Constrained Flexibility in the Acquisition of Causative Verbs

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1. Introduction

Whenever we learn a novel word, whatever its grammatical category, what we are learning is a label for a category of things in the world. The word "dog," then, refers to the category of dog-entities in the world, and the word "jump" refers to the category of jumping events. A large literature has grown up around the kinds of categories that children assign to novel nouns, asking, for example, whether a novel count noun refers to a particular individual, to a basic level category, or to a superordinate category (e.g., Waxman 1990, Markman 1993). However, the corresponding questions have not yet been asked about novel verbs: i.e., what categories of events can a novel verb be extended to include?

Linguists have shown that there are systematic regularities in the mapping between verb meaning and verb syntax, such that verbs that refer to similar event types, i.e., verbs that have similar meanings, can occur in similar sentence structures (Gruber 1965, Carter 1976, Jackendoff 1990, Levin 1993, etc.). We know, for example, that only verbs that label a change of state can participate in the so-called causative/inchoative alternation. Compare the behavior of *bounce* in (1), which labels a change of state that the girl causes in the ball, with *hit* in (2), which does not.

(1) a. The girl bounced the ball.
b. The ball bounced.

(2) a. The girl hit the ball.
b. * The ball hit.

There is, moreover, a rich body of syntactic bootstrapping literature demonstrating that young children can tap into this kind of information and use

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cues from the syntactic structures a novel verb occurs in to constrain their hypotheses about its meaning (Landau & Gleitman 1985; Gleitman 1990; Naigles 1990, 1996; Fisher 1996; inter alia). Naigles (1990), for example, demonstrates that 2-year-old children can use cues from syntax to help them figure out which of two simultaneous events is being labeled by a novel verb. And in Bunger & Lidz (2004), we take these findings a step further to demonstrate that 2-year-olds can also use cues from syntax to figure out which subpart of a single complex event is being labeled by a novel verb.

The complex events that we have been studying are causative events, those in which some agent performs some action that causes some change of state in another entity. Recent work in infant event representations reveals that by as early as 10 months of age, children are sensitive to elements of events that are relevant for linguistic structure (Gordon 2004). Our own work shows that 2-year-olds, like adults, represent events of direct causation as decomposable into the same subevents that are relevant for their linguistic representation (Bunger & Lidz 2004). Imagine, for example, an event in which a girl makes a ball bounce up and down by hitting it repeatedly with her hand. We can identify three subparts of this event, as in (3).

(3) [[girl hits ball] CAUSE [ball bounces]]
MEANS RESULT

First, there's the means subpart: this is the activity that the agent is engaged in that serves as a means of causing a change of state in the other relevant entity. In this case, the girl is hitting the ball. Then there's the result subpart: this is the change of state undergone by the entity affected by the agent. In this case, the ball is bouncing. And then there's also the notion of causation: this is the relation that links the other two subevents to each other. Here, it is the notion that the girl's hitting of the ball directly results in the ball's change of state.

The linguistic evidence for these subparts comes from the fact that single verbs can refer to the individual subparts of the causative as well as to various combinations of the subparts, as in (4). The verb *hit* used in a transitive frame labels only the means subevent (4a), and the verb *bounce* used in an unaccusative intransitive frame labels only the result subevent (4b). However, the verb *dribble* used in a transitive frame encodes the entire causative event, both the result and the idea that that result has been caused by the girl hitting the ball in a characteristic way (4c).

(4)	a. The girl hit the ball.	Means
	b. The ball bounced.	Result
	c. The girl dribbled the ball.	Causative event

One thing that we know is true cross-linguistically of verbs labeling causative events is that languages don't have verbs that encode subparts of the causative that aren't constituents (e.g., Rappaport Hovav & Levin 1998). So,

languages can have single verbs that label any of the individual subevents of the causative, or single verbs that label the entire event, but there are no verbs that encode, for example, a means subevent and a result subevent that are not causally related.

The broad goal of the research reported here was to examine the constraints that language learners put on the categories of events that a novel verb can apply to. To address this issue, we sought to gain a more precise idea of the different ways that 2-year-olds are willing use single verbs to encode the subparts of a causative event by asking two more specific questions. First, we wanted to find out how children are willing to package information about causative events into verbs: i.e., to find out whether kids would be willing to accept any combinations of the subevents of a causative as the meaning of a single verb, or whether they, like adults, would be constrained by something like a constituency constraint.

Second, we wanted to find out how flexible the world-to-word mapping is for verbs labeling causative events: i.e., how specific children are about the event features they're encoding when they're acquiring a novel verb. So, for example, when they see an event in which a girl dribbles a ball and hear it described with a novel verb like *pimming*, we want to know whether *pimming* has to mean something very specific like "cause to bounce by hitting," or whether the semantic identity of the subevents might be underspecified, with alternate meanings something like "cause to bounce by performing some unspecified action" or even "cause to move in some unspecified way by performing some unspecified action."

To investigate these questions, we conducted two experiments using the preferential looking paradigm developed by Spelke (1979) and Golinkoff et al. (1987) to test 2-year-olds' interpretations of novel verbs used to describe causative events. Together these experiments give us some initial insight into the categories of events that a novel verb can be extended to include: Experiment 1 explores children's flexibility in encoding the semantic content of the means subpart of a causative, and Experiment 2 their flexibility in encoding the semantic content of the result subpart.

2. Experiment 1

2.1 Design

The participants consisted of 24 children (6 boys and 6 girls in each experimental condition) ranging in age from 22;7 (months;days) to 26;1 (mean 23;29). All were being raised in English-speaking homes.

In the preferential looking procedure, participants are presented with two scenes displayed simultaneously on opposite sides of a large video monitor accompanied by some auditory stimulus. Our version of the task consists of three phases: familiarization, contrast, and test. During the familiarization phase, participants were presented with videos of causative events accompanied by a digitally synchronized auditory event description that included a novel verb (e.g., "Look! The girl is pimming the ball."). The event was shown three times

(6s each presentation) and on both sides of a large projection screen, first once on each of the left and right sides in sequence, and then once on both sides simultaneously. A complete list of the causative events used as stimuli is given in Table 1. During the contrast phase, participants saw the agent of the causative event presented during familiarization participating in a different (noncausative) event involving the object presented during familiarization (Table 1). Accompanying this contrast event, they heard an event description that repeated the novel word presented during familiarization, but that made it clear that the referent of that word was not depicted (e.g., "Oh no! Now the girl is not pimming the ball.").

Table 1—Familiarization and contrast events

Novel verb	Causative event	Contrast event
Grek	girl turns crank attached to light, light bulb turns on	girl puts light on her head
Blick	boy pumps bike pump attached to garden flower, flower spins	boy waves flower back and forth
Pim	girl hits ball with tennis racquet, ball bounces	girl swings ball back and forth
Lorp	boy hits ring tower with stick, tower rocks back and forth	boy turns tower over and over

The contrast phase was followed by one final presentation of the causative event + event description pairing presented during familiarization (with the causative event on both sides of the screen). During the familiarization and contrast phases, each presentation of an event was accompanied by two mentions of the novel word, for a total of 10 mentions.

The two experimental conditions differed between participants and were distinguished by the syntactic frame in which the novel verb was presented during the familiarization and contrast phases. Participants in the unaccusative condition heard the novel verb used in an unaccusative intransitive sentence like "The ball is pimming," and participants in the transitive condition heard the novel verb used in a transitive sentence like "The girl is pimming the ball."

During the test phase of the experiment, participants were presented with two new events presented simultaneously on opposite sides of the screen, and the auditory stimulus directed participants to find the action represented by the novel verb introduced during familiarization. Both of the test events involved

Table 2—Representative trial: Experiment 1, unaccusative condition

Phase	Left side of screen	Right side of screen	Audio track
Familiarization	girl bounces ball by hitting it with a tennis racquet	black screen	Look! The ball is pimming. Do you see the ball pimming?
	black screen	girl bounces ball by hitting it with a tennis racquet	Wow! The ball is pimming. Do you see the ball pimming?
	girl bounces ball by hitting it with a tennis racquet	girl bounces ball by hitting it with a tennis racquet	Yay! The ball is pimming. Do you see the ball pimming?
Contrast	(centered) girl waves ball from side to side		Oh no! Now the ball is not pimming. The ball is not pimming.
Familiarization	girl bounces ball by hitting it with a tennis racquet	girl bounces ball by hitting it with a tennis racquet	Yay! Now the ball is pimming. Do you see the ball pimming?
Test	<u>New Means</u> girl bounces ball by hitting it with her hand	<u>No Cause</u> girl waves racquet but does not hit ball; ball bounces	Oh look, they're different. Do you see pimming? Do you see pimming? Where's pimming now?

the person and objects presented during familiarization, but they differed in which of the subparts of the familiarized causative event were repeated. One of the test events was a causative event that differed from the familiarization event in the means of causation (New Means test event), and the other was an event in which no causation occurred, but the means and result presented during familiarization were both repeated (No Cause test event). In both test events, then, the result subevent was the same as that presented during familiarization, but in the New Means test event, the means by which that result was brought about was changed, and in the No Cause test event, the means and result subparts were both repeated but were no longer causally related.

The side of the projection screen on which the causative event was first presented during familiarization was counterbalanced, as was the location (right vs. left side) of the new events shown during the test phase. A schematic depiction of a representative trial, including specific examples of test events, is presented in Table 2.

Participants were tested individually, seated in a chair facing the projection screen, and their attention to the stimuli was recorded using a digital video camera situated just below the projection screen. In most cases, each child was accompanied by a parent who was seated just behind and to the left of the child's chair. Accompanying parents were asked to refrain from talking or offering nonverbal encouragement while in the testing room. Children whose parents did not adhere to this request were excluded from the analysis. Research assistants who were not aware of the predicted responses coded videos of the participants for duration of attention to the stimuli during each of the test phases. An ANOVA was performed to test for differences in mean visual fixation to the New Means and No Cause test events across experimental conditions.

2.2 Results and Discussion

In essence, the goal of the test phase in this experiment was to find out whether participants would be more willing to extend the novel verb presented during familiarization to refer to an event that is of the same event type as the familiarization event (i.e., a causative event) but that differs in the semantic content of the means subevent or to an event that is of a completely different event type than the familiarization event (i.e., not a causative event) but that matches the familiarization event in perceptually salient ways. The relevant question to ask when examining these data, then, is which test event participants are willing to accept as an extension of the meaning of the novel verb presented during familiarization. Previous studies have shown that participants in the preferential looking task tend to look longer at the scene that matches the speech stimulus. In this study, we expect participants to look longer at the test event that they were willing to label with the novel verb presented during familiarization.

Previous work in syntactic bootstrapping has demonstrated, furthermore, that the meaning that 2-year-old children assign to a novel verb is heavily

influenced by the syntactic frame in which that novel verb is presented. Given this effect, we expect to find differences in patterns of looking across conditions that reflect the mapping between verb meaning and verb syntax.

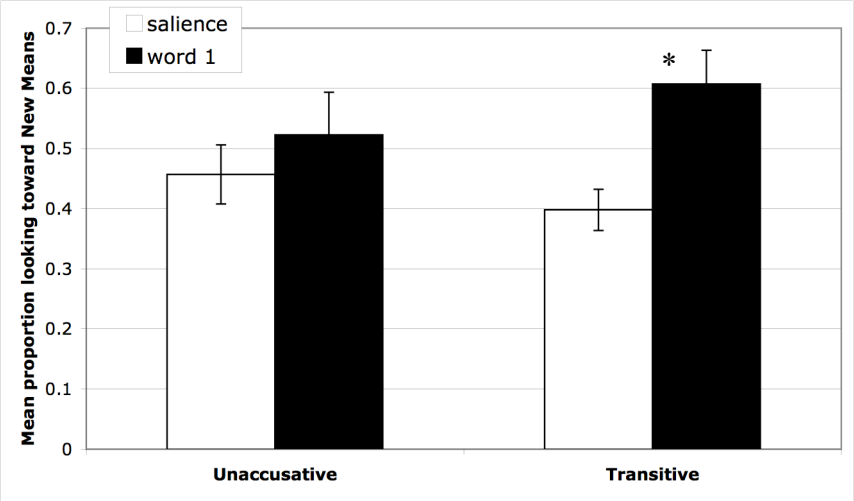

Figure 1—Mean visual fixation at test, Experiment 1
*In the transitive condition, attention to test events was significantly different during salience vs. at the first mention of the novel word in the test audio.

Figure 1 depicts the mean proportion of visual fixation toward the causative New Means test event for each experimental condition, averaged across participant and trial. Data are presented from a 2s salience period at the beginning of the test phase and from a 2s window around the first mention of the novel verb in the test audio (word 1). During the salience period, participants have not yet heard the novel verb repeated, and their pattern of looking provides some information about baseline preferences for the two test events. Looking patterns during the word 1 period, on the other hand, provide information about participants' preferences for extension of the novel verb presented during familiarization.

When asked to find the test event that could be labeled by the novel verb presented during the familiarization phase, participants in the unaccusative condition showed no significant preference for either test event (p=0.45). This result is not surprising, considering that the verb in an unaccusative intransitive frame unambiguously labels the result of a causative event. We can compare the novel verb input in (5a) with the English verbs in (5b), each of which we know labels just what happens to the ball in a given causative event.

(5) a. The ball is pimming.
b. The ball is bouncing/rolling/spinning. Result

In this experiment, then, both of the test events included the subevent that participants in the unaccusative condition would have identified as the meaning of the novel verb presented during familiarization, and their lack of preference for a single test event simply reflects this interpretation.

Participants in the transitive condition, on the other hand, showed a significant increase in their preference for the causative New Means test event (vs. salience) when asked to find the referent of the novel verb (p=0.004). Unlike the unaccusative, the transitive frame is ambiguous: the verb in a transitive frame can label either just the means of a causative event, as in (6b), or it can label an entire causative event, as in (6c).

(6) a. The girl is pimming the ball.
b. The girl is hitting the ball. Means
c. The girl is dribbling the ball. Causative event

The preference for the causative New Means test event demonstrated in this condition, then, provides further evidence that children of this age are biased to interpret verbs in a transitive frame as causatives (Lidz et al. 2003). Note, moreover, that participants made this choice regardless of the fact that the causing activity in the test event was different from that presented in the familiarization event. This flexibility reveals that the semantic content that these participants assigned to their representation of the novel causative could not have included a highly specified means subevent.

Finally, it is important to note that neither group of participants showed a preference for the No Cause test events. This demonstrates that they were unwilling to extend the novel verb to refer to an event that includes subparts of the familiarization event that are not constituents.

3. Experiment 2

In Experiment 1, we observed that 2-year-olds would group two of the subparts of the causative together—i.e., cause and result—when extending the meaning of a novel transitive verb and allow for flexibility in the identity of the means subevent. What we didn't know was whether this was the only possibility for grouping the subparts, or whether, if they were given the opportunity, children of this age would also be willing to group the means and cause subparts together without identifying a specific result. If so, then this might suggest that what they've learned about these verbs is that they label causative events of some type, with no commitment to the identity of the means or the result subevents. Experiment 2 was undertaken to shed some light on this mystery by exploring children's flexibility in encoding the semantic content of the result subpart of a causative.

3.1 Design

The participants consisted again of 24 children (6 boys and 6 girls in each experimental condition) ranging in age from 22;12 to 25;25 (mean 23;28); all were being raised in English-speaking homes. These children participated in a preferential looking task that was identical in procedure to the one described in section 2.1. During the familiarization and contrast phases, participants saw the same exact events as those presented in Experiment 1. Beyond that similarity, however, this experiment differed from Experiment 1 in two ways: first, in the auditory conditions that were presented during familiarization, and second, in the ways in which the test events differed from the familiarized causative.

In Experiment 2, participants were assigned either to an unergative condition, in which they heard the novel verb used in an unergative intransitive sentence like "The girl is pimming," or to a transitive condition, in which they heard the novel verb presented in a transitive sentence like "The girl is pimming the ball."

Then, in the test phase of Experiment 2, children were given the option of extending the novel verb either to a causative event that differed from the familiarization event only in the change of state undergone by the object (New Result test event) or to the same No Cause test events that were presented in Experiment 1. Recall that in Experiment 1, the result presented during familiarization was repeated in both test events, but we varied whether it was caused or not. In Experiment 2, the agent's activity is repeated in both test events, but we varied whether the activity was still a means of causation. Specific examples of the test events that would follow the causative *pimming* event (detailed in Table 2) are presented in Table 3.

Table 3—Test events: Experiment 2

Phase	**Left side of screen**	**Right side of screen**	**Audio track**
Test	<u>New Result</u> girl deflates ball by hitting it with the racquet	<u>No Cause</u> girl waves racquet but does not hit ball; ball bounces	Oh look, they're different. Do you see pimming? Do you see pimming? Where's pimming now?

3.2 Results and Discussion

As in Experiment 1, the goal of the test phase in this experiment was to find out whether participants would be more willing to extend the novel verb to refer to an event that is of the same event type as the familiarization event but that differs in the semantic content of the result subevent (now the ball does something else when the girl hits it with the racquet) or to an event that is of a different event type than the familiarization event but that matches the familiarization event in easily observable ways (both the girl and the ball are doing the same thing they were during familiarization). To this end, an ANOVA was performed to test for differences in mean visual fixation to the New Result and No Cause test events across experimental conditions.

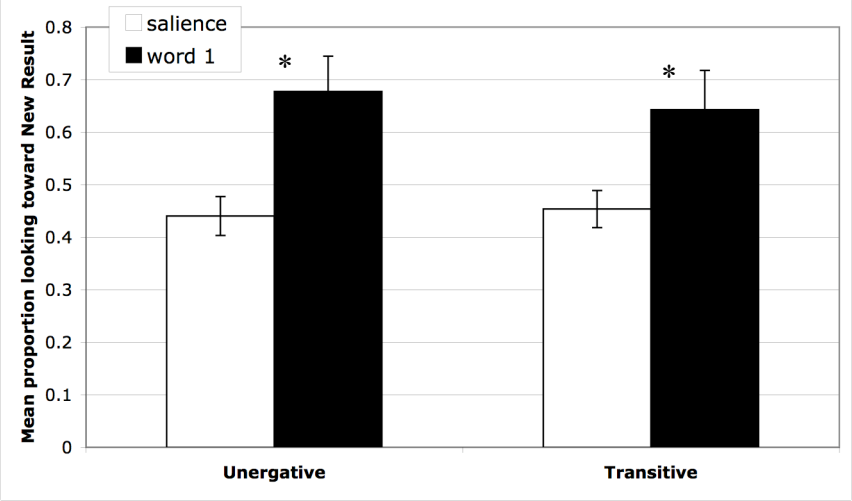

Figure 2—Mean visual fixation at test, Experiment 2
*In both conditions, attention to test events was significantly different during salience vs. at the first mention of the novel word in the test audio.

Figure 2 depicts the mean proportion of visual fixation toward the causative New Result test event for each experimental condition, averaged across participant and trial. When asked to find the test event that could be labeled by the novel verb presented during the familiarization phase, participants in both the unergative (p=0.005) and the transitive (p=0.03) conditions showed a significant preference for the causative test event. This suggests that participants in both of these conditions interpreted the novel verb as a label not for a specific subevent, but rather as a label for the causative event. Again, though, note that they are choosing to extend the meaning of the novel verb to include causative test events that differ in the change of state that the girl causes in the ball. This flexibility indicates that the semantic content that these participants assigned to

their representation of the novel causative could not have included a highly specified result subevent.

4. Conclusions

A rich body of research exists that addresses the question of how children learn verbs, investigating, for example, the kinds of input that are most informative for verb learning. Very little work, however, has examined the precise nature of the meanings children assign to verbs. The research reported here has been carried out with the goal of investigating the limits that 2-year-old children put on their hypotheses about the meanings of novel verbs they are acquiring.

The results of these two experiments provide further evidence that 2-year-olds can use information from the syntactic frames in which novel verbs appear to guide their hypotheses about what the verbs mean. In Experiment 1, for example, when participants heard the novel verb in an unaccusative frame, they understood it to refer to just the result subevent of the complex causative, but when they heard it in a transitive frame, they understood it to refer to the causative event.

In addition, these children appear to be limited in the way that they can map verb meanings onto structural representations of events, such that verbs can only encode subparts of the representation that form constituents. Recall that across both experiments, participants never chose to extend the meaning of the novel verbs to label the No Cause test events, in which the means and result were repeated but were not causally related. This suggests that 2-year-old children are only willing to encode as single verbs combinations of the subparts of a causative event that correspond to possible structural representations. As long as that structural constraint is satisfied, however, children can be flexible in the specificity of the semantic content they assign to their representation of the causative.

What we've done in the experiment, essentially, is to ask these kids to extend a novel verb to refer to an event that conflicts with the familiarized causative in one of two ways: they have the choice of extending the verb to refer either to an event that matches the familiarization event in event-structure but that differs in the identity of the subevents within this structure, or to an event that is perceptually similar to the familiarized event (i.e., it includes the same subevents) but that has a different event structure. And what we have found is that they are willing to loosen their commitment to the semantics of the event but not to the kind of event representation they have assigned to the verb. That is, they are willing to be flexible in what they will permit as the means or the result subevent of a causative, but they still represent the meaning of the novel verb as causative. This kind of flexibility would be an extremely powerful tool for word learning, allowing children to refine their hypotheses about the meanings of words they're acquiring as they encounter new information about them in the world.

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