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Argument structure and the child's contribution to language learning

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One of the oldest questions in cognitive science asks whether children are able to learn language (or anything) because they are equipped with a very powerful general-purpose learning mechanism or because they are equipped with a domain-specific constrained language acquisition device. Recent advances in statistical approaches to language learning seem to boost the plausibility of general-purpose learning. However, in this article we propose that in the domain of verb learning, children rely more on their internally generated preconceptions about linguistic structure than on robust cues in the input, suggesting that at least in this aspect of language learning, domain-specific grammatical knowledge guides linguistic development.

A much-debated question in the literature of language learning concerns who is in the driver's seat. Is the phenomenon of language learning most faithfully described by saying that the human infant, a natural absorber and organizer of all kinds of information, simply takes in all the patterned properties of the speech that she hears and thus acquires a language? Or does the child learner play a much more creative role, imposing his or her own expectations about the nature of a linguistic system on the data of language experience, and thus acquires a language? In this article we will not enter this debate in its general form. We believe it is both obvious and a shared conclusion that what the child ultimately learns is a function of both the input language (no child exposed only to French ever learned Malayalam) and of some fundamental aspects of human nature (no ficus trees or Cocker spaniels have ever learned a language). Thus, it serves no purpose to ask about language *in toto* whether it is learned in response to the input or through some domain-specific constrained learning device. Rather, the task of the acquisitionist is to determine for any given piece of knowledge the relative contributions of experience and inherent linguistic principles on the growth of that knowledge in the learner [1]. Our purpose here is to examine one property of children's linguistic knowledge that in some remarkable cases arises in the absence of any input at all, and in other cases arises despite being hard to detect in the exposure language. Such knowledge, we argue, must derive from a learning mechanism that is inherently biased from the outset, because the input in these cases is unreliable. The unlearned linguistic expectation we are concerned with is the generalization [2–5] that can be stated as follows:

(i) *Every participant in an event as it is mentally represented shows up as a syntactic phrase in a sentence describing that event*.

The expectation that (i) will be true in the language being acquired holds even among learners who never heard the events described that way. We first describe this idealized alignment of participants and their expression in adult language and then move on to discuss how this alignment expresses itself in language learners.

The complete thought and its expression in the linguistic clause

One of the simplest pieces of linguistic knowledge that we can attribute to speakers of a language is a corollary of (i), namely:

(ii) *The number of participants in (our mental representation of) an event predicts the number of phrasal arguments that occur in a sentence describing that event*.

For example, it takes only one entity to snore and so we express snoring events with a verb and one noun phrase:

(1) *My grandfather snores*.

There are two core participants in an event of kicking and so we have two noun phrases:

(2) *My grandmother kicked my grandfather*.

And we have *mutatis mutandis* for three-participant events such as sending:

(3) *My grandmother sent my grandfather to the garage*.

At first sight this one-to-one alignment of conceptual arguments with noun phrases seems inevitable, following automatically from the nature of the events involved. However, it is quite easy to imagine that human languages could have been organized differently. Indeed, we do not have to look further than English to see independent syntactic factors interacting with (i) and (ii) to mask the effects of these principles. English requires every sentence to have a subject, so even events with no participants, like RAIN, are expressed with a pleonastic noun-phrase subject:

(4) *It is raining*.

Similarly, infinitival clauses do not allow overt subjects

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and so, although (5a) and (5b) express the same events, there is one fewer overt noun phrase in (b).

(5) a. *My grandmother persuaded my grandfather that he should sleep outside*.

b. *My grandmother persuaded my grandfather to sleep outside*.

What these facts tell us is simply that the mapping between conceptual structure and linguistic structure is complicated by the details of syntax, but they do not undermine the principles (i) and (ii). Rather, wherever it appears that these principles are violated, it is not because they are false but because they interact with other grammatical properties.

We will ask in this article what gives rise to the harmony between linguistic and conceptual structures. Is there something about being a human language that demands this kind of system, or is it simply an accident of cultural–linguistic history? Asked differently, does a human child learn that noun phrases line up one-to-one with event participants [principles (i) and (ii)] because she noticed that the exposure language just *is* this way, or because she *expects* it to be this way? (see Box 1).

One-to-one alignment as a learning principle

Sporadically, one hears a child say something like '*Daddy giggles me*' [6]. This kind of creative error suggests that he has at least 'learned' the English way of adding noun phrases to add arguments. Indeed, there is a good deal of evidence showing that children as young as 22 months honor the mapping between syntactic arguments and event participants [7–14]. Together, these experiments show that English-learning children use this one-to-one mapping principle as a guide to their interpretations of novel verbs and their interpretations of known verbs in novel syntactic contexts.

Our aim in this article, however, is not simply to assert that learners use this alignment, which we believe no-one would deny, but to go further and show that they use it by virtue of the fact that they are human language learners. The weak point for making such an argument is that English-speaking children who use the one-to-one principle might have learned it by observation. Because it is true that this particular form–meaning correlation holds in English, the principle (i) underlying it might have been deduced after making dozens of observations of sentences instantiating it. On this view, children use this principle in learning because they first learn that it holds.

To show that this principle is not learned but rather supplied by the child's own language-learning mechanism, we will examine two cases. First, we will look at children who have no language model – those congenitally deaf children of hearing parents who are not exposed to a signed language. If these children respect the alignment between syntactic and semantic participants, it could not be because they learned it from their linguistic input; these children have no such input. Second, we will examine children learning a language in which the number of arguments is not the most reliable indication of the kind of event being described. If these children use argument number as a cue to verb meaning, despite the presence of more reliable cues in the input, then this is evidence of the child's expectations about linguistic systems. By selecting certain cues over other, more reliable, ones, the child reveals the nature of his language learning mechanism.

The case of the isolated deaf

Most congenitally deaf children are born to hearing parents who do not sign, and therefore these children might not come into contact with gestural languages for years. Their deafness also makes it impossible to acquire the language spoken in the home. Children in these circumstances spontaneously invent gesture systems called 'Home Sign' [15–17]. Remarkably, although these children are isolated from exposure to any conventional language, their home sign systems partition their experience into the same elements that characterize human languages, ranging from Abkhaz to Zuni. Specifically, home sign systems have nouns and verbs, distinguishable from each other by their positions in the children's gesture sequences and by their distinctive iconic properties. Moreover, sentence-like combinations of these gestures

Box 1. The origins of the one-to-one principle

The one-to-one principle that is the subject of this article is an unlearned linguistic expectation that can be described as:

(i) *Every participant in an event as it is mentally represented shows up as a syntactic phrase in a sentence describing that event.*

An important question surrounding principle (i) concerns its origins. Is (i) true because of properties of grammatical architecture or it is true because of general properties of communication?

On the former, syntactic, view, (i) is built into any linguistic system as an organizing prinicple; human languages simply couldn't be built any other way. From this perspective, (i) is an innate aspect of grammatical knowledge that leads learners to interpret their linguistic input only in ways that are compatible with this principle, even when it appears to be violated on the surface. This is what is intended by theoretical principles such as the 'Theta-criterion' in the Principles and Parameters framework [2,3] or the 'Completeness condition' of Lexical Functional Grammar [4,5].

On the latter, functionalist, view, (i) does not derive from language-specific knowledge but rather from domain-general pragmatic constraints on communication and social interaction [28]. Here, (i) is true because it is the easiest way of communicating, deriving from principles of relevance and cooperation (in the sense of [29]).

Teasing apart these perspectives is extremely subtle, but at a first approximation it would seem that if (i) were a consequence of functional considerations, we would expect it to be true at the surface level and not at the abstract level of linguistic representation. For example, constructions like (1a), in which a syntactic argument is present but necessarily unpronounced [30,31], would be predicted not to exist because here the speaker would have failed to express a communicatively relevant event-participant.

(1) a. *Bill persuaded Hillary* [__ *to run for office*]

b. *Bill persuaded Hillary* [*that she should run for office*]

Notice further that relying on pragmatic notions like recoverability to explain the missing argument in (1a) fails to generalize to cases where pronoun arguments are required (as in 1b) because the subject of the tensed clause is just as recoverable as the subject of an infinitival clause but is obligatorily expressed on the surface only in the former.

vary in both the number and positioning of the nouns as a function of what their verbs mean [18,17].

Systematically appearing with each verb in a child's home sign system are other signs spelling out the thematic roles required by the logic of the verb – the 'agent' or initiator of the act, the 'patient' or thing affected, the 'goal' of the action, and so forth. Importantly, in these spontaneously generated signing systems, the number and position of noun-phrase arguments is predicted by the meanings of the verbs. Thus, the same fundamental relationships between verb meaning and clause structures surface both in the speech of children who are acquiring a conventional language and in the gestures of linguistically isolated children who must invent one for themselves [17].

When the one-to-one principle is hidden

Another way that we have investigated children's respect for the alignment between argument number and event participants is to test how they extend known verbs into syntactic contexts in which they have not previously heard them [12–14]. In these experiments, 2, 3 and 4-year old children use objects from a Noah's Ark play set to act out sentences presented to them. By examining systematicities in their act-out behavior, particularly when the sentence presented is a novel and ungrammatical one (for adults), we can determine something about what these youngsters think the sentence means. When presented with a sentence like 'the zebra comes the giraffe to the ark', children acted out a scene in which the zebra brings the giraffe to the ark, showing that the extra argument is interpreted as a causal agent. By the same token, 'the giraffe brings to the ark', is acted out with the giraffe coming to the ark, with no causal agent. The important generalization here is that their extensions of these verbs into new contexts are precisely what is expected if the child implicitly obeys principle (i).

But, as noted above, it is insufficient to show merely that children obey this principle; we must show further that they do so because of their inbuilt nature. To show that (i) is part of the child's language-learning armamentarium from the outset of language acquisition, we need to look at a case in which children respect the participant-to-argument-number alignment even when the language they are exposed to masks it.

Before turning to such a language, we need to emphasize that the child's use of argument number as a cue to verb meaning must be based on probabilistic information. When the child infers that a novel transitive use of a familiar intransitive verb (e.g. *the giraffe came the zebra*) expresses a causative event, this inference must be based on a tendency for transitive sentences to express causal meaning, rather than a hard and fast rule. This is because in the exposure language, the presence of two arguments does not necessarily entail causativity. Although there are many cases in which two-argument sentences express causal events, as in (6), there are many in which they do not (7):

(6) a. *John opens the door*
b. *John makes the door open*
c. *John vaporizes the door*

(7) a. *John sees the door*
b. *John eats the apple*
c. *John climbs the mountain*

That is, '*John sees the door*' doesn't mean that he causes the door to see. There are many kinds of events with two participants and so an inference from two arguments to causal meaning cannot be based on a deterministic principle; rather, this is a probabilistic learning heuristic based in part on the one-to-one alignment principle. It is precisely the non-deterministic character of the inference that gives us a way to ask the question about whether this inference is licensed by the child's observation of the exposure language or by a prior bias concerning the relation between event meaning and argument number.

Kannada

We can now turn our attention to Kannada, an Indian language that, like English, manifests the probabilistic generalization that simple sentences with two noun phrases express events in which one entity causes another to do something [18]. However, unlike English, Kannada has an extremely frequent and salient piece of morphology

Box 2. The expression of causativity in Kannada

As in all languages, causative events are expressed with transitive structures in Kannada. However, Kannada also includes a causative morpheme (citation form – [isu]; the [u] deletes preceding a vowel), which provides a deterministic surface cue to causal meaning. This morpheme never occurs unless causal meaning is intended [19,20]. Transitivity, however, freely occurs with or without causal meaning and with or without causative morphology, as illustrated by:

(1) a. kudure eer-utt-ade
horse rise-npst-3sn
'*The horse rises*'

b. * moSale kudure-yannu eer-utt-ade (* = ungrammatical)
alligator horse-acc rise-npst-3sn
'*The alligator raises the horse*'

c. moSale kudure-yannu eer-**is**-utt-ade
alligator horse-acc rise-**caus**-npst-3sn
'*The alligator raises the horse*'

Here, we see that the verb *eeru* ('rise') can be used intransitively (1a) and that to transitivize it, the causative morpheme *–isu* is required (1b vs. 1c). In general, the causative morpheme can be added to any verb, adding a causing event (and hence a causal agent) to the event described by the verb. As in all languages, there are many transitive verbs in Kannada that do not describe causative events. The following example (2) does not mean that the alligator makes the horse see:

(2) moSale kudure-yannu nooD-utt-ade
alligator horse-acc see-npst-3sn
'*The alligator sees the horse*'

Given this pattern of facts, it is clear that the causative morpheme is a robust surface cue to causal meaning. If the causative morpheme occurs, the event described is necessarily causative; but, if a sentence has two arguments, the event being described may or may not be causative.

which simply means 'causative', similar to the morpheme [ize] in *vaporize* in (6c). In essence, Kannada has sentences like the following:

(8) a. *John rise-ized the chair* = John lifted the chair
b. *John melt-ized the ice* = John melted the ice
c. *John come-ized the giraffe* = John brought the giraffe

In this language, the most reliable cue for causation is this causative verbal affix (see also Box 2). This morpheme never occurs unless causal meaning is intended [19,20]. Transitivity, however, freely occurs with or without expressed with transitive structures, the child making inferences from structure to meaning cannot be sure that transitivity marks causativity, as this is only probabilistically true. On the other hand, a child learning Kannada can make a valid inference from causative morphology to causal meaning.

These properties of Kannada give us a way to examine the origins of children's use of the one-to-one mapping principle. On one view, this principle arises as a consequence of the way the child encodes the input. Under this interpretation, the child uses argument number as a cue to transitivity independent of its reliability in the exposure language. On the other view, children use this mapping principle only after taking careful note of those properties that dominate in the input. These perspectives lead to different predictions for Kannada verb learning.

A learning mechanism that takes advantage of universal principles of mapping between meaning and syntax will expect that transitive syntax corresponds to causal meaning most of the time simply as a consequence of the unlearned principle (i), applying this principle even when the language forbids it for a particular case (e.g. '*Daddy giggled me*.'). This theory therefore leads us to expect children learning Kannada to show a bias towards interpreting transitive syntax as expressing causal meaning, just as we have found for English-learning children. On this view, we might also expect to find a stage in which children would largely ignore the role of the causative morpheme in expressing causal meaning, for this is a special feature of Kannada (an outcome of learning, to be sure). That is, the feature of the input that best predicts causal meaning would take a back seat to the child's internally generated expectations about what languages are like. Only after years of confrontation with this language would its novice speakers come to acquire the less natural, or disfavored, morphological cue.

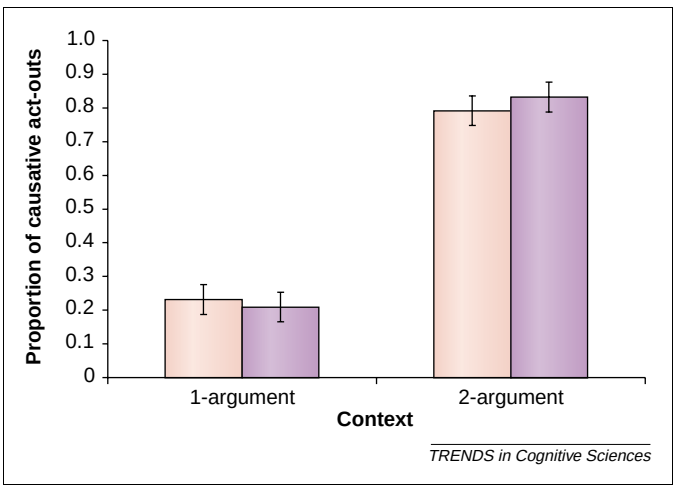

Figure 1. Proportion of causative act-outs by 3-year-old learners of Kannada in 1-argument versus 2-argument contexts with (purple bars) and without (pink bars) causative morphology. It is seen that children acted out two noun-phrase sentences as causative and one noun-phrase sentences as non-causative, independent of the presence or absence of the causative morpheme. (Extended from [21], Figure 1).

The alternative mechanism, which builds syntax–semantics correspondences by observation of input features, will rapidly learn that the best predictor of causal meaning in the Kannada case is causative morphology. This theory therefore leads us to expect Kannada-learning children to show a bias towards interpreting causative morphology as causal meaning, independent of syntactic transitivity. This mechanism is predicated on the idea that the child has no internally generated preconceptions about language structure and so will learn just what can be most straightforwardly extracted from the input.

To test these hypotheses, we used the Noah's Ark methodology described briefly above. Children were presented with known verbs, with either one or two noun-phrase arguments and either with or without the causative morpheme [21]. Our predictions were as follows. If children approach the language-learning problem with an open mind concerning its syntax-to-meaning mappings and look for the most reliable features of the input with regard to these mappings, then we would expect Kannada learners to honor the morphological cue over the syntactic one. That is, when presented with '*the giraffe come-ized*', we would expect them to interpret this causatively and thus act out something in which some other animal brought the giraffe. By the same token, the children would be expected to treat '*the zebra came the giraffe*' (with no causative morphology) as non-causative (either ignoring one of the arguments or treating them as two equal participants, neither playing a causal role). On the other hand, if children are predisposed to take the number of arguments as indicative of event structure, we would expect them to ignore the causative morphology and treat '*the giraffe come-ized*' as no different from '*the giraffe came*' and to treat '*the zebra came the giraffe*' as causal.

The data were clear. Three-year-old Kannada-learning children treated argument number as an indication of causativity and failed to treat causative morphology as an indication of causativity, despite the fact that the latter is the more reliable cue in their input [21]. Figure 1 shows the mean proportion of causative act-outs provided by the children for each type of structure: they acted out two noun-phrase sentences as causative and one noun-phrase sentences as non-causative, independent of the presence or absence of the causative morpheme. In effect, they ignored the more reliable morphological cue to verb meaning and instead obeyed the less reliable syntactic cue (noun-phrase number). We take this result as evidence for the priority of principle (i), which aligns noun phrases with semantic participants, and for the unlearned nature of this organizing principle. The observation that learners discarded the best cue in favor of a weaker one reveals the active role that learners play in acquiring verb meanings. Learners use argument number as a cue to verb meaning

Box 3. Questions for future research

- How does innate knowledge interact with frequency information and statistical learning in the acquisition of verbs, and of linguistic structure more generally?
- How can the study of verb learning inform theories of non-linguistic event representations?
- How can the study of non-linguistic event representation inform theories of verb meaning and verb acquisition?
- What is the contribution of social cognition and functional–communicative goals in the acquisition of grammar?

not just because it is there in the input, but because they expect to find it there.

We should add that Kannada-speaking adults eventually do acquire this special ('language specific') feature of their language; after all, to say they did not would mean that the Kannada language had changed. So it is reassuring to find, as we did, that Kannada adults – unlike their young offspring – show sensitivity both to argument number and to the causative morpheme when they participated in this experiment [21].

Conclusions

At the outset of this article we noted that everyone is in agreement that there is some balance of nature and nurture to be found in language acquisition. Only humans learn language and they only learn the languages they are exposed to. The central problem for a theory of language acquisition is how to identify which aspects of language reside on each side of the balance (see also Box 3). As advances are made in statistical approaches to language acquisition [22–25], it becomes harder to identify test cases. Even those aspects of grammar that surface in every language might have a statistical signature that can be detected by learners (but see [26,27]). Consequently, the nativists can claim their universality as evidence for their position and the anti-nativists can point to this statistical signature as evidence for theirs.

Our approach in this article has been to examine a part of grammar that can be hidden from the learner. We have found that this knowledge emerges in all learners in the same way despite the vagaries of the input. It surfaces in learners whether the input supports its acquisition (as in English), whether the input hides its effects (as in Kannada) and even when there is no input at all (as in the linguistically isolated deaf). It is this robustness to the strength or weakness of the input information that represents the learner's contribution to language acquisition.

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