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Inferring Meaning from Syntactic Structures in Acquisition: The Case of Transitivity and Telicity

Laura Wagner
Ohio State University

Abstract

This paper investigated children's ability to use syntactic structures to infer semantic information. The particular syntax-semantics link examined was the one between TRANSITIVITY (transitive/intransitive structures) and TELICITY (telic/atelic perspectives; that is, boundedness). Although transitivity is an important syntactic reflex of telicity, it is neither necessary nor sufficient for predicting a telicity value; it is therefore a weak cue for telicity semantics. Nevertheless, children do make use of it. Experiment 1 used a match-to-sample task and found that 3-year children could use transitivity information to guide their interpretations of telicity. Experiment 2 used a preferential looking task with 2-year-old children and similarly found that these children could successfully use transitivity as a cue to telicity. Children in both experiments succeeded with both causal and directed-motion events, suggesting that telicity judgments are not tied to any one event type. These results are discussed in the context of other semantic elements that children can link to transitivity, and taken together, are argued to support a largely inferential link between transitivity and telicity.

Inferring Meaning from Syntactic Structures in Acquisition: The Case of Transitivity and Telicity

Events in the world are inherently ambiguous, composed of many overlapping dimensions. One of the important tools we have for identifying a particular event perspective among these dimensions is linguistic structure. How children (and adults) use this tool has been studied under the name of Syntactic Bootstrapping (Landau & Gleitman 1985, Gleitman 1990). This paper will examine children's knowledge of one particular link between syntax and semantics, namely the one that exists between transitivity and telicity. TELICITY refers to the semantic dimension of boundedness: telic predicates describe events in terms of their boundaries (e.g. outcomes and results), and atelic predicates describe them without boundaries (e.g. processes and activities). It is one of the handful of semantic dimensions that organizes grammatical systems cross-linguistically and it is a useful dimension for perspective-taking because telic and atelic predicates emphasize different kinds of event information. Beyond its general conceptual importance, telicity is also interesting to study in the context of syntactic bootstrapping because its relationship to structures is far from straightforward. TRANSITIVITY - that is, one vs. two argument structures - is strongly associated with telicity, but it is neither necessary nor sufficient for signaling specific telicity values. Nevertheless, these studies will examine children's knowledge of this imperfect link, specifically, their ability to use it to generalize novel events described with novel verbs. Children's success in these tasks will support an inferential account of this syntax-semantics

Address for Correspondence: Laura Wagner, Department of Psychology, The Ohio State University, 1835 Neil Avenue, Columbus, OH 43210, wagner.602@osu.edu, Phone: 614-688-3260, Fax: 614-292-4537 .

link, particularly when they are considered in the context of other semantic elements that children link to transitivity.

The Semantics and Syntax of Telicity

The fundamental semantic notion underlying telicity is that of boundedness: TELIC predicates describe events in terms of an inherent end-point and ATELIC predicates do not. This essential semantics supports a variety of inferences which have been exploited in conceptual and linguistic tests of telicity for many years (Vendler 1967, Dowty 1979, Smith 1991, Klein 1994). Conceptually, telic and atelic predicates differ in the property of homogeneity. Atelic predicates present homogenous events: every part of them is the same. For the event described in (1), singing happens for 5 minutes, and also for 4 minutes, 3 minutes, 2 minutes, and so on. The predicate *sing* applies truthfully to every part of the event just as much as it does to the event as a whole. By contrast, at least one part of an event described with a telic predicate - the end-point - is different from the rest of the event. The event described in (2) also lasts for 5 minutes, but the predicate *sing a song* is not true of what happens at minute 4, minute 3, minute 2 and so on. The end-point boundary is part of the meaning of *sing a song* and so the ending must be included to make the predicate true.

1 Lakisha sang for 5 minutes

2 Melinda sang a song in 5 minutes

The previous examples also illustrate a linguistic test for telicity: atelic predicates combine naturally with “for X time” adverbials as a way of describing duration while telic predicates combine naturally with “in X time” adverbials to describe duration. For both (1) (atelic) and (2) (telic), the adverbials describe the duration of one complete instance of the event. The *for* adverbial locates the arbitrary ending of the event while the *in* adverbial specifies how long it took for the end-point to be reached.

Similarly, the so-called imperfective paradox also depends on the fact that only telic predicates specify their endpoint. Imperfective aspect (the progressive, in English) takes an interior perspective on an event that does not consider boundaries (Comrie 1976, Smith 1991, Klein 1994). Because atelic predicates are homogenous, this has little effect on their interpretation, and the imperfective version of an atelic predicate (3a) entails the perfective version (3b). However, it radically changes the implications of a telic predicate. Imperfective (4a) does not entail the completion of the event although the perfective version in (4b) does.

3a Sanjaya was smiling

3b Sanjaya smiled

4a Haley was driving to the store... but she had a flat tire and never got there

4b ?? Haley drove to the store... but she had a flat tire and never got there

Finally, the *almost* test depends on the fact that telic and atelic predicates differ in their specification of an event’s endpoint. *Almost* indicates that something specific didn’t happen. With atelic predicates (5), it indicates that the event never started, since the beginning of the event is the only specific point implicated by the predicate. By contrast, telic predicates offer two specific points that can be targeted by *almost* - the beginning point (as with atelic predicates) and the end-point. Thus, (6) is ambiguous: it can mean either that Blake never started writing, or that he started, but never finished the whole verse[2].

5 Jordin almost laughed

6 Blake almost wrote a verse

Syntactically, there are a variety of syntactic structures that help to signal telicity (Smith 1991, Jackendoff 1996, Hay, Kennedy & Levin 1999 inter alia). Just as an event's boundary in the world can be created in many ways so too, boundaries are coded linguistically in a variety of ways. For example, some verbs inherently describe changes of state with well-specified transition points (e.g. *die*); prepositional phrases are often used to specify the arrival at a particular destination point (e.g. *Simon walked to the theatre*); count nouns can be used to indicate the creation of a specific object (e.g. *Randy made a sandwich*); and specific measure phrases can be used to identify a boundary (e.g. *Paula lengthened her hem 3 inches*).

One particularly important syntactic cue to telicity is transitivity, with transitive sentences linking to telic semantics and intransitive sentences to atelic semantics. The internal direct objects of transitive sentences provide a useful means to define boundary points for creation events (*make a sandwich*), destruction events (*eat a sandwich*), and many change of state of events (*paint a box*). Of course, not all internal direct objects can serve this function, either because the relationship between the verb and the object is not of the right type (*push a cart* is atelic) or because the object itself does not define a good boundary point, as with mass nouns and bare plurals (*eat peanut-butter/peanuts* is atelic). Nevertheless, transitivity has played a central role in many linguistic accounts of telicity. Some of these accounts focus on the special structural properties of the internal direct object position (Tenny 1994, van Hout 1996); other accounts focus on the semantic properties of the direct object for measuring out the progress of the event (Krifka 1992, Dowty 1992) or for defining the end-point (Verkuyl 1993); and the functionalist account of Hopper & Thompson (1980) partially inter-defines telicity and transitivity with each other as part of a larger functional-semantic anchoring point.

The Acquisition of Telicity

Thus, the link between transitivity and telicity is neither necessary nor sufficient: a transitive sentence might, or might not, signal telic meaning, while conversely, telic semantics might, or might not, be conveyed through a transitive sentence. This many-to-many correspondence is far from ideal for a learning situation and one might expect that it would be quite difficult for children to find and exploit the link between transitivity and telicity.

In the course of acquisition, children do seem sensitive to telicity semantics, but their record in mapping those semantics into structures is a bit spotty. There is some evidence that children may initially link telicity to elements of verb morphology. In children's early production, they tend to combine telic meanings with past and perfective morphology and atelic meanings with present and imperfective morphology (e.g. Antinucci & Miller 1976, Bronckart & Sinclair 1973, Bloom, Lifter & Hafitz 1980, Shirai & Andersen 1995). Moreover, in a verb generalization task, Berhend and colleagues found that 3-year-olds continue to use verb morphology to signal a telic/atelic distinction (Behrend 1990, Behrend, Harris & Cartwright 1995). However, since these morphemes do not in fact mark telicity, these data suggest that children may be over-eager to find morpho-syntactic correlates to telicity. In terms of understanding actual markers of telicity, children's earliest successes are with particles and prepositional phrases. Penner, Schulz & Wymann (2003) found that children as young as 2;10 understand the particle *auf* as a telicity marker, and that events with this particle should have a designated end-point. In English, Wagner (2006) found that children under three years succeeded robustly at using prepositional phrases (e.g. *The butterfly flew to a tree*) to adopt a telic perspective in an event individuation task: when the prepositional phrase was present, they were more likely to individuate the event in terms of a goal-oriented boundary.

The knowledge that transitivity can signal telicity is available to children shortly thereafter. Van Hout (2000) found that children could use the difference between transitive and intransitive structures to choose among events in a picture selection task, and Wagner & Carey (2003) (also Wagner 2006) found that children used transitivity as a cue to telicity in an event individuation task. All of these studies, however, have used real lexical items familiar to the children being tested. It is unclear, therefore, the extent to which these children succeed by compositionally interpreting the various cues to telicity as opposed to simply recovering stored meanings of words and predicates. These children certainly know a lot about their native language, but from this previous work, we cannot tell if they have formed general connections between the structural markers of telicity and telicity semantics.

There is some suggestive evidence from Wagner (2006) that at least early on, children have created a more general connection between transitivity and telicity. The children in that study participated in an event individuation task, in which telic interpretations lead to individuation based on the event's end-point and atelic interpretations lead to individuation based on intermediate spatio-temporal breaks. Overall, all children (two, three, and five year olds) were able to successfully use the telicity of the target sentences to adopt an appropriate individuation strategy. However, there was an interesting interaction between the age groups and the transitivity of the sentence. The youngest children actually out-performed the older ones with sentences that were transitive and telic (*the girl painted a flower*): they chose a goal-based individuation criteria for these sentences at the same rate as adults, and significantly more than their older peers. However, this success came at a price. The same young children also showed a strong tendency to interpret all transitive sentences as telic, even when older children correctly knew they were not (e.g. *the dog pushed a ball*). Thus, the youngest children seemed to be adopting a strategy in the task of assuming that all transitive sentences were telic, a strategy which sometimes worked to their advantage and sometimes did not.

The evidence from Wagner (2006), however, can only be taken as suggestive of children haven created a robust link between transitivity and telicity. The older children showed no evidence for such a link, and even the youngest children only showed it for transitive structures to telic semantics, and not for intransitive structures to atelic semantics, as would be expected from a more general mapping. Moreover, as noted before, the study used familiar words so children could have used stored knowledge to aid in their performance. In order to determine if children really have created a general, abstract link between a structural cue like transitivity and telicity semantics, it is necessary to test them with wholly novel verbs. Novel verbs by definition are not part of children's memorized inventory of lexical knowledge. Therefore, any inferences children can make about the meaning of predicates containing them must be the result of on-line connections drawn from the cues provided through the experimental manipulations.

Syntactic Bootstrapping

The idea that children can use the syntactic context in which a new word appears to infer some semantic information about that word goes back at least to Brown (1957). In that classic study, children were presented with an ambiguous scene containing a novel action, a novel solid object, and a novel substance; the scene was labeled with a nonsense word. How children chose to generalize the novel word to new scenes depended on the syntactic context in which it had been used. For example, when the word was used in verb syntax ("She is zibbing"), children generalized on the basis of the action, but when the word was used with count-noun syntax ("It's a zib"), they generalized on the basis of the solid object. Since the word itself bore no independent meaning, children's inferences had to depend on their understanding of the structural implications of its use.

More recently, under the term of Syntactic Bootstrapping, Gleitman and colleagues have refined this idea and documented children's ability to use it in a variety of domains. For example, they have shown that adults perceive links between syntactic structures and semantic meaning (Kako 2006, Fisher, Gleitman, & Gleitman 1991); that adults exploit those links to help them guess the meanings of words, particularly verbs (Gilette, Gleitman, Gleitman & Lederer 1999, Snedeker & Gleitman 2004); that children exploit those links to choose among events (Naigles 1990, Fisher 2002, Gertner, Fisher & Eisengart 2006); and even that young children sometimes give greater weight to the syntactic structure than to a familiar verb within the structure in interpreting an event (Naigles, Fowler & Helm,1992; Lidz, Gleitman, & Gleitman 2003).

Transitivity has received a great deal of experimental attention in the syntactic bootstrapping literature. For example, Naigles (1990) showed that children would link transitivity to causality. The children were shown an ambiguous event that contained both a causal component (in which a duck made a bunny bend over) and a non-causal component (both the duck and bunny wheeled their arms to the side. This event was described with a nonsense verb, either contained in a transitive or an intransitive structure. At test, children were faced with a choice between the two event components - one choice showed just the non-causal, arm-wheeling event while the other showed just the causal, force-to-squat event. Children's choice about how to extend the novel verb depended on the syntactic structure in which it had been used: Children who heard the transitive structure extended the novel verb to the causal event and children who heard the intransitive structure extended it to the non-causal event. This result has been supported and extended by similar looking-time studies (Hirsh-Pasek & Golinkoff 1996, Fisher 2002, Naigles & Kako 1993, Bunger & Lidz 2004) as well as by related act-out studies (Naigles, Fowler & Helm 1992, Lidz et al. 2003).

Moreover, children also appear to know that transitivity can signal other semantic information. Naigles & Kako (1993) found that 2-year-old children link transitive structures also to events involving contact, even of a non-causal variety. In addition, Hohenstein, Naigles, and Eisenberg (2004) found that 3.5-year-old children link transitivity to a path-manner distinction in directed motion verbs. Children generalized a novel verb in a transitive frame (e.g. "The girl gorped the tree") to an event with the same path (to vs. from the tree) and one in an intransitive frame with a prepositional phrase (e.g. "The girl gorped to the tree") to an event with the same manner of motion. Altogether, these data show that children can link transitivity to various kind of semantic information.

It should be noted, however, that the existing studies have not directly tested telicity itself. Telicity overlaps with notions such as causality, contact, and path/manner, but it is not coextensive with any. For example, the causal events used in the studies just mentioned (Naigles 1990, Naigles & Kako, Naigles 1996, Fisher 2002, Bunger & Lidz 2004) were not telic. For their causal alternative, these studies have all used variations of actions involving pushing and pulling. While such actions are decidedly causal, common descriptions of them do not pass tests for being telic. More particularly, these studies tend to depict repeated or ongoing instances of the events, stressing the relevant causal interaction, but not presenting a clear boundary point needed to create a telic interpretation. Thus, while these studies truly test the causal/non-causal distinction, they do not speak to the telic/atelic one. A similar analysis can be made of the contact events in Naigles & Kako (1993). Contact often does not create a natural event boundary, and the specific contact events used in that study did not. The one study that did examine a semantic element directly relevant to telicity was the path/manner work of Hohenstein et al. (2004). Although not all path descriptions are telic (e.g. *the girl ran around the table*), the particular directional paths used in that study in fact did create the right type of event boundary and common descriptions of the events would indeed be classed as telic. The contrasting events focused on manners of motion, and descriptions

of these virtually always receive atelic interpretations. Thus, this study does provide preliminary support for the idea that children can map telicity to transitivity. However, it does it with a single event type, that of directed motion events.

The experimental work just discussed has largely been concerned with children's ability to bootstrap from the syntactic information to specific elements of a verb's meaning (cf. Hohenstein et al 2004, Naigles & Kako 1993, Bunger & Lidz 2004 among others). Thus, children hear a novel verb introduced with the target syntactic structures, but the test trials ask children to generalize with no syntax at all (e.g. "Find gorping!"). The removal of the syntax at the test phase licenses the inferences in these papers that children have extended the meaning associated with the syntactic frame to reside in the verb itself. This kind of extension, however, is not wholly sensible for the case of telicity. Although some verbs do allow only a single telicity value (e.g. *die* is inherently telic), many verbs can shift their telicity value depending on their syntactic context and surrounding arguments. For example, *eat* is atelic when it appears in an intransitive structure and telic when it appears in a transitive one (provided it has the right kind of direct object). The relevant unit for evaluating telicity is not, therefore, the verb, but instead it is the entire predicate. The studies presented here reflect this fact; they test children's knowledge of link between structures and semantics, which is the link that actually corresponds to telicity.

Note that the fact that telicity does not directly extend to verb meaning does not lessen the relevance of the information. The perspective information provided by telicity is critical both for acquisition and for general communication. Knowing that the speaker has adopted a telic perspective on an event tells the listener to focus on the outcome or result of the event; to the extent the action is important, it is important as a means for achieving the end-point. Knowing that the speaker has adopted an atelic perspective on an event tells the listener that the end-point can be ignored and that the action or process is speaker's focus. This kind of global perspective alignment will insure that the listener is thinking about the world in the same way the speaker is, a necessary step for the process of learning the specific words of the speaker, as well as for maintaining coordinated communication more generally.

Experimental Overview

The following two experiments investigated children's ability to link transitivity to telicity. Both studies essentially used a match-to-sample technique in which children were presented with a sample, and asked whether variations on the sample are a good match to it. Experiment 1 was conducted with slightly older children (3-year-olds) and required children to make explicit judgments; Experiment 2 was conducted with younger children (2-year-olds) and used an implicit measure of looking-time. Both studies tested children with nonsense verbs to insure that children's performance reflects links they may have made between the structures themselves and telicity, uncontaminated by previous knowledge of the specific verbs involved. Moreover, both studies used full syntactic frames both when introducing the sample events and when children were asked to evaluate the potential match events. As just noted, this was done because telicity information is not a function of the verb, but of the verb within a particular predicate. Finally, both studies tested children with both causal and non-causal directed motion events. Telicity is a more general semantic category that encompasses both event types, and real understanding of the transitivity-telicity link should extend equally to the different event types.

Experiment 1: Generalizations from Form to Meaning with Pre-School Aged Children—Can children use the link between transitivity and telicity to make generalizations about new events? The procedures was a basic match-to-sample task. Children were shown a short sample movie of a distinctive process (e.g. dripping paint)

leading to a distinctive result (e.g. covering a box with the paint). They were then shown two potential matching movies, one which matched the process and changed the result (the Process Match) and the other which matched the result and changed the process (the Result Match). Their task was to simply say whether either movie depicted the same thing as the sample. If children have formed a link between transitivity and telicity, then they should generalize a verb in a transitive structure to the Result Match (which shares the same outcome) and the intransitive structure to the Process Match (which shares the same process).

Methods

Subjects: A total of 34 children participated, with a mean age of 3;8 (range = 2;10 to 4;11). Approximately half the children were girls. All children were tested in a campus laboratory with one parent present. The data from one additional child was excluded for not completing the task.

Stimuli and Procedures: Children watched short animated movies on a laptop computer. They were first presented with a Sample movie described with one of the target sentences. The Sample movie depicted a distinctive goal (e.g. arriving at an X) achieved by a distinctive process (e.g. hopping). Following the sample, children saw two Match movies in sequence. The Process Match showed the same action as the Sample but used to achieve a different result (e.g. departing from an X). The Result Match showed the same result as the Sample achieved by a different process (e.g. cartwheeling). Children were asked to make their judgment about both match movies independently.

There were four items: two events depicting causal events (a creation event and a change of state event) and two events depicting non-causal, directed motion events. Each Sample movie was described with a novel verb in either a transitive or an intransitive sentence. Children heard only one description per movie, but every child received two trials with transitive sentences and two trials with intransitive sentences. Moreover, across subjects, each movie received both kinds of descriptions. A sample set is shown in Figure 1. A complete list of movies and target sentences is in Appendix A.

Procedures: Children participated in four trials, each consisting of a Sample and two Match movies. The Sample movie was presented along with at least two repetitions of the target sentence, one prior to the movie and one following it: “In this movie, we’re going to watch a boy drack. Let’s watch! Did you see? The boy dracked!” The order of the two match movies was counterbalanced across subjects, but all children saw both movies and were asked to make their same-different judgment for each movie. The specific queries matched the sentence structure of the target sentence: “In this movie, did the boy also drack, or did he do something different?” Children were allowed to watch the Sample movie up to 3 times before the Match movies. They were also reminded about the Sample before each Match movie: “Do you remember what the boy did?” Children who claimed to have forgotten the sample movie were allowed to watch it once between the two match trials.

Results: As can be seen in Figure 2, children accepted the Process Match more frequently with the intransitive sentences (m = 37%) than with the transitive sentences (m = 19%) and contrastively, they accepted the Result Match more frequently with the transitive sentences (m = 34%) than with the intransitive sentences (m = 21%). To insure that this effect was not driven just by the oldest children, the participants were grouped by age (younger half and older half of the sample): no effect of age was found (acceptance of Process Match with intransitive sentences: Older M = 38%, Younger M = 33%; acceptance of Process Match with transitive sentences: Older M = 18%, Younger M = 19%; acceptance of Result match

with transitive sentences.: Older M = 32%, Younger M = 36%; acceptance of Result match with intransitive sentences.: Older M = 21%, Younger M = 22%).

An ANOVA was conducted on the rate of acceptance of the match movies with the independent variables of sample event type (causal vs. directed-motion), description type (transitive vs. intransitive) and type of match (Process match vs. Result match). There were no significant main effects, and the only significant interaction was between the type of match movie and the description type ($F(1,64) = 4.84$, $p < .031$). Post-hoc comparisons confirmed that children accepted the Result Match more with transitive than intransitive sentences ($t(33) = 2.05$, $p < .05$) and the Process Match more with intransitive than transitive sentences ($t(33) = 2.66$, $P < .01$).

Overall, there was a high rate of rejection for both of the potential matches: Children rejected 72% of the match movies. Only 2 of the children (6% of the total), however, rejected all eight match choices across the entire experiment. Thus, the results do reflect the patterns of the vast majority of participants. Further, each child's pattern of responses was evaluated for how well it conformed to the overall pattern: Only 3 children (9%) reversed the dominant pattern, accepting Process Matches with transitive sentences and Result Matches with intransitive sentences. Thus, there was no bimodal distribution in the data, and most children contributed positively to the overall pattern.

Discussion: Children were highly sensitive to the differences between the Sample and Match movies, leading them to frequently reject both kinds of Match movies as being different form the sample. This result is consistent with other recent work suggesting that children are conservative in their willingness to generalize new words given very limited exposure (Xu & Tenenbaum, 2007). However, when children saw commonalities between the match and sample movies, they were guided by the syntactic structure of the target descriptions. Children were more likely to accept a Process match given an intransitive description and a Result match given a transitive description. Moreover, children's performance was not influenced by the type of event depicted, as they succeeded with both causal and directed-motion events. These data suggest, therefore, that the individual structures of transitive and intransitive sentences lead children to focus on different dimensions of these events.

Experiment 2: Generalizations from Form to Meaning With Toddlers—The previous study provided evidence that children were able to link transitivity and telicity, across different event types and with completely novel verbs. Experiment 2 asks *when* children are able to make that link. The participants in this study were over a full year younger than those in Experiment 1 and therefore had substantially less experience with the linguistic input and less time to form generalizations over the distributional regularities there.

Because the children were substantially younger, a less demanding method was used: the Inter-modal Preferential Looking task. Conceptually the study is the same as the previous one: children were asked to generalize the meaning of a new verb based on the structure in which it appears for both causal and directed-motion events. More specifically, children were shown a sample movie and heard it labeled with a nonsense verb in either a transitive or an intransitive frame. At test, children chose between a Result Match (a movie that shows a new process to achieve the same result as the sample) and a Process Match (a movie that shows the same process as the sample but used to achieve a new result). As before, for the causal events, the telic result also corresponded to a causal change to an object but for the non-causal events, there was no causal change to the object that defines the telic result.

Unlike the previous study, the two kinds of Match movie were shown simultaneously side by side, and the dependent measure was the time children spend looking at the movies.

In addition, several minor methodological changes were made to improve the validity of the results relative to the previous study. First, the stimulus movies in this study showed real people engaged with real objects and were therefore much more naturalistic than the animated movies used previously. Second, special care was taken to insure that the object of the action was involved equally in the events of both Result Match and Process Match movies. Children could not succeed at this task simply by noting the number of key participants in the event as all events portrayed critically involved two participants.

Methods

Subjects: Twenty-six children participated, with a mean age of 29.2 months. Approximately half the participants were girls. The data from an additional 2 children was not included because these children failed to watch all four novel events. All children were tested in a campus laboratory.

Stimuli: Each trial consisted of a 6-second Sample movie, depicting a distinctive goal achieved by a distinctive process. For each Sample, two 6-second Match movies were created. The Process match showed the same action as the Sample, but used to achieve a different result; the Result match showed the same result as the Sample, but achieved by a different process. For example, one Sample event showed a girl rolling paint onto a box and covering it. The Process match showed a second girl using the roller on the box, but with no paint; the Result match showed a third girl spray-painting a box and covering it. Two of the trials depicted non-causal directed motion events and two depicted causal change-of-state events. All the movies were live-action depictions of real people and real objects. Each trial was associated with a target sentence which described the event using a nonsense verb, in either a transitive or an intransitive sentence frame. These target sentences were uttered by an adult woman in child-friendly intonation.

In addition, two practice trials were shown using familiar actions described with familiar verbs. The first practice trial contrasted clapping and waving; the second one contrasted jumping and bending over. Still frames from a sample novel trial are shown in Figure 3 and a complete list of movies and target sentences is in Appendix B.

Procedure: Participants sat in a booster chair, approximately 18” from 52” screen TV; one parent sat in the test room, in a separate chair approximately 2 feet behind the participant. Parents were instructed not to interact with their children during the testing. Children watched a total of 6 trials: two practice trials with known verbs and familiar events followed by four novel trials.

Novel Trials: For each child, two of the novel trials were linked to transitive target sentences and two were linked to intransitive target sentences. Each test trial consisted of 3 phases. In the first phase, the Sample was introduced along with the target sentence description. Children saw the Sample on both sides of the screen separately, and then on both sides simultaneously for a total of 18 seconds of exposure. Participants heard the target description with each presentation of the Sample for a total of 8 utterances of the target sentence. Following the sample, children saw the Process and Result Match videos side-by-side. The first paired presentation of the Match videos was the Baseline phase, and children were given no instruction about which one to look at. The second paired presentation of the Match videos was the critical test phase, and children were explicitly told to look at the one matching the target sentence. Prior to each paired presentation, children’s attention was

drawn to the center of the screen with a 3-second video clip of a laughing baby. A layout for one trial is shown in Figure 4.

Every child saw an identical video presentation but across participants, there were two different audio conditions that alternated the linking between sentence type and event. Thus, Audio A described events 1 and 4 with a transitive sentence while Audio B described those events with an intransitive sentence; similarly, Audio A described events 2 and 3 with an intransitive sentence while Audio B described those events with a transitive sentence. Therefore, across participants, each event was paired with both transitive and intransitive target sentences. The order of the events themselves was the following: Blowing up a balloon (Change of State), crawling to a pinwheel (Directed Motion), painting a box (Change of State), and raking a ball to a net (Directed Motion).

Practice Trials: The practice trials preceded the Novel trials. Because they used verbs and events that children were expected to know, these trials did not use the Sample phase as shown in figure 4. Children simply saw the two Match movies one additional time each with a neutral description ("Look at her!") and then proceeded directly to the Baseline phase.

Coding and Analysis: Children's looking at the screen was recorded and coded off-line using the Super Coder program. Two independent coders judged the recordings frame-by-frame to determine which side of the screen the children were looking at. The coders' scoring correlated very highly (Pearson R = .977).

The primary measure used for analysis was the percentage of looking to one of the sides of the screen (right or left). The calculated percentages were based only on looks to one of the target sides; looks at the center or away from the screen as a whole were not included. Another critical element of the analysis was that it compared children's looking to the target side to their preference at the baseline phase. The baseline phase established children's individual preferences between the movies, and provides a baseline from which their looking at the test phase could be judged. The critical dependent variable in this study was therefore not how long children looked at the correct side during the test phase; it was how much they shift their looking to the correct video at the test phase *relative* to the baseline phase. Thus, if children had a natural preference for the correct video at baseline, they did not get credit for succeeding at test unless the linguistic target made their preference even stronger.

Results: Children were very attentive throughout the study and during the test phases of the study, they attended to the movies an average of 89.3% of the time; moreover, there were no significant differences in the attention rates across trials. Children's performance, therefore, reflects an informed decision about what they were watching.

The first analysis was conducted on children's looking at the familiar verb pairs. The "correct" screen for both baseline and test phases was defined as the screen that correctly matched the linguistic description used at the test phase. At the baseline phase, children watched the correct screen for 48% of the time but when they were provided with a familiar linguistic description at the test phase, they looked at the correct screen 60% of the time. This shift to the correct screen was significant: $t(25) = 4.1$, $p < .001$. The success with these familiar verbs validates the procedures in general: children do let the linguistic descriptions guide their pattern of looking.

The next analysis examined children's looking a the novel verb pairs. As with the familiar verbs, the "correct" screen for the baseline trials was defined as being the one which correctly matched the linguistic target at the test phase; note that for the novel trials, children

did hear this target prior to the baseline during the sample phase of the trial. Overall, children succeed at this task. They looked at the correct screen more at the test phase (.56) than during the baseline phase (.46). These data are displayed broken down by syntactic target and event type in Figure 4.

An ANOVA was conducted with the independent variables of target sentence (transitive vs. intransitive), event type (causal vs. directed-motion), and trial phase (baseline vs. test), and the dependent variable of the proportion of time spent looking at the "correct" screen. The analysis found a main effect for trial phase ($F(1,25) = 6.3$, $p < .02$), reflecting the data just noted. Main effects were also found for event type ($F(1,25) = 11.3$, $p < .002$) and target sentence ($F(1, 25) = 8.3$, $p < .008$). Note that these last two effects collapse over baseline and test phases and indicate that children looked at the correct answer more even at the baseline phase for causal over directed-motion events (.57 vs. .46) and for transitive targets over intransitive targets (.57 vs. .46). These effects suggest that even before receiving explicit direction to generalize, they were already beginning to do so at least for causal and transitive items. There were no significant interactions.

To determine if sentence structure truly guided children towards the right interpretation, an analysis was conducted over the degree to which children shifted their looking from the baseline to test phases. The Result Match screen was chosen as an anchor point arbitrarily, and successful performance therefore required a positive shift towards the Result Match for transitive structures and a negative shift away from the Result Match for intransitive structures. An ANOVA was conducted over the degree of shift to the Result Match with event type (causal vs. directed-motion) and sentence structure (transitive vs. intransitive) as independent variables. No main effect was found for event type, and there was no interaction between event type and sentence structure. There was, however, a main effect for structure ($F(1, 25) = 6.2$, $p < .02$) showing that the structures correctly guided children's shifts in looking. This effect is illustrated in Figure 5.

Discussion: Using a different method and a substantially younger participant pool, this study found the same result as Experiment 1: Children had correctly formed a link between transitivity and telicity. They generalized verbs in transitive structures to events with similar results and verbs in intransitive structures to events with similar processes. Children succeeded with both causal and directed motion items and there was no interaction between successful shifting to the correct answer and the type of event; these facts support the idea that the link between structure and meaning is a reasonably general one. However, there was a main effect of event type favoring the causal items, suggesting that children may be faster in this task at using structures to guide generalizations for these items relative to the non-causal ones. A similar effect favoring transitive structures, moreover, suggests that specific structures can also facilitate generalizations. These two findings were not predicted, and they suggest that children are anticipating the test phase of the task: they seem to expect to apply the knowledge they have just acquired in the training phase to new events.

Reviewers noted that the preferences during the baseline phase are not ideal. For the causal verbs and verbs in transitive structures, the anticipatory looking at baseline suggests that children's generalizations don't depend on explicit linguistic prompting. However, the fact that children did significantly shift their looking at the test phase in accordance with syntactic structures suggests that the specific linguistic guidance provided at the test phase does aid in children's ability to make generalizations. A related point can be made about the directed motion events: in this case, children showed a general preference for looking at the wrong screen at baseline (regardless of syntactic condition) which was not predicted. Post-hoc analysis of the data showed that this preference was not driven by differences in condition, attention levels, or the specific movies involved. In general, these baseline

patterns argue for the importance of using shifts in looking as the critical dependent measure: individual children and/or trials may show unanticipated sources of bias. Nevertheless, across all types of trials, children did change the way they looked in the predicted directions as a function of syntactic structure during the test phase.

Finally, as the age of the children in this study was just under 2 ½ years, it appears that the link between transitivity and telicity can be forged at least that quickly.

General Discussion—The goal of these experiments was to examine children's acquisition of the link between one particular pair of structures (transitive and intransitive) and one particular pair of meanings (telic and atelic). The results from the two experiments showed that children as young as 29 months old can indeed use this link to generalize a novel verb in these structures to new events: children generalize on the basis of result information (corresponding to a telic interpretation) when a novel verb is in a transitive structure and on the basis of process information (corresponding to an atelic interpretation) when the novel verb is in an intransitive structure. Moreover, children's success is not tied to any one specific type of event, but extends to both causal and directed motion events.

Previous work has established that children can link transitivity to multiple semantic elements, including causality (e.g. Bunger & Lidz 2004, Fisher 2002, Naigles 1990), contact (Naigles & Kako 1993), and event path/manner (Hohenstein et al. 2004). The current work goes beyond these results first and foremost, by testing a new semantic element. Although telicity overlaps in practice with all three of the other semantic dimensions, it is not co-extensive with any of them. More importantly, the events actually used in the previous work focused on causality did not consist of events that corresponded to a telic-atelic distinction. The studies presented here were the first to explicitly test children's ability to link transitivity and telicity with causally oriented events. The path/manner distinction tested in Hohensten et al. (2004) was very similar to the telicity distinction tested here through the directed motion events. However, the children tested in the current Experiment 2 were a full year younger than those tested by Hohenstein et al. Moreover, the current experiments used two different event types - causal and directed motion - and even the younger children were able to succeed with both kinds of events in the same experimental tasks, showing that children can apply a telicity interpretation across different events easily from trial to trial.

Given the current results, in combination with the results of the previous work noted above, we can ask what semantics children have in fact linked to transitivity. Telicity, causality and contact are not reducible to one another conceptually, so the semantic associate of transitivity can not simply be one of these notions. An event can be telic without being causal (e.g. directed motion events) or involving contact (e.g. telling a story); similarly, an event can be causal without being telic (e.g. pushing a cart along) or involving contact (e.g. most instances of indirect causation); and finally, an event can involve contact without being either telic or causal (e.g. tapping on a table). One possibility is that children have simply found syntax-semantics regularities for each of these semantic features independently. If this is the case, then there need be no general meaning associated with transitivity that ties all of these semantic elements together. Support for a position of this kind comes from Casenhiser & Goldberg (2005), who found that children were able to learn novel syntax-semantics pairings after training on only a tiny number of examples. Children may view syntactic constructions akin to the way they view word forms, and allow arbitrary pairings of form and meaning.

This position, however, misses a critical fact, namely that there is in fact a general meaning associated with transitivity that can account for all of the semantic elements associated with it, and moreover, one which is motivated by linguistic theory. One of the foundational

notions of generative grammar (and other kinds of grammars as well) is the idea that logical arguments of a verb should be represented syntactically (cf. Chomsky's Projection principle, 1986a). In other words, transitive sentences (2-argument structures) should describe events with 2 logical participants and intransitive sentences (1-argument structures) should describe events with 1 logical participant. Fisher and colleagues (see Fisher, Hall, Rakowitz & Gleitman 1994, Fisher and Song 2006) have explicitly proposed that children initially link transitivity to just this sort of meaning: the number of syntactic arguments signals of the number of key participants in the event. Knowing the number of key participants in an event is a rather limited piece of semantic information in and of itself, but it is one which can license a variety of highly relevant inferences about the event in question.

Linguistic theory has tried to capture these semantic inferences through analyses of how syntactic positions link to different thematic roles (see Fillmore, 1968; Dowty, 1992; Jackendoff 1990). These analyses note, among other things, that syntactic direct objects (present in transitive, but not intransitive structures) often receive the thematic role of patient, or affected object. This is a role that is intimately connected with notions such as causality (caused elements are affected elements), contact (contacted elements have the core patient property of being acted-upon), and telicity (event boundaries are often measured out by affected objects: e.g., a creation event is bounded by the object that gets created). Transitivity provides logical information about the number of key participants, and regularities in the distribution of thematic roles by syntactic positions provides strong cues to the kinds of semantic relations that are being discussed. One might be tempted to say that transitivity encodes the information about thematic roles directly (that is, transitive sentences denote events with affected objects) but that is unlikely to work. The same linguists mentioned above, as well as others, have long noted that generalizations about thematic roles are plagued by frequent and common exceptions; the relationship between syntactic positions - and by extension, whole syntactic structures - and semantic roles is quite messy. The presence of a syntactic argument may logically imply that this argument has some key role to play in event, but precisely what that role is non-deterministic. The difficulties of this position arise in a limited fashion for causality and contact, but they are quite pronounced in the case of telicity.

As was discussed in the introduction, the number of arguments in a sentence is not directly predictive of the telicity value of a predicate: both transitive and intransitive sentences can be telic, just as both can be atelic. Thus the transitivity of a structure is neither a necessary nor a sufficient condition for determining telicity. Looking just within transitive structures, we find that some direct objects do indeed receive patient/affected object role but nevertheless fail to create the boundary necessary for a telic interpretation: *David ate peanut-butter* is atelic despite the fact that the peanut-butter is very definitely affected by the eating. The reverse case is also true: some direct objects that do not receive the patient/affected object role are in fact able to create a telic boundary: *Sayesha read War and Peace* and *Miley climbed the mountain* are both telic although neither Tolstoy's novel nor the mountain are affected by these events. If transitivity does not directly encode the semantics of telicity then these semantics must be inferred, likely as a by-product of something transitivity does encode, namely that the event with two arguments.

Certainly the children in these experiments were willing to use transitivity as a cue to telicity, even if such a link isn't perfectly warranted by the grammar. Children's motivation for making this inference potentially comes from several sources. The first source is the central tenet of any bootstrapping account: some information is better than none. Transitivity may be a highly imperfect cue to telicity, but it is robust enough to have received ample attention from Linguists; presumably it is therefore robust enough for children to have identified it. The second motivational source comes from the structure of the tasks

themselves. In the tasks used, children were not asked open-ended questions about what perspective they were taking on the sample event; instead, they were given choices corresponding to atelic and telic interpretations. The forced-choice nature of the task dramatically lessens the inferential burden on the child by providing a fairly narrow hypothesis space in which to operate. Note that the hypothesis space wasn't completely reduced to telicity in these tasks. For example, in the Experiment 2 box event (see Figure 3), children were choosing between a result alternative that eliminated the dimension of contact from the sample event's process (the spray paint can never touches the box as the paint roller does) and a process alternative that preserved the contact dimension of the sample event while altering the result. Naigles & Kako (1993) found that children associate transitive sentences with contact semantics, so in this particular item children had to choose between matching on the basis of contact versus telicity. As it happens, the children chose telicity, although in Naigles & Kako 1993, children showed no preference between a contact option and a causal, atelic option.

A final motivational source or children's inferences in these tasks comes from their non-linguistic analysis of events. Just as the structure of the experimental tasks serves to artificially narrow down children's inferential space, children's own cognitive biases may serve to do the same thing in a more natural way. Infants and young toddlers do not analyze events in the world in a totally neutral way, equally open to any of the many possible interpretations one can think of. In fact, infants seem to find the outcomes of events to be particularly important: they preferentially imitate them (as in Carpenter, Call & Tomasello, 2005), preferentially track them in a habituation task (as in Lakusta, Wagner, O'Hearn & Landau 2007), and use them to draw inferences about antecedent processes and environmental constraints (as in Csibra, Biro, Koos & Gergely, 2003). Somewhat older children may find it easy to draw inferences about telicity because they are cognitively primed to analyze events for the presence/absence of distinctive outcomes, that is, the kind of event boundaries that would make an event telic. Indeed, there is evidence that children are eager to find syntactic correlates for telicity. Beyond the transitivity data presented here, recall that in their early production, young children also tend to (wrongly) associate verbal morphemes with different telicity values. Telicity may simply be at the top of children's list for possible semantic inferences.

The data presented here in combination with previous work shows that children are flexible in their interpretation of transitivity, and are able to link a variety of semantic notions to it. Based on the specific meanings involved, there is no one larger meaning that encompasses them all, which suggests that it is not possible to identify a general semantics of transitivity that will cover all the data. However, transitivity does consistently indicate the number of key participants in an event, and it is possible that this piece of information can motivate inferences that get children to the various specific semantic correlates of transitivity. Further support for the idea that the connection is an inferential one is the fact that for telicity, at least, the connection between transitivity (or for that matter, number of key participants) and telicity is non-deterministic; the link that connects them is not going to be a wholly straight-forward one. However, to truly determine if children's ability to link transitivity to specific semantic content such as telicity is mediated by transitivity's role in marking the number of key participants in an event (as opposed to being linked directly to the structure itself, as Casenhiser & Goldberg 2005 might potentially argue) it will be necessary to directly pit the two possibilities against each other. Do children preferentially link a transitive structure to an event with two key participants or to an event that is telic/causal/contact oriented?

The results presented here speak to the fact that telicity is an important semantic category for children and one they readily link to the syntactic structures of transitivity. This link helps children choose a perspective on a scene and facilitates syntactic bootstrapping operations.

From the perspective of language acquisition, therefore, these data add telicity to the list of critical semantic elements that children use to help them navigate the process of early language learning. However, as telicity has such non-deterministic relationship to transitivity in the grammar itself, these data also support the idea that inferential processes are integral to the process of associating structures and semantics. Children can elevate a highly imperfect link to a useful cue because they depend not only on secure grammatical facts but also on secondary grammatical relations (such as common thematic roles associated with a direct object) as well as their own biases in event analyses.

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Appendix A

Complete materials used for Experiment 2.

Causality refers to whether the direct object was causally affected by the event.

Sample Movies	Event Type	Target Sentences intransitive/transitive	Manner Match	Result Match
A bird pushes a ball into a net with a stick	Non-Causal (Directed Motion)	The bird tarked/tarked the net.	A butterfly pushes a ball out of a net with a stick	A boy kicks a ball into a net
A boy hops across the screen, ending on a large X	Non-Causal (Directed Motion)	The boy dracked/dracked the X	A boy hops across the screen, starting at a large X	A boy cartwheels across the screen, ending on a large X
A butterfly covers a box by dripping paint on it	Causal (Change of State)	The butterfly glipped/glipped the box	A bird drips paint beside a box	A boy covers a box by rolling paint onto it
A girl builds a sandcastle by scooping and dumping sand	Causal (Creation)	The girl pilked/pilked the sandcastle	A girl builds a sandcastle magically by lifting her hat	A girl destroys a sandcastle by scooping and dumping sand

Appendix B

Complete materials used for Experiment 3.

In addition, two practice movies were used, contrasting clapping and waving, and jumping and bending over.

Sample Movies	Event Type	Target Sentences intransitive/transitive	Manner Match	Result Match
A girl uses a rake to push a ball into a net	Non-Causal (Directed Motion)	*The girl zibbed/zibbed the net*	A girl uses a rake to push a ball around a net	A girl kicks a ball into the net

Sample Movies	Event Type	Target Sentences intransitive/transitive	Manner Match	Result Match
A girl crawls to a pinwheel	Non-Causal (Directed Motion)	*The girl ricked/ricked the pinwheel*	A girl crawls away from the pinwheel	A girl crab-walks to a pinwheel
A girl uses a roller to cover a box with paint	Causal (Change of State)	*The girl motted/motted the box*	A girl uses the roller on the box, but with no paint	A girl spray-paints the box, covering it with paint
A girl blows up a balloon	Causal (Creation)	*The girl kaded/kaded the balloon*	A girl blows at a full balloon, deflating it	A girl uses a small pump to inflate a balloon

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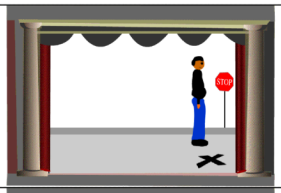
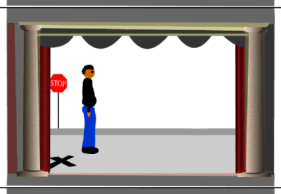
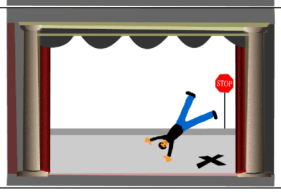
Sample Movie		Target Descriptions intransitive: The boy dracked transitive: The boy dracked the X
Process Match		*Is this boy also dracking/dracking the X, or is he doing something different?*
Result Match		*Is this boy also dracking/dracking the X, or is he doing something different?*

Figure 1.

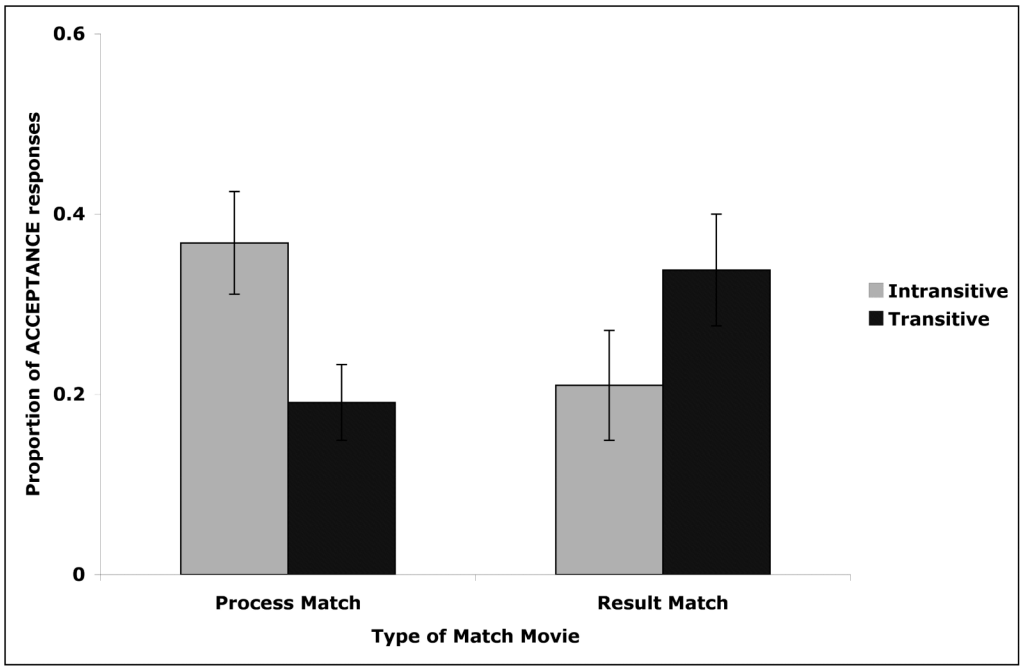


Figure 2.

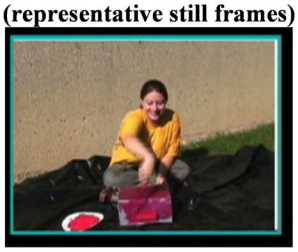
Sample Movie	**Video (representative still frames)**	**Audio Description**
		*See the girl? She motted the box. She motted it. She wants to mott it again. Look! The girl motted it. See, she motted it. She's gonna mott it again. Look! She motted on both sides! She motted it.*
Baseline Phase		*Wow, these are different girls!*
Test Phase		*Let's find the girl who motted the box. See the girl who motted the box? Find the girl who motted it.*

Figure 3.

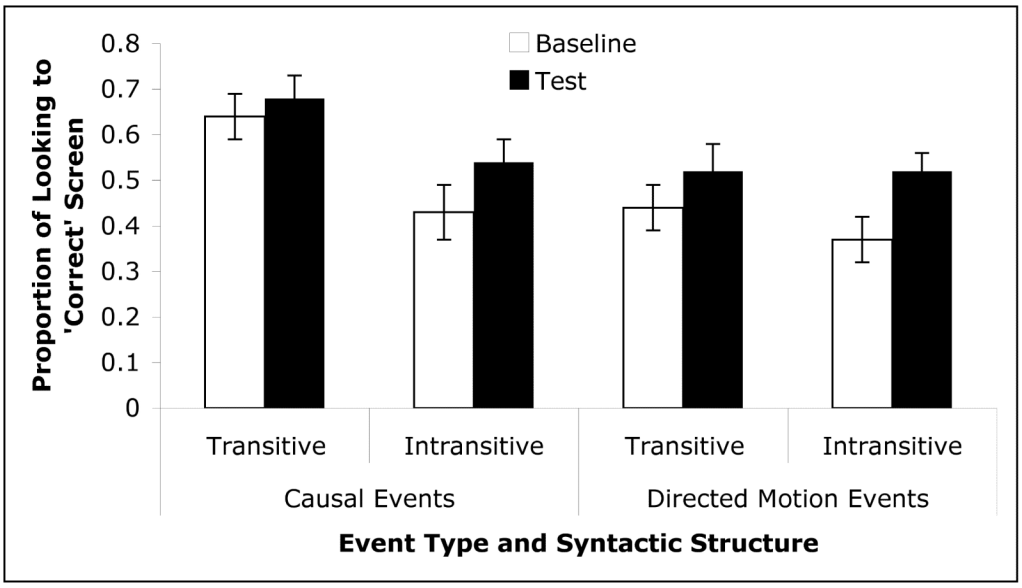


Figure 4.

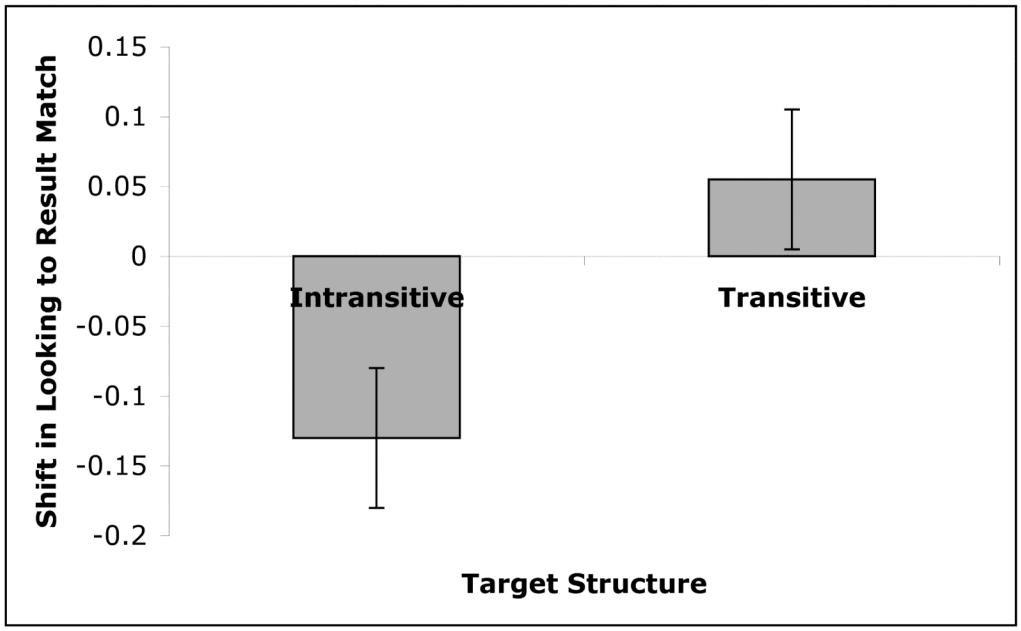


Figure 5.