

Verb learning as a probe into children's grammars

Jeffrey Lidz
Northwestern University

Let us begin this chapter by asking what constitutes an explanation in linguistics and in the field of language development. Since Chomsky's seminal work in generative grammar (Chomsky 1957, 1965), the research program of linguistic theory has been set towards circumscribing the set of possible human languages. In an idealization of this program, one must first construct a set of phenomenological descriptions of individual languages. This description leads to the construction of individual grammars, viewed as the relevant cognitive state achieved by the speakers of those languages. Next, the comparison of particular grammars leads to the formation of general principles that underlie all of these grammars.¹ That is, we aim to understand the cognitive code that is shared by all humans who have the ability to acquire a language. Thus, the goal of comparative linguistics is not merely to account for the properties of extant languages but to use the existing languages to develop hypotheses about what patterns of properties might occur in other yet to be encountered languages. More generally, the goal of modern linguistics is to identify the range and limits of cross-linguistic variation, so as to understand the cognitive principles that underlie the spectrum of human language.

For the field of language acquisition, the ultimate goal is to explain how language acquisition is possible and how it unfolds over time under varying conditions of exposure. To be sure, given the complexity of the acquisition task, language learners will

¹ This is an idealization of the research program because in reality research in all of these areas is conducted simultaneously.

take advantage of any source of information they can, including at least their core conceptual knowledge (Baillargeon 1998, Spelke 2000), their pragmatic and social abilities (Woodward 1999, Baldwin and Baird 1999, Carpenter et al. 1998, Bloom 2000, Diesendruck and Markson 2001), their logical competence (Halberda 2004) and their domain general statistical learning mechanisms (Saffran et al. 1996, Gomez and Gerken 1999, Gomez 2002). But just as surely, learners are constrained in how they approach the language learning problem (Gelman and Williams 1998, Markman 1989, Newport and Aslin 2000, Crain 1991). There are certain hypotheses that learners simply do not consider, either because they are outside of their computational capacity, because the properties consistent with those hypotheses are not apprehended by the relevant perceptual or conceptual systems, or because they lie outside the range of what human languages allow.

Restricting our attention to the last source of constraints, we return to the explanatory goals of linguistics. One of the fundamental hypotheses of generative grammar is that the linguistic constraints that limit the hypotheses that learners consider in acquiring a language are exactly those constraints that limit cross-linguistic variation. (Chomsky 1981, 1986; Hornstein and Lightfoot 1981; Pinker 1989; Jackendoff 2001; Baker 2001). On this view, then, hypotheses about the cognitive code underlying the limits of linguistic variation are also hypotheses about constraints on language acquisition (Crain and Thornton 1998, Thornton 1990, Lidz and Musolino 2002).

In this paper, I explore this possibility in the domain of verb learning. I first consider constraints on possible verbs that are deduced from linguistic description and analysis and then examine whether we find their effects in the acquisition of verbs. If it is

true that cross-linguistic constraints parallel constraints on acquisition, we should be able to see those constraints in action both at the level of language description and in language development. Indeed, that is precisely what we find, lending support, at least in the domain of verb learning, to the view that research on language acquisition profits and can be guided by research on mature linguistic systems.²

The general framework of inquiry simultaneously applies both linguistic and behavioral research methods, with the aim that conclusions derived from one methodology provide testable hypotheses for the other. By integrating linguistic research with research on language acquisition, we can triangulate on the principles and constraints that both guide language acquisition and delineate the boundaries of possible languages.

Methodologically, the current chapter takes advantage of children's use of syntax to guide verb learning. Given that children show a sensitivity to syntactic structure in assigning meaning to verbs (Gleitman 1990, in press), we can use this sensitivity to probe their knowledge of the kinds of grammatical constraints on verbs that are active in adult language. If the syntax of a novel verb is important for the identification of that verb's meaning, then to the extent that children can learn a novel verb's meaning, it follows that they have the syntactic knowledge that triggers that acquisition. Given this general perspective, then, we can use verb learning as a probe into children's knowledge of the mapping between syntax and semantics. In cases where we understand the relationship

² Of course the reverse should also be true. Conclusions from language acquisition can and should guide the development of explanatory linguistic theories. See Grodzinsky and Reinhart 1993, Snyder and Stromswold 1995, Thornton and Wexler 1999, Lidz and Musolino 2004, for some examples in the domain of syntax and semantics.

between syntax and verb meaning, children's acquisition of a given verb's meaning can tell us how and whether the relevant piece of syntactic knowledge plays a role in the acquisition process.

The paper proceeds as follows. In section 2, I describe the basic grammar of verbs, identifying certain aspects of verb representation that are universal and certain that are more variable. By starting from a detailed understanding of the syntax and semantics of verbs, we can identify clear questions about how verb learning proceeds and about the role of inherent constraints in verb learning. In section 3, I describe some basic findings on verb learning, arguing that these findings enable us to develop tests of those properties of verb meaning identified in section 2. Section 4 then goes on to describe a set of results that test possible constraints on language learners that are derived from detailed linguistic description. By taking advantage of principles derived from linguistic research, we can begin to identify the correct balance between the learner and the environment in verb learning.

2. What is a verb such that we can learn it?

In order to address the question of how children learn verbs, we must first be clear on what it means to be a verb. Perhaps the most straightforward description we can offer is to say that the meanings of verbs represent generalizations over categories of events. This description already represents a simplification, since it is difficult to define the category of verbs semantically. There are many verbs whose meanings are states (1a), relations (1b), or properties (1c).

- (1) a. John is **sitting** on the floor.
- b. John **knows** who stole the bacon.

- c. John **appears** to be late.

Worse, there are events that are realized in other syntactic categories, as in (2).

- (2) a. The **earthquake** was frightening.
- b. The children are **noisy** today.

And, the very same concept can sometimes be realized in multiple lexical categories, as in (3).

- (3) a. The results **surprised** me.
- b. The results were **surprising** to me.
- c. The results were a **surprise** to me.

Clearly, a better understanding of grammatical categories must ultimately be developed (see Baker 2003, Croft 1991 for discussion), but for the present purposes, we can restrict our attention to verbs whose meanings represent categories of events.

Now, a crucial aspect of events is that they have participants. Consequently, a fundamental property of verbs is that they take arguments that realize these participants. A jumping event is not a jumping event unless there is someone who jumps. Concomitantly, the verb *jump* requires the sentence it occurs in to include a phrase making reference to the jumper. Similarly, hitting requires two participants (a hitter and a hittee) and so the verb *hit* requires two syntactic arguments. From the perspective of verb learning, then, the learner must minimally identify the number of participants entailed by the concept denoted by the verb.

Beyond identifying the number of participants entailed by an event, different kinds of events have different kinds of participants. It follows, then, that different verbs can take arguments of different types. For example, *think* expresses an event in which an

individual stands in a relation with a proposition whereas *eat* expresses an event involving two individuals (i.e., the thing that eats and the thing that is eaten).

Accordingly, *think* can take a sentential complement whereas *eat* take a noun phrase complement, since the former expresses a proposition and the latter an individual.

- (4) a. Al thinks **that the election was rigged**
b. Al ate **a sandwich**.

Two things are important to note here. First, the mapping between syntactic types and semantic types is largely universal, and hence a potential consequence of grammatical architecture. For example, in no language do verbs whose meanings require propositional arguments systematically occur only with noun phrase arguments.³ Likewise, in no language are individual entities uniformly expressed as clauses. These kinds of universals are likely to be explained by inherent constraints on linguistic structure. Second, there is not a one-to-one mapping between semantic argument types and syntactic argument types. A verb that expresses a relation between an individual and a proposition can take a noun phrase complement, as long as that noun phrase can be interpreted as referring to a proposition (Grimshaw 1979):

- (5) a. Sally knows **what time it is**
b. Sally knows **the time**

The sentential complement [*what time it is*] and the noun phrase complement [*the time*] both express the same proposition and so the semantic requirements of the verb are met independently of the syntactic type of the argument.

³ A word of caution is in order here as well. In some languages, embedded clauses are case-marked, typically a property of NPs. However, it is possible in such languages to distinguish NPs that are clausal from those that are not, allowing us to maintain the basic generalization.

In this regard, however, it is important to note that the syntactic requirements of a verb cannot be reduced to the semantic requirements of the concept denoted by that verb.

Compare *know* with *wonder* (Grimshaw 1979, Pesetsky 1982):

- (6) a. Kim wonders what time it is
- b. * Kim wonders the time

Here, the noun phrase [*the time*] is not allowed even though we know independently (from sentences like 5b) that it can express the relevant meaning. Hence, there must be some syntactic requirements associated with verbs that are independent of their meaning. Hence, learning a verb entails identifying this kind of syntactic restriction.

The independence of syntactic and semantic types can also be seen by comparing the verbs *like* and *enjoy* in (7):

- (7) a. she liked the concerto
 she enjoyed the concerto
- b. she liked hearing the concerto
 she enjoyed hearing the concerto
- c. she liked to hear the concerto
 * she enjoyed to hear the concerto

Although *like* and *enjoy* express essentially the same relation, only the former can occur with an infinitival complement. In sum, some syntactic requirements of a verb are derivable from semantics (that propositional arguments can be realized as sentential complements), but others are not and must therefore be included as information associated with that verb in the lexicon.

We can therefore add to the list of tasks for the verb learner the ability to identify (a) the semantic types of the participants entailed by the verb; (b) the mapping between semantic types and syntactic types; and, (c) any idiosyncratic properties of the verb that restrict that mapping (e.g., whatever explains the difference in complementation

possibilities found between *know* and *wonder* or between *like* and *enjoy*). Property (a) is a property of the concept denoted by the verb; property (b) is a property of language in general which could be used to help identify property (a); property (c) is a property of particular lexical items, beyond the constraints that are due to grammatical architecture as a whole.

Finally, knowing what the arguments of a verb are and what syntactic categories they are realized in is not sufficient to understanding the verb. A speaker must also know how those arguments are mapped to syntactic positions. That is, why does the NP *Kim* occur as the subject of *know* while the propositional argument occurs as the object? Why is the meaning associated with *know* expressed as in (5) and not as in (8)?

(8) * what time it is knows Kim.

This question is typically referred to as the *linking* problem (Carter 1976), and concerns the relationship between the meanings of individual verbs and the positions that their arguments take in the syntactic structure of a sentence. One of the fundamental discoveries of research in linguistics regarding the syntax of verbs is that the linking properties of verbs are not arbitrary (Gruber 1965; Jackendoff 1972, 1983, 1990; Carter 1976). Rather, the syntactic positions of a verb's arguments are largely predictable from the meaning of that verb (Levin and Rappaport 1986; Baker 1988; Grimshaw 1990; Levin 1993; for experimental evidence Fisher, Gleitman and Gleitman 1991, Kako 1999). Consequently, verbs that share meaning also share important properties of syntactic distribution. For example, verbs that refer to causative events involving a change of state (e.g., *break*, *melt*, *close*) can participate in the "causative-inchoative" alternation, whereas

verbs that do not express a change of state (*hit, see, eat*), cannot (Fillmore 1967, Grimshaw 1990, Jackendoff 1990, Levin and Rappaport-Hovav 1995):

- (9) a. Chris broke the vase
- b. The vase broke
- c. Chris hit the vase
- d. * The vase hit

Similarly, in the domain of locative verbs (i.e., verbs expressing the movement of some object (the figure) to a location (the ground)), verbs that describe the manner of motion (*pour, spill, shake*) require the figure to occur as the direct object, whereas verbs that describe a change of state (*fill, cover, decorate*) require the ground to occur as the direct object (Rappaport and Levin 1988, Gropen et al. 1991, Pinker 1989, Kim, Landau and Phillips 1998):

- (10) a. Edward poured water into the glass
- b. * Edward poured the glass with water
- c. * Edward filled water into the glass
- d. Edward filled the glass with water

Thus, the language learner must come to know the systematic mapping between verb-meaning and syntactic structure. These mapping principles are not part of a given verb's representation, given that they hold for whole subcategories of verbs, but one way to tell whether a verb has been acquired correctly is to determine whether it shows the appropriate mapping to syntax for its category of meaning.

Certain verbs also seem to be more restricted in their distribution than their meaning alone would predict. For example, whereas the verbs *give* and *donate* express essentially the same relation, only the former occurs in both the prepositional dative and the double object construction:

- (11) a. Georgia gave her paintings to the museum
- b. Georgia gave the museum her paintings

- c. Georgia donated her paintings to the museum
- d. * Georgia donated the museum her paintings

What this tells us is that certain verbs must have additional information as part of their lexical representation that restricts their distribution. Wherever a verb appears to violate the general linking properties of the language, that verb must be additionally specified so as to correctly limit its distribution.

Putting this all together, we can see that the task of the verb learner is to identify from experience a rich concept that entails a set of participants of various semantic types. In order to do this, the learner must identify the correct mapping from semantic types to syntactic types and from semantic arguments to syntactic positions. Simply put, verbs express who did what to whom. Hence, learning a verb requires the ability to identify the participants of the event it denotes. Thus, to know what a novel verb refers to, one must be able to identify in the sentence those phrases that serve as the arguments of the verb and to determine what semantic type (e.g., object, proposition, property, etc.) those arguments realize.

Importantly, certain aspects of the mapping from form to meaning are cross-linguistically stable, while others are cross-linguistically variable. For example, in all languages propositional arguments are realized as embedded clauses whereas the range of possible embedded clauses (e.g., tensed, infinitival, gerundive, etc.) varies from language to language and from verb to verb within a language. From the perspective of verb-learning, then, we can take these cross-linguistic properties as hypotheses regarding constraints on verb learning that may come from within the learner himself. Those properties that are cross-linguistically stable potentially represent constraints on

children's hypotheses about the verbs they are learning. However, those properties that vary either across or within languages should not so constrain acquisition.

Before we can examine how constraints on language acquisition derived from linguistic description operate, we must first discuss the motivations behind the methodology of using verb learning as a probe for these constraints.

3. Verb learning and the syntactic bootstrapping hypothesis

A well-known problem for the acquisition of language generally and of words in particular is the stimulus-free nature of language use (Chomsky 1959). Extralinguistic context is not a very good predictor of what someone is going to say. For example, when looking at a Rembrandt painting, one might say, "Dutch," "It's crooked," "I prefer abstract expressionism," "Remember our camping trip last summer?" or just about anything else. Hence, if the language learner is to learn about what is being said on the basis of what is happening in the world, the lack of reliable correlations between language and events represents a serious obstacle. Worse, even when someone is talking about the here and now, the world makes available many different possible descriptions of the visible scene. Consider a scenario in which a boy and his mother are flying a kite. A novel word used in this context might refer to the kite, the string, wind, boredom, excitement, clouds, blue, flying, waiting, saying, hoping, thinking, breathing, etc. Given the multiplicity of interpretations of any given context, the learner faced with a novel word needs to determine which of the objects, events and properties made available by perception that word refers to. A theory of word learning must therefore determine a procedure by which alternatives are eliminated. At minimum, such a theory must allow the learner to compare across situations to narrow down the hypotheses. But even

allowing for cross-situational comparison, a word-to-world pairing procedure still cannot overcome Quine's (1960) cooccurrence problem: rabbits always occur with rabbit-ears, jumping always occurs with legs, giving always occurs with receiving, and sugar always occurs with sweetness.

Recent findings document that this problem is particularly severe for the case of verbs. Verb use even by mothers of very young children lines up very poorly with ongoing events (Lederer, Gleitman and Gleitman 1995). That is, people do not use a verb at the moment that the event it describes is happening. And as we have seen, observation makes available many salient verb-like descriptions of a single observed event. A single event in the world can be described in countless ways (Landau and Gleitman, 1985; Gleitman 1990, Gillette et al., 1999).

As a way to overcome the difficulties of observational learning of verb-meaning, the Syntactic Bootstrapping Hypothesis posits that one important source of additional information lies in the systematic relationships between verb meaning and syntactic structure (Landau and Gleitman 1985; Fisher, Gleitman, and Gleitman, 1991; Fisher, 1994; Snedeker and Gleitman, 2004). Because they can find a reliable mapping between syntax and lexical semantics, children make use of this mapping in learning verb meanings.

The Syntactic Bootstrapping Hypothesis finds support in several results. First, maternal speech in several languages maps a highly overlapping verb-meaning set onto the same range of complement structures (Lederer et al., 1995; Lee, Nelson and Naigles 2003). Children as young as 16 months old have been shown to be sensitive to properties of heard speech that could render aspects of these linkages useful, e.g., the semantic

differences between subjects and objects (Hirsh-Pasek and Golinkoff 1996). Indeed, there is some evidence that some syntax-semantics correspondences at this level are unlearned. Isolated deaf children project about these same structures for the same predicate meanings in their self-invented gestured languages (Feldman, Goldin-Meadow, and Gleitman, 1978; Goldin-Meadow and Mylander, 1984; Senghas, Coppola, Newport, and Supalla, 1997).

There is also evidence that young children make use of structural evidence in their verb learning. For instance, by about 24 months they will use information from the number of noun-phrases in the utterance to choose between situationally plausible interpretations that differ in argument-number of a novel verb (Naigles, 1990; Fisher 1996). Children of this age have also been demonstrated to be sensitive to syntactic cues in learning the specially problematic verbs like *chase/flee*, which differ only by the perspective they take on the events they denote (Fisher, Hall, Rakowitz, and Gleitman, 1994; Fisher, 1994). Finally, in an act-out task in which children were presented with verbs that they already knew in novel syntactic frames, young children systematically altered the meaning of the verb to fit the meaning associated with the syntactic frame (Naigles, Gleitman and Gleitman 1993). For example, asked to act out “Noah comes the elephant to the ark,” they pick up first Noah, then the elephant, and move them together to the ark. That is, ditransitive *come* must mean something like BRING. In this sense, young children are *frame compliant*, altering their construal of the verb to fit its new linguistic environment.

All of these findings go to the idea that the learning procedure in some way makes joint use of the structures and situations that co-occur with verbs so as to converge on

their meanings. Neither source of evidence is strong or stable enough by itself, but taken together they significantly narrow the search space.

The fact that children can use syntax as one source of information in learning novel verbs allows us to ask questions not only about how children learn verbs but also about the existence of constraints on verb learning. We can ask whether children are limited in their verb learning by the same kinds of constraints that appear to hold across languages. We can take information about what a possible verb is or about what a possible linking pattern is by looking for cross-linguistically stable generalizations and then ask whether children also exhibit those constraints in their acquisitions. The idea behind this reasoning is that linguistic universals derive from principled constraints on what a possible human language is. Thus, to the extent that these constraints can be found in verb learners, we add to the evidence in support of these constraints as part of the cognitive code underlying language acquisition. Looked at from another angle, cross-linguistically stable generalizations provide us with hypotheses about constraints on verb learners which can then be tested on children who are in the process of developing a lexicon. In contrast, to the extent that a property of verb meaning or linking can vary cross-linguistically, we expect to find that property to be highly sensitive to aspects of the linguistic environment since it will depend not on principled constraints from the learner, but on the observation of the particular language being learned (i.e., the linguistic input).

3. What verb learners can tell us about grammatical constraints

We now turn to three studies which examined these questions. What we will see is (1) that children rely on universal cues to verb meaning even when those cues are less reliable in the input than other cues; (2) that universal restrictions on verb-syntax pairings

are obeyed by learners while cross-linguistically variable restrictions are not; (3) that universal aspects of semantic representation can be found to guide very young verb learners' acquisition of novel verbs.

3.1 Constraints on argument number

One way that children's use of syntax to learn verb meanings has been documented involves tests of the way that children extend known verbs into syntactic contexts that they have not previously heard them in (Naigles, Gleitman and Gleitman 1993; Naigles, Fowler and Helm 1993, Lidz 1998). In these experiments 2, 3, and 4-year old children used objects from a Noah's ark play set to act out sentences presented to them by the experimenter. By examining systematicities in their act-out behavior, particularly when the sentence presented is a novel and apparently ungrammatical one, these experiments enable us to examine the role of syntax in guiding children's interpretations.

As noted above, when presented with novel uses of familiar verbs, English-learning three-year-olds' act-outs were frame compliant, relying on information in the syntax to guide their interpretations (Naigles et al 1993). Children acted out sentences like (12) with a scene in which the zebra brings the giraffe to the ark,

(12) The zebra comes the giraffe to the ark.

Here, the "extra" argument not typically associated with this verb is interpreted as a causal agent. By the same token, (13) is acted out with the giraffe coming to the ark, with no causal agent.

(13) The giraffe brings to the ark.

What these studies show is that children can use syntax to broaden the scope of the events that they think a novel verb refers to. Although *come* expresses only motion towards a location in the adult language, if this verb is presented with an additional syntactic argument, children who have not yet settled on a representation for the verb's meaning will take that additional syntactic argument as evidence that the verb can also express caused motion.

The close connection between transitivity and causation found in these studies represents a particularly interesting case to examine. It is a linguistic universal that causative events are expressed with transitive structures and that noncausative events are expressed in intransitive structures. But is this universal a principled consequence of grammatical architecture or simply of the fact that it can be observed in the input? Do children learn about the connection between causativity and transitivity through their experience with the language, or rather do their expectations about this relation color their perception of the linguistic input they are exposed to?

The problem here is that there are two possible explanations for children's behavior in any syntactic bootstrapping experiments. Children could behave the way they do because they have learned by examining their input that there is a connection between causation and transitivity. Alternatively, children could behave this way because they expect there to be such a connection. Given that causatives are universally expressed as transitives, how can we find out whether children's use of transitivity to infer causation is due to their first having learned that the language is this way or whether they approach the task of verb learning with this principle to guide them?

Lidz et al. (2003) examined this question by looking at Kannada-learning children's use of syntax to guide verb learning. As noted, all languages show a strong connection between causation and transitivity. However, one thing that varies cross-linguistically in this domain is whether the alternation between causative and noncausative verbs is morphologically marked (see Comrie 1985, Haspelmath 1993, *inter alia*). For example, in many languages the intransitive variants are basic and an additional causative morpheme is added to indicate causation. In other languages, the transitive variants are basic and an additional anticausative morpheme is added to indicate the lack of causation. In still other languages, both strategies exist for different verbs. Thus, the addition and subtraction of arguments is used universally to mark the alternation whereas the presence of verbal affixes to mark the alternation varies both cross-linguistically and within a language.

With these properties of cross-linguistic variability in mind, we pitted the universal property of argument number against the cross-linguistically variable property of morphology in Kannada, a language with causative morphology. Kannada was the appropriate probe language due to the abundance of the morphological cue to causativity (see Lidz 2003 for the details of causation in Kannada). In Kannada, any verb can be made causative through the addition of a causative morpheme, as in (14).

- (14) a. barf-u karg-i-tu
 ice-NOM melt-PST-3SN
 'The ice melted.'
- b. surya barf-annu karag-**is**-i-tu
 sun ice-ACC melt-CAUS-PST-3SN
 'The sun melted the ice.'

Moreover, whenever this morpheme is present, the causal interpretation is entailed.

Finally, in Kannada, as in all languages, many verbs with two arguments (e.g., *see*, *climb*) are not interpreted causally. Given this pattern of facts, the causative morpheme is a more reliable surface cue for causation than is the number of arguments.

Because the presence of the causative morpheme guarantees a causal interpretation but the presence of two arguments is only probabilistically associated with causal interpretation, this language offers some insight into the source of children's use of argument number to guide their interpretations. If children use the most reliable cues in the input to determine the syntax to semantics mapping, then we would expect children learning Kannada to rely more heavily on the causative morpheme as an expression of causativity than on the number of arguments. On the other hand, if children are guided by expectations about the syntax-semantics mapping that are based on the principles of grammatical architecture that are responsible for grammatical universals, then children should rely more heavily on argument number than causative morphology. In the latter case, children would be expected to ignore the most reliable cue in the input in favor of the less reliable cue determined by inherent grammatical constraints.

In order to test these possibilities, Lidz et al used the Noah's ark methodology described briefly above. Children were presented known verbs with either one or two noun phrase arguments and either with or without the causative morpheme. The predictions were as follows. If children approach the language learning problem open-mindedly and look for the most reliable features of the input, then children were expected to honor the morphological cue to causation over the syntactic one. That is, we expected children who were presented with sentences like (15a), which has a causative morpheme

added to a known intransitive verb, to interpret this causatively and thus act out something in which some other animal made the tiger come. By the same token, such children were expected to treat sentences like (15b), in which an extra argument was added without causative morphology, as noncausative.

- (15) a. huli bar-is-utt-ade
tiger come-CAUS-NPST-3SN
- b. huli dumbi-yannu bar-utt-ade
tiger beetle-ACC come-NPST-3SN
- c. huli bar-utt-ade
tiger come-NPST-3SN

On the other hand, if children are predisposed to take the number of arguments as indicative of event structure, then they were expected to ignore the causative morphology and treat (15a) as no different from (15c), which has one argument and no causative morpheme, and to treat (15b) as causative.

The data were clear. Three-year-old Kannada-learning children treated argument number as an indication of causality and failed to treat causative morphology this way, despite the fact that the latter is the more reliable cue in the exposure language. This data is shown in figure 1, which represents the proportion of causative act-outs provided by children as a function of argument number and the presence vs. absence of causative morphology. In sum, children acted out two noun phrase sentences as causative and one noun phrase sentences as noncausative, independent of the presence or absence of the causative morpheme.

FIGURE 1 ABOUT HERE

In effect, these children ignored the more reliable morphological cue to verb meaning and instead relied on the syntactic cue (noun phrase number). This result

provides evidence for the priority of the principle aligning syntactic phrases with semantic participants and for the unlearned nature of this constraint on verb-syntax linking. 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 not because it is there in the input, but because they expect to find it there.⁴ Thus, the connection between causal meaning and transitivity appears to be a guiding constraint on verb-learning rather than a learned response to the input.

3.2 Constraints on argument type

The method of testing children's extensions of known verbs into novel contexts has also been used to investigate children's knowledge of the connection between syntactic and semantic types of arguments and the range of possible verb meanings. As discussed above, some aspects of the mapping from event participants to syntactic categories are universal, while other aspects are more variable both within and across languages. Thus, a propositional argument can be realized as a tensed clause (*John thinks that Mary will win*) or an infinitival clause (*John expects Mary to win*) but not as a noun phrase referring to an individual (**John thinks the winner*). The choice of tensed or untensed clause, however, is subject to lexical variability and must be learned on a verb by verb basis. Similarly, some change of state verbs that can occur with one argument (*the vase dropped*) can also occur with two (*I dropped the vase*), while others happen not

⁴ We should add that Kannada-speaking adults eventually do acquire this special ("language specific") feature of their language; after all, to say that 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 participate in the Noah's ark experiment.

to allow this alternation (*the vase fell* vs. **I fell the vase*). But, verbs in this class never have their arguments realized as sentential complements (**John falls that it is Bill*; **John drops Bill to be here*).

Given the existence of principled constraints on the syntax-semantics mapping, as well as lexically specific constraints, we can ask whether children are limited in the ways that they are willing to extend known verbs in accordance with these constraints. To do this, Lidz, Gleitman and Gleitman (2004) compared children's understanding of known verbs in two kinds of ungrammatical syntactic contexts. In the "near" contexts, verbs were presented in environments that are permitted by language in general, but not by English, as in (16). In the "far" contexts, these verbs were presented in contexts that are not permitted by any language, as in (17).

(16) "near" extensions. Possible in principle, but not in English.

- a. * the zebra falls the giraffe.
- b. * the zebra thinks the giraffe to go to the ark.

(17) "far" extensions. Not possible in any language.

- a. * the zebra falls the giraffe to go to the ark
- b. * the zebra thinks the giraffe

The reasoning behind this manipulation was this. If children are constrained to allow only those mappings that are licensed by the grammatical architecture, then we should expect to find that children distinguish these two types of extensions, showing frame compliant behavior in the "near" contexts, but not in the "far" contexts. When presented with a "far" extension, one which is not consistent with universal constraints on complement types, children should not show frame compliant behavior.

This expectation was met. We found that children relied on the syntactic structure to guide their act-out behavior only when the novel verb-sentence pairing was a possible pairing in principle (but not in practice). Three year old children were significantly more likely to act out frame compliant responses in “near” contexts than in “far” contexts. For example, children who heard “near” sentences like (16b) typically acted out scenes reflecting only the content of the embedded clause, i.e., the giraffe goes to the ark, just as they did for grammatical verbs in those structures. However, children who heard “far” sentences like (17a) behaved differently. These children acted out scenes reflecting only the matrix verb (e.g., the zebra falls) or scenes in which the matrix subject performed the action of the embedded verb (e.g., the zebra goes to the ark). In the cases in which the novel syntactic structure would violate principles mapping syntactic argument type to semantic argument type, children performed non-frame-compliant actions that relied more heavily on what they already knew about the verb.

In other words, children accepted extensions of known verbs into new syntactic frames only when the verb-frame pairing was one that might have been possible. Because all of the test items in this study were ungrammatical sentences in the adult language, children had no prior experience with these materials. Yet, they distinguished these materials precisely along the lines that grammatical architecture would predict, accepting only extensions of known verbs into constructions that could be possible for some other related verb (or for a verb with the same meaning in some other language).

This finding suggests that children’s knowledge of the syntax-semantics mapping guides their acquisition of novel verbs even when they are at a stage in development in which their lexical representations for certain verbs have not solidified. In other words,

some aspects of the syntax to semantics mapping do not have to be learned. Rather they serve as inherent constraints that guide learners' hypotheses regarding verb meanings and that block them from accepting certain verb-frame pairings. At the same time, of course, we see the role that linguistic experience will ultimately play. In exactly the cases that fall within the range of possible mappings between verbs and frames (i.e., the "near" cases), children are flexible and must rely on their experience with particular verbs to properly constrain this flexibility.

3.3 Constraints on verb meaning

Beyond the role of constraints on the syntax-semantics mapping, we can also ask whether aspects of lexical-semantic representation itself can be examined through experimentation with young verb learners. If cross-linguistic analysis reveals a universal of semantic representation for certain types of events, then we should also be able to find that this representation guides verb learning. To examine this possibility, we return to the acquisition of causatives.

Examination of causative verbs cross-linguistically reveals that their meanings are internally complex. Evidence for this internal complexity comes from several sources. First, in many languages there is a morphological operation that converts intransitive verbs into causative verbs. Thus, alongside a pair like (18) in English, we find a pair like (19) in Kannada.

- (18) a. the ice melted
b. the sun melted the ice

- (19) a. barf-u karg-i-tu
ice-NOM melt-PST-3SN
'The ice melted.'

- b. surya barf-annu karag-is-i-tu
 sun ice-ACC melt-CAUS-PST-3SN
 'The sun melted the ice.'

Because the meanings are alike in the two languages, what this suggests is that there is an unpronounced piece of semantic representation in the English causative (18b) that adds causativity to the change of state meaning contributed by the root. Second, certain adverbials can take scope either over or under the causative element, suggesting that it is present in the semantic representation. For example, (20) is ambiguous.

- (20) John melted the ice again.

One interpretation of this sentence is that John had some ice, melted it, refroze it and then remelted it. On this reading the adverbial includes the causation in its scope. What happens again is John's causing the ice to melt. Another interpretation of the sentence, however, is that while John only melted the ice once, it had already been in a melted state. Here, imagine that there was a block of ice that melted and that Bill froze it. If John then took the ice out of the freezer and applied heat, we could say (20), even though it was the first time John melted the ice. Thus, the adverbial can take scope only over the result subevent of the complex event. For further discussion see McCawley (1968), vonStechow (1996).

Bunger and Lidz (2003) asked whether children had access to the internal structure of such events, representing them as having subparts, as in (21), where the first subpart of this structure [X do something] specifies the causing subevent, or the means, and the second subpart [Y become state] specifies the resulting change of state (Dowty 1979, Jackendoff 1990, Hale and Keyser 1993, Levin & Rappaport Hovav 1995).

- (21) [[X do something] CAUSE [Y become state]]

This study took advantage of a prior result on syntactic bootstrapping using the preferential looking paradigm. Studies carried out by Naigles and associates (Naigles 1990, Naigles & Kako 1993, Naigles 1996) have demonstrated that given a scene depicting two simultaneous events (a causative event and a non-causative continuous event), the structure of the sentence in which a novel verb is presented can influence a child's interpretation of the meaning of that verb. Specifically, children who hear a novel verb in a transitive sentence (*X is gorping Y*) interpret it as labeling the causative action, whereas those who hear the novel verb in an intransitive sentence (*X and Y are gorping*) interpret it as labeling the continuous, non-causative, action.

If syntax can guide the difference between and causative and noncausative interpretation, and if causative events have internal structure, we reasoned that syntax should also be useful in distinguishing which aspect of a single internally-complex event is labeled.

To determine whether children are like adults in representing causative events as having internal structure, we conducted a preferential looking study in which 2-year-old children saw internally complex causative events labeled by a novel verb occurring in distinct syntactic structures. Children were first familiarized to an event of direct causation (e.g., a girl bouncing a ball) described by a novel verb. The syntactic frame in which the novel verb was presented varied across children in four ways: control (*Look at that.*), transitive (*The girl is pimming the ball.*), unaccusative (*The ball is pimming.*), or multiple frame (transitive + unaccusative: *The girl is pimming the ball. Do you see the ball pimming?*). This training phase was followed by a test phase in which children heard the novel verb (*where's pimming now?*) while they saw, on opposite sides of the screen,

the separate subevents depicting the means (the girl patting a ball, but no bouncing) and the result (the ball bouncing with the girl standing idly by) of the complex causative presented during training.

Because the unaccusative variant of a causative verb labels the result subevent without making reference to the means, we predicted that subjects in the unaccusative and multiple-frame conditions would be more likely than subjects in the transitive and control conditions to interpret the novel verb as referring to the result subevent. This prediction was borne out, as shown in figure 2. At test, subjects in the unaccusative and multiple-frame conditions demonstrated a significant preference for the result subevent. Subjects in the no word and transitive conditions showed no significant preference for either subevent. Thus, when the syntax focused children's attention on the result of a given causative event, they interpreted a novel verb as describing that subevent.

FIGURE 2 ABOUT HERE

This study provides further evidence, then, that observation of the syntactic behavior of a novel verb provides information about the kind of event that the verb labels. Note that if the syntactic nature of the input did not influence the interpretations that subjects assigned to novel verbs in this study, then we should not have observed this difference in attention at test between the unaccusative and multiple frame conditions on the one hand and the no word and transitive conditions on the other. Importantly, cross-linguistic analysis leads us to believe that all causative verbs denote events with internal structure. Consequently, we predicted that children should assign internal structure to the meanings of novel causative verbs. This prediction was borne out. If the subjects in this experiment were not representing the causative events as having internal structure, the

syntax would not have been able to guide them to these different interpretations: i.e., if their representations of these causative events did not include a result subpart, then even subjects in the unaccusative and multiple frame conditions would not have been able to tease that subevent apart from the whole event. Thus, we see that children are constrained to hypothesize meanings for novel verbs in just the ways that those verbs are represented cross-linguistically in adult languages.

4. Conclusions

In sum, the studies presented here support a general framework of inquiry in which linguistic description and theory-building provide testable hypotheses for constraints on language acquisition. Principles of grammar that are found to be invariant across languages should be evident as constraints on learners. Properties of grammar that vary across languages should not so constrain language learners. In the present case, we have examined the role of syntactic constraints on verb meaning and verb syntax in guiding verb acquisition. In this domain we find that children are limited in their hypotheses about verb meaning and verb syntax by precisely those constraints that are posited by linguistic description, lending further support to those constraints as principled aspects of the cognitive code underlying human language.

It is important to note, however, that although the work I have described focuses on constraints from the learner, this focus by no means diminishes the contribution of the input and linguistic experience in the development of the syntax and semantics of verb representations. In the cases where there are no inherent constraints guiding acquisition, we expect to see a larger role of the input. Indeed, this role has been documented for the acquisition of argument structure preferences that play a role in parsing (Snedeker and

Trueswell, in press), for learning which verbs encode exceptions to general linking principles (Naigles, Fowler and Helm 1992), for identifying the set of syntactic frames that a verb occurs in (Hoff and Naigles 2002), among various other properties. Thus, the theory of verb-learning that develops is not one that is myopically focused exclusively on constraints from the learner or on the role of the input, but rather on the important interactions between the two.

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Figures:

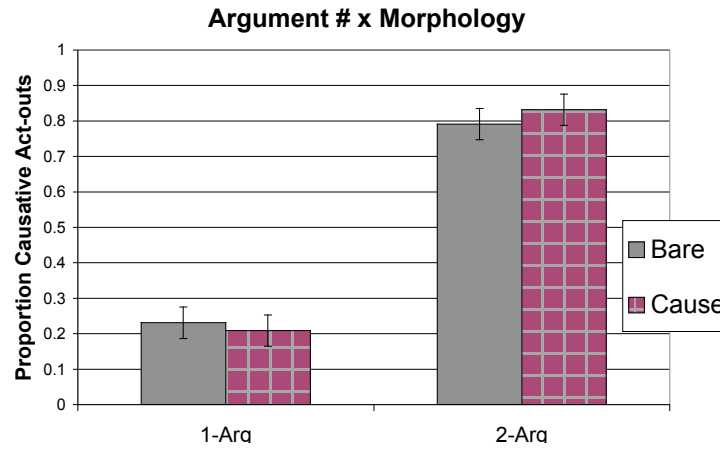


Figure 1: Proportion of Causative Act-outs by 3-year-old learners of Kannada in 1-argument vs. 2-argument contexts with and without causative morphology.

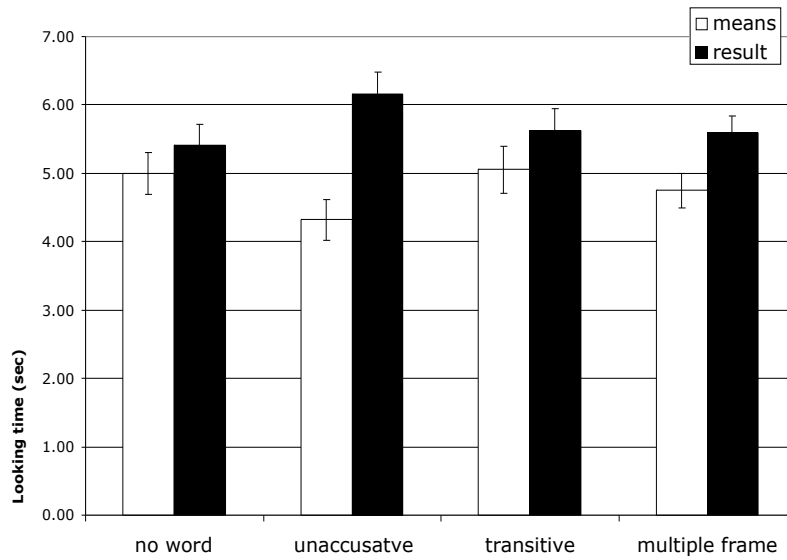


Figure 2: Mean visual fixation to means vs. result subevent at test, by condition.

* Difference in attention to the means vs. result subevent was significant in the unaccusative and multiple frame conditions.