of the verb relative to the position of the other elements, without attending to the morphology. Therefore, it is possible in principle for learners in all four experiments to acquire this pattern. However, Figure 3 illustrates a different outcome. Accuracy on items testing the Fronting pattern was significantly above chance only when V2 was marked morphologically (V2+CC: $M = .73$, $t(7) = 2.76$, $p = .01$;V2+OC: $M = .60$, $t(7) = 1.93$, $p = .05$). Performance was numerically better when V2 morphology was closed-class than when it was open-class. In contrast, accuracy was not significantly above chance when V2 was not marked (V2-ø: $M = .54$, $t(7) = .40$, $p = .35$; Vfinal+CC: $M = .48$, $t(7) = -.28$, $p = .61$). This result indicates that learners acquire the full set of V2 patterns only when V2 is marked morphologically, and that V2 patterns are learned best when V2 morphology is strongly distinctive.

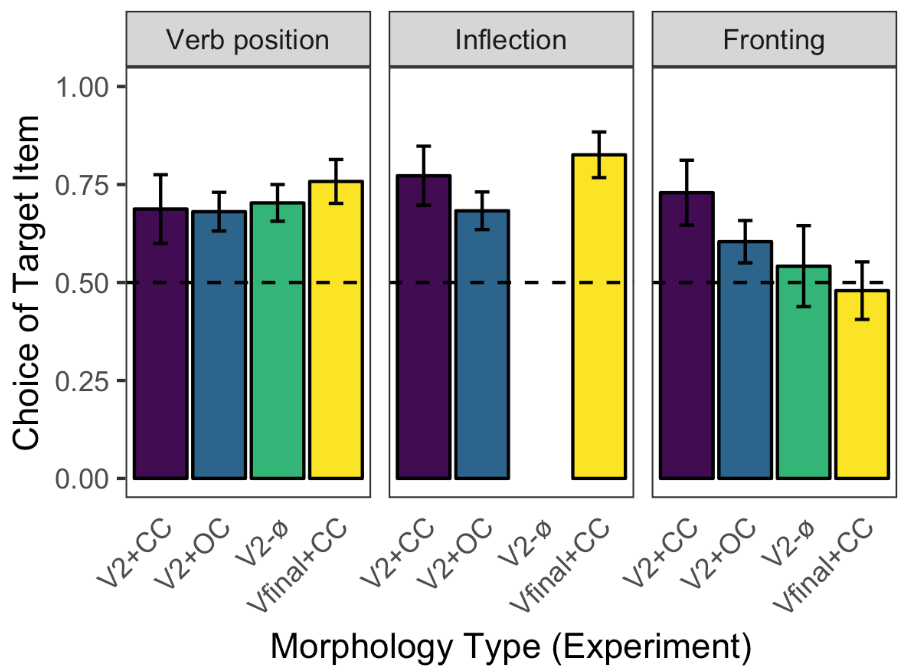

Figure 3. Results of Experiments 1-4 (miniature V2 languages with altered morphology) on items testing V2 patterns. Results for Experiment 1 (V2+CC) are included for comparison; these results are the same as in Figure 2 except that this graph shows only the proportion of times participants chose the target item (i.e., accuracy), rather than the proportion of times participants

chose each of the two alternatives. Learners successfully acquired the verb position and verb inflection patterns regardless of the type of morphology in the language. However, accuracy on items testing the Fronting pattern was significantly above chance only when V2 was marked morphologically (V2+CC and V2+OC).

Rules. As in Experiment 1, the test also required learners to choose between sentences that could be generated by the language's grammar and those that could not. Learners in Experiment 1 performed poorly on these items (V2+CC: $M = .48$, $t(7) = -.22$ $p = .57$) and learners in Experiments 2 and 4 performed no better (V2+OC: $M = .56$, $t(7) = 0.88$, $p = .20$; Vfinal+CC: $M = .44$, $t(7) = -1.00$, $p = .82$). In all of those experiments, the language contained morphology. In contrast, performance actually was above chance for the language without morphology (V2-ø: $M = .58$, $t(7) = 1.93$, $p = .05$). Given that learners in this experiment did not learn the Fronting pattern (see above), their performance on the Rules test seems unlikely to actually reflect knowledge of the language's generative rules. A more likely explanation is that when there is no morphology for learners to focus on, they turn their attention to the linear order of the language. In a language with complex word order like this one, a linear-order approach will not be very productive, but it might ultimately allow learners to reject sentences with unattested bigrams (e.g. *S-V-O-Adv, and all of the other incorrect alternatives on the Rules test items). Interestingly, a linear-order approach would be well-suited for learning real languages that lack morphology, which rely on word order to express grammatical relations. I return to this point in the Discussion.

Experiments 2-4 discussion

Experiments 2-4 were designed to ask whether the morphology of a miniature V2 language affects learning of the other V2 patterns. Adults were exposed to a version of the miniature V2 language from Experiment 1 where the morphology was less distinctive (Experiment 2), there was no morphology (Experiment 3) or the morphology did not correlate with V2 patterns (Experiment 4). In contrast to Experiment 1, learners struggled to acquire the defining pattern of V2 word order—a contingency between fronting and verb placement—when there was no V2 morphology (Experiments 2 and 4). Learners did acquire V2 word order when there was V2 morphology that was not distinctive (Experiment 3), but learning was weaker than in Experiment 1.

Learners' failure to acquire the fronting restrictions without V2 morphology is particularly interesting because learners' exposure always contained ample distributional evidence for this pattern. The fronting pattern could in principle be learned by tracking the position of the verb relative to the position of other elements. Statistically, this contingency is equally reliable in all four experiments and is not affected by the language's morphology. However, learners apparently noticed the fronting pattern only when there was morphology on V2. This result suggests that learners are not simply identifying and correlating all possible patterns in the language. Rather, their search for patterns is constrained, and they only acquire a fronting pattern when there is also a morphological pattern marking V2. In the Discussion I consider what kind of constraint could lead to these results.

As in Experiment 1, when the language contained some kind of morphology, learners did not perform above chance on items testing knowledge of the language's generative rules. However, in the language without any morphology, learners did succeed on these items, likely through knowledge of linear order. Taken together with the previous results, this suggests the following. When a language contains morphology, learners acquire complex distributional patterns that correlate with that morphology, but they struggle with linear order. When a language does not contain morphology, learners acquire linear order but struggle with complex syntactic patterns. These results accord with language typology: natural languages with morphology often have variable word order (like V2 languages), while natural languages without morphology have relatively fixed word order. Thus, the mechanism that adults used to acquire the miniature languages in this paper appears to be well suited for the acquisition of natural languages.

Discussion

Using a miniature language learning paradigm, this paper explored a pattern learning approach to the acquisition of V2 word order. Experiment 1 demonstrated the feasibility of this approach, showing that adults learn complex distributional patterns relatively quickly and without full linguistic representations. Experiments 2-4 explored the character of this learning mechanism and showed that when the miniature V2 language did not mark V2 morphologically (i.e., when the language is unlike natural V2 languages), learners fail to acquire V2 word order. These results demonstrate that widespread skepticism in the generative literature over the learnability of linguistic patterns is unfounded. In fact, adults appear to have access to a robust pattern-learning mechanism that operates quickly, does not require full linguistic representations, and is most effective under typologically natural conditions. Such a mechanism could be extremely valuable in the early stages of natural language acquisition.

Implications for child language acquisition

What are the implications of these results for child language acquisition? Children are very young when they master V2 patterns, and they have more limited memory and processing abilities than adult learners. However, evidence increasingly suggests that when child and adult learners are exposed to languages with predictable (as opposed to unpredictable or variable) patterns, they learn using similar mechanisms (e.g. Aslin, Saffran, & Newport, 1998; Reeder, Newport, & Aslin, 2013; Saffran, Newport, & Aslin, 1996; Schuler, Lukens, Reeder, Newport, & Aslin, in preparation).[5] It therefore seems possible that children, like adults, might acquire concrete linguistic patterns before representing an abstract grammar. At the very least, this possibility must be credited when evaluating the source of children's grammatical knowledge. There is no justification—especially given the present results—for dismissing this possibility *a priori*.

How could one find out whether children have the same pattern-learning mechanisms as adults? Miniature language experiments have been done with young children (e.g. Austin, 2010; Culbertson & Newport, 2015; Hudson Kam & Newport, 2005), but the languages in all of those experiments are quite simple. The miniature V2 language used in this paper is much more complex, raising methodological challenges for extending these results to children. A procedure for doing this is under development. In the meantime, as an alternative source of information, one can ask whether children learning real V2 languages ever make the same kind of errors as adults did in Experiments 1-4. In fact, children have been observed to produce such errors. In particular, participants in Experiments 1-4 failed to reject complex sentences in which the third and fourth words—whose order should be the same as in the basic sentence structure—were

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[5] A popular position in the generative acquisition literature is that researchers should assume "continuity" between the cognitive mechanisms available to adults and those available to children, otherwise one must specify how new cognitive mechanisms become available. This is usually noted as part of an argument for innate linguistic representations. Those who favor this assumption might consider, alternatively, that powerful statistical learning mechanisms might be what is continuously available throughout development. Indeed, that is what current evidence suggests. From that perspective, if syntactic patterns are learnable by adults, there is good reason to think they should be learnable by children as well.

scrambled (e.g., subjects accepted *S-V-O-Adv in addition to S-V-Adv-O). This was interpreted as evidence that adults did not represent the complex sentences as derived from a basic structure. The same kind of error has been attested for children learning a variety of V2 languages including Dutch (Schlichting 1996), Norwegian (Westergaard 2008) and Swedish (Waldman 2011, Santelmann 1995). The similar types of errors made by adults learning a miniature V2 language and by children acquiring natural V2 languages are at least consistent with the hypothesis that children, too, represent patterns and not necessarily abstract movement rules.

Constraints on pattern learning

The full set of V2 patterns was learned only when V2 was marked morphologically (whether this morphology was closed- or open-class). When Vfinal was marked rather than V2, and when there was no morphology at all, learners did not acquire the defining pattern of V2 word order: a contingency between verb placement and fronting. Thus, learners apparently do not identify and correlate all possible patterns in the language. Rather, something constrains learners' search for patterns, such that V2 patterns are only discovered when there is V2 morphology. What is the nature of these constraints?

A traditional Universal Grammar account might be that learners know innately that V2 patterns are dependent on finite morphology, and therefore only acquire V2 patterns when such morphology exists. The challenge for this account is that innate knowledge must be specified in highly abstract terms, so in order to draw on innate knowledge for information about how patterns may be related, learners must first represent patterns in those abstract terms as well. For example, learners in Experiments 1 and 2 would need to recognize the meaningless inflections as the realization of the innate feature "finite", and to represent verbs in second position and non-Subjects in first position as the result of an innate verb movement and fronting operation, respectively. At that point, knowledge of Universal Grammar might tell learners that verb movement and fronting are linked to finiteness, and therefore—for this language—sentences that start with Objects or Adverbs must have the verb second and inflected. However, careful testing revealed that learners did not represent the language in terms of an underlying structure and abstract movement operations. In other words, learning could not have been constrained by Universal Grammar because learners' knowledge is not yet encoded in abstract enough terms.

An alternative type of constraint, raised in the introduction to Experiments 2-4, is that learners "anchor" their search for patterns to closed-class items (the Anchoring Hypothesis; Morgan, Meier & Newport, Valian & Coulson, 1998; Braine, 1963; Shi & Lepage, 2008). On this account, learners need their attention drawn to V2 patterns in order to notice them. Several pieces of evidence from Experiments 1-4 are consistent with this type of constraint.

First, of the two experiments where V2 patterns were learned (V2+CC and V2+OC), learning was stronger when the V2 inflection was most distinctive (high frequency and phonologically different from the other words in the language: V2+CC). In the other experiment, the V2 inflections were lower frequency and phonologically like the other words in the language, hence less distinctive. Note that in all of these experiments, the inflections were the only forms in the language that did not mean anything, which might have made them somewhat distinctive even when they were otherwise like the other words in the language. This could explain why there was some learning of V2 patterns when V2 morphology was open-class, a situation in which the Anchoring Hypothesis might otherwise have predicted learners would fail.

Second, learners completely failed to acquire the critical Fronting pattern when the language contained closed-class morphology on Vfinal. This result was not inevitable. One could have theorized that morphology draws learners' attention to the existence of a contingency between the verb's form and its position, which then allows learners to track a higher-level contingency between the verb's form/position and the first word of the sentence. On this account, the position of the marked verb should not matter: V2 patterns should be learned just as easily when Vfinal is marked as when V2 is marked. This is not the result that was observed. Rather, learning V2 patterns required morphology *on V2*, suggesting that learners need a local cue on V2 in order to notice V2 patterns.

Both pieces of evidence suggest that—consistent with the Anchoring Hypothesis—learners notice V2 patterns only when one or more distinctive forms draw their attention to V2. There are a number of different ways that this might constrain how learners search for patterns. For example, V2 morphology could focus attention on second-position verbs, potentially motivating learners to search for patterns involving those elements (as opposed to patterns involving verbs in final position, patterns involving Subjects first, etc.). V2 morphology could also provide a stable positional cue around which learners could organize knowledge of patterns. For example, in the V2+CC language, learners could identify patterns like "*ka* occurs on V2" and "V2+*ka* occurs after Objects, Adverbs, and Subjects". This is a way of learning V2 patterns without directly tracking the position of verbs relative to Objects, Adverbs, and Subjects. Indeed, it has long been known that learners struggle to track the position of open-class items relative to each other, faring much better when there is a high frequency or closed-class item relative to which the position of open-class items can be encoded (Braine, 1963; Valian & Coulson, 1988). The results of Experiments 1-4 are consistent with these classic findings. Learners did not acquire V2 word order when the only way to do so was to track the position of Subjects, Objects, and Adverbs relative to the position of the verbs (i.e., in the experiments without V2 morphology). Learning was successful only when learners had the option of tracking the distribution of open-class items relative to a morphological anchor, and learning was best when this anchor was most distinctive.

Thus, pattern learning appears to be constrained not by innate knowledge of linguistic structure—such knowledge is too abstract to play a role at this early stage—but by a low-level bias to focus on distinctive items or to organize knowledge of patterns around these elements. As a result, V2 word order is learned only when there is V2 morphology. Such morphology is always present in natural V2 languages and may be necessary for maintaining V2 word order during periods of language change (Lightfoot, 2006). The results of this paper suggest that biases in play during the early stages of language acquisition could explain this link.

Acquiring more complex knowledge

More work is needed to understand how pattern learning contributes to the acquisition of abstract, hierarchical representations. For example, on this approach, learners do not initially represent complex sentences as derived from a basic structure. Instead, they learn the properties of complex sentences—their patterns—independently, and only later represent their relationship to the basic structure. If learners do not initially represent a relationship between basic and complex structures, how do they learn that one exists? One possibility is that knowledge of the relationship among sentence structures emerges with increased exposure to different sentence types. Support for this possibility comes from a miniature language study by Thompson and Newport (2007). In that study, learners were exposed to a phrase-structure language with the basic word order (AB)(CD)(EF) where each letter represents a form-class category. Acquisition of phrase structure was facilitated when learners were exposed to complex sentences where phrases had been repeated, deleted, and/or re-ordered, for example (CD)(EF)(AB)(AB). Of relevance here, learners were able to acquire the basic word order of the language (ABCDEF) even when 95% of the sentences in their input had been permuted. Learning was significantly better than in a control condition where learners had the same amount of exposure to the basic sentence type, but where the permutations in complex sentences did not respect phrasal groupings. These results suggest that basic word order can be learned from exposure to sentences that have been transformed in a systematic way.

Another key question is how knowledge of concrete patterns develops into representations of functional projections. One possibility is that patterns are eventually translated into the features and categories of an innate Universal Grammar. This is possible for a pattern-learning approach because knowledge is in the right format: individual patterns (e.g., specific morphemes) correspond to individual features (e.g., finiteness), and so it is at least possible in theory to link the two, though one would still need to specify on what basis. Alternatively, patterns might be stored abstractly in terms of language-specific features. Either way would allow knowledge acquired in the early stages of learning to ultimately be represented in terms of functional projections, with individual patterns represented as features and contingencies between patterns represented as multiple features on a single functional head (not unlike the feature-assembly approach proposed by Hegarty, 2005 and developed for second language acquisition by Lardiere, 2009). This is importantly unlike the outcome of a construction-based learning process, where representations are formatted so differently from those in generative syntactic theory that there is no structural correspondence at any level and no hope of ever linking the representations. The fact that a pattern-learning mechanism would acquire and store information in a format that aligns with current syntactic theory is a significant advantage of this approach.

Conclusion

In syntactic theory, abstract representations are posited to link grammatical patterns that cluster together across sentences. Children's knowledge of the contingencies among patterns has traditionally been interpreted as evidence for full linguistic representations. Here, I showed that adult learners can learn V2 patterns without representing the full structure of the language, as long as there is morphology on V2. These results raise the possibility that children acquiring natural languages might also begin by learning patterns, without necessarily representing them in an adultlike linguistic tree, a possibility under investigation in ongoing work. If children, too, can learn complex linguistic patterns, this may be an important mechanism enabling learners to acquire the morphosyntax of natural languages.

Acknowledgements redacted for blind review.

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Appendix A: Exposure set for Experiment 1

Sentence structures were identical across all four experiments. Sentence strings were modified for Experiments 2-4 according to the inflection patterns of the language, as detailed in the text.

Number	Structure	String (Experiment 1)
1	SVO	flugit nimka mawg
2	SVO	daffin nimka flugit
3	SVO	mawg zemperka daffin
4	SVO	daffin zemperka mawg
5	OVS	flugit nimka daffin
6	OVS	daffin nimka mawg
7	OVS	mawg nimka flugit
8	OVS	flugit zemperka mawg
9	OVS	daffin zemperka flugit
10	SOV	flugit mawg nim
11	SOV	daffin flugit nim
12	SOV	mawg daffin nim
13	SOV	flugit daffin zemper
14	SOV	daffin mawg zemper
15	SOV	mawg flugit zemper
16	SVAO	mawg nimka lepal daffin
17	SVAO	flugit nimka spad mawg
18	SVAO	mawg zemperka spad daffin
19	SVAO	daffin zemperka lepal flugit
20	SAOV	flugit spad daffin nim
21	SAOV	daffin lepal mawg nim
22	SAOV	mawg spad flugit nim
23	SAOV	flugit lepal mawg zemper
24	SAOV	daffin lepal flugit zemper
25	SAOV	mawg spad daffin zemper
26	OVSA	daffin nimka flugit lepal
27	OVSA	mawg nimka daffin spad
28	OVSA	mawg zemperka daffin lepal
29	OVSA	flugit zemperka mawg spad
30	OVSA	mawg zemperka flugit spad
31	AVSO	lepal nimka daffin flugit
32	AVSO	spad nimka mawg flugit
33	AVSO	spad nimka daffin mawg
34	AVSO	lepal nimka flugit daffin
35	AVSO	lepal zemperka flugit mawg
36	AVSO	spad zemperka daffin flugit
37	AVSO	lepal zemperka mawg daffin
38	AVSO	spad zemperka flugit mawg

Appendix B: Test Sentences for Experiment 1

Each test item had two choices, one grammatical (G) and one ungrammatical (UG). Strings were novel (did not occur in the exposure set for Experiment 1) except where indicated. Test strings were modified for Experiments 2-4 according to the inflection patterns of the language. See text for details.

Verb Position

Item	Structure	String	Choice	Exposed?
1	SVO	mawg nimka daffin	G	
1	VSO	nimka mawg daffin	UG	
2	SVO	flugit zemperka mawg	G	Exposed as OVS
2	VSO	zemperka flugit mawg	UG	
3	SOV	mawg flugit nim	G	
3	VSO	nim mawg flugit	UG	
4	SOV	daffin flugit zemper	G	
4	VSO	zemper daffin flugit	UG	
5	SVAO	flugit nimka spad daffin	G	
5	SAVO	flugit spad nimka daffin	UG	
6	SVAO	mawg zemperka lepal flugit	G	
6	SAVO	mawg lepal zemperka flugit	UG	
7	SVAO	flugit nimka lepal daffin	G	
7	VSAO	nimka flugit lepal daffin	UG	
8	SVAO	mawg zemperka spad flugit	G	
8	VSAO	zemperka mawg spad flugit	UG	
9	SAOV	flugit spad mawg nim	G	
9	SAVO	flugit spad nim mawg	UG	
10	SAOV	daffin lepal mawg zemper	G	
10	SAVO	daffin lepal zemper mawg	UG	
11	SAOV	mawg spad daffin nim	G	
11	VSAO	nim mawg spad daffin	UG	
12	SAOV	flugit spad daffin zemper	G	
12	VSAO	zemper flugit spad daffin	UG	
13	OVSA	mawg nimka flugit lepal	G	
13	OSVA	mawg flugit nimka lepal	UG	
14	OVSA	flugit zemperka daffin spad	G	
14	OSVA	flugit daffin zemperka spad	UG	
15	AVSO	spad nimka daffin flugit	G	

15	ASVO	spad daffin nimka flugit	UG
16	AVSO	lepal zemperka mawg flugit	G
16	ASVO	lepal mawg zemperka flugit	UG

Verb Inflection

Item	**Structure**	**String**	**Choice**	**Exposed?**
1	SVO	daffin nimka mawg	G	Exposed as OVS
1	SVO	daffin nim mawg	UG	
2	SVO	mawg zemperka flugit	G	
2	SVO	mawg zemper flugit	UG	
3	SVO	flugit nimka daffin	G	Exposed as OVS
3	SOV	flugit daffin nimka	UG	
4	SVO	daffin zemperka flugit	G	Exposed as OVS
4	SOV	daffin flugit zemperka	UG	
5	OVS	daffin nimka flugit	G	Exposed as SVO
5	OSV	daffin flugit nimka	UG	
6	OVS	flugit zemperka daffin	G	
6	OSV	flugit daffin zemperka	UG	
7	OVS	mawg nimka daffin	G	
7	OVS	mawg nim daffin	UG	
8	OVS	daffin zemperka mawg	G	Exposed as SVO
8	OVS	daffin zemper mawg	UG	
9	SOV	flugit daffin nim	G	
9	SOV	flugit daffin nimka	UG	
10	SOV	flugit mawg zemper	G	
10	SOV	flugit mawg zemperka	UG	
11	SOV	daffin mawg nim	G	
11	SVO	daffin nim mawg	UG	
12	SOV	mawg daffin zemper	G	
12	SVO	mawg zemper daffin	UG	
13	SVAO	daffin nimka lepal mawg	G	
13	SVAO	daffin nim lepal mawg	UG	
14	SVAO	flugit zemperka spad daffin	G	
14	SVAO	flugit zemper spad daffin	UG	
15	SVAO	mawg nimka spad flugit	G	
15	SAOV	mawg spad flugit nimka	UG	
16	SVAO	daffin zemperka lepal mawg	G	
16	SAOV	daffin lepal mawg zemperka	UG	
17	SAOV	mawg lepal flugit nim	G	

17	SAOV	mawg lepal flugit nimka	UG
18	SAOV	flugit spad mawg zemper	G
18	SAOV	flugit spad mawg zemperka	UG
19	SAOV	daffin spad mawg nim	G
19	SVAO	daffin nim spad mawg	UG
20	SAOV	mawg lepal daffin zemper	G
20	SVAO	mawg zemper lepal daffin	UG
21	OVSA	flugit nimka mawg spad	G
21	OVSA	flugit nim mawg spad	UG
22	OVSA	daffin zemperka flugit lepal	G
22	OVSA	daffin zemper flugit lepal	UG
23	OVSA	daffin nimka mawg spad	G
23	OSAV	daffin mawg spad nimka	UG
24	OVSA	mawg zemperka flugit lepal	G
24	OSAV	mawg flugit lepal zemperka	UG
25	AVSO	lepal nimka mawg daffin	G
25	AVSO	lepal nim mawg daffin	UG
26	AVSO	spad zemperka flugit daffin	G
26	AVSO	spad zemper flugit daffin	UG
27	AVSO	lepal nimka daffin mawg	G
27	ASOV	lepal daffin mawg nimka	UG
28	AVSO	spad zemperka mawg flugit	G
28	ASOV	spad mawg flugit zemperka	UG

Fronting

Item	Structure	String	Choice	Exposed?
1	OVS	flugit nimka mawg	G	Exposed as SVO
1	OSV	flugit mawg nim	UG	Exposed as SOV
2	OVS	mawg zemperka daffin	G	Exposed as SVO
2	OSV	mawg daffin zemper	UG	
3	OVSA	flugit nimka	G	

		daffin lepal	
3	OSAV	flugit daffin lepal nim	UG
4	OVSA	daffin zemperka mawg spad	G
4	OSAV	daffin mawg spad zemper	UG
5	AVSO	spad nimka flugit mawg	G
5	ASOV	spad flugit mawg nim	UG
6	AVSO	lepal zemperka daffin mawg	G
6	ASOV	lepal daffin mawg zemper	UG

Rules

Item	**Structure**	**String**	**Choice**	**Exposed?**
1	SVAO	daffin nimka lepal flugit	G	
1	SVOA	daffin nimka flugit lepal	UG	Exposed as OVSA
2	SVAO	flugit zemperka spad mawg	G	
2	SVOA	flugit zemperka mawg spad	UG	Exposed as OVSA
3	SAOV	daffin lepal flugit nim	G	
3	SOAV	daffin flugit lepal nim	UG	
4	SAOV	daffin spad flugit zemper	G	
4	SOAV	daffin flugit spad zemper	UG	
5	OVSA	mawg nimka flugit spad	G	
5	OVAS	mawg nimka spad flugit	UG	
6	OVSA	flugit zemperka mawg lepal	G	

6	OVAS	flugit zemperka lepal mawg	UG
7	AVSO	lepal nimka flugit mawg	G
7	AVOS	lepal nimka mawg flugit	UG
8	AVSO	spad zemperka daffin mawg	G
8	AVOS	spad zemperka mawg daffin	UG