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Comprehension of Argument Structure and Semantic Roles: Evidence from English-Learning Children and the Forced-Choice Pointing Paradigm

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Abstract

Research using the intermodal preferential looking paradigm (IPLP) has consistently shown that English-learning children aged 2 can associate transitive argument structure with causal events. However, studies using the same methodology investigating 2-year-old children's knowledge of the conjoined agent intransitive and semantic role assignment have reported inconsistent findings. The aim of the present study was to establish at what age English-learning children have verb-general knowledge of both transitive and intransitive argument structure using a new method: the forced-choice pointing paradigm. The results suggest that young 2-year-olds can associate transitive structures with causal (or externally caused) events and can use transitive structure to assign agent and patient roles correctly. However, the children were unable to associate the conjoined agent intransitive with noncausal events until aged 3;4. The results confirm the pattern from previous IPLP studies and indicate that children may develop the ability to comprehend different aspects of argument structure at different ages. The implications for theories of language acquisition and the nature of the language acquisition mechanism are discussed.

Keywords: Verb argument structure; Semantic roles; Form-meaning mapping; Forced-choice pointing paradigm

1. Introduction

When acquiring a language, children must learn not only the meaning of words but also how to combine words into syntactic structures to convey meaning. Mastery of the

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form-meaning mapping system of a language involves the acquisition of several different kinds of knowledge. First, children need to learn which structures they should use to express particular kinds of meaning. For example, in English, the transitive construction is used to express causal meanings. Second, children must learn how to link semantic and syntactic roles in different structures. For example, in the English active transitive, the agent links to the grammatical subject, but in the English passive, the agent links to the object. Third, children must learn the syntactic cues to meaning used by their language. For example, agent–patient relations in English are marked using word order, but, in Turkish, who did what to whom is marked using a system of case marking, allowing the word order to vary while keeping the meaning constant.

Once children have acquired verb-general knowledge of the form-meaning mappings of their language, then they, like adults, can use this knowledge to constrain the meaning of novel verbs. However, the questions of *when* children acquire this knowledge and *whether* children's verb-general knowledge extends to a range of syntactic structures early in development have polarized the field. In this article, we argue that the current literature is still underdetermined with respect to these issues, in part because of constraints imposed by the available methodologies. We therefore use a new method—the forced-choice pointing paradigm (FCPP)—to investigate English-learning children's knowledge of form-meaning mappings, with the specific aim of determining whether children have verb-general knowledge of both transitive and intransitive argument structure early in development.

Evidence from production studies (in which children are required to produce novel verbs in structures in which they have never heard them used) and act-out methods (in which children act out sentences with novel verbs) seem to suggest a gradual, developmental trend between the ages of 2 and 3 years of age, even for children's acquisition of a simple frequent structure like the English transitive (e.g., Abbot-Smith, Lieven, & Tomasello, 2001; Akhtar, 1999; Akhtar & Tomasello, 1997; Dodson & Tomasello, 1998; Olguin & Tomasello, 1993).[1] More specifically, English-learning children under the age of 3 years have been shown to have great difficulty generating grammatical transitives with novel verbs (e.g., producing *Big Bird is gopping the grapes*) when they have never heard the verb used in this structure (e.g., have only heard it in intransitive structures, such as *Big Bird is gopping* or in ungrammatical structures, such as *Big Bird the grapes gopping!*). They are also unable to use word order to correctly act out transitive sentences with novel verbs (e.g., *Make Cookie Monster dack Big Bird*). These results have been cited as evidence in favor of accounts that suggest that children's knowledge of syntactic structure emerges gradually via a process of learning from specific exemplars in the language that they hear and use, with abstraction across verbs predicted not to occur until later in acquisition (e.g., 3 years of age even for frequent structures such as the transitive, see Dodson & Tomasello, 1998).

However, this position has been challenged by research using a different paradigm—the intermodal preferential looking paradigm (IPLP)—which appears to show that children are sensitive to the implications that different syntactic structures have for meaning much earlier in development. The IPLP is based on the assumption that children who are able to interpret an auditory stimulus will look significantly longer at a matching screen than a distracter (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995), and it can be used to test whether very young children can identify the correct referent of a novel verb when the only information provided about the intended referent is the syntactic structure of a spoken sentence. Studies using this paradigm have shown that hearing a transitive sentence, even one with a novel verb (e.g., *The duck is glorping the rabbit*), significantly increases looking times to a causal action (e.g., a duck forcing a rabbit into a bending position) as compared to a non-causal action (a duck and rabbit flexing their own arms) in children as young as 25 months of age (Naigles, 1990). This finding has been replicated with children of 27 months (Naigles & Kako, 1993), 28 months (Yuan & Fisher, 2009), 29 months (Hirsh-Pasek, Golinkoff, & Naigles, 1996) and 30 months of age (Kidd, Bavin, & Rhodes, 2001). In a more recent study, Gertner, Fisher, and Eisengart (2006) also showed that children could use transitive structure to assign agent and patient semantic roles (e.g., assigning the agent role to the rabbit and the patient role to the duck on hearing, *The rabbit is gorping the duck*) correctly by 21 months of age.

The evidence provided by IPLP studies suggests that at least some of young children's difficulties in production and act-out studies can be attributed to task demands, rather than a lack of verb-general knowledge. However, while the IPLP findings indicate that children have verb-general knowledge of argument structure younger than some accounts propose (e.g., Tomasello, 1992), the pattern of results across different IPLP studies is still far from consistent, meaning that the precise nature of this verb-general knowledge is still far from clear. For example, we are aware of only one published study that replicates Gertner et al.'s (2006) finding that young 2-year-olds can use the transitive structure to assign agent and patient roles to the correct participants in a causal event. Dittmar, Abbot-Smith, Lieven, and Tomasello (2008) found that 21-month-old German children were able to demonstrate verb-general understanding of transitive word order in an IPL task. However, children were successful only after receiving a training phase containing the exact same nouns that they would later hear at test used for the same syntactic roles and with the same syntactic marking (as in the original Gertner et al., 2006 study). A second group, trained without the nouns used at test, was unsuccessful. Dittmar et al. (2008) concluded that success on this task relies on the children experiencing a learning task which prepared them for the test, thus throwing doubt on Gertner et al.'s original conclusion that only a fully developed verb-general representation of transitive syntax can explain the children's successful performance.

Attempts to replicate Naigles's (1990) findings have also been mixed. Although there have been successful replications of the finding that young 2-year-olds are able to interpret transitive sentences as referring to causal events (Arunachalam & Waxman, 2010; Hirsh-Pasek, Golinkoff, & Naigles, 1996; Kidd et al., 2001; Naigles & Kako, 1993; Yuan & Fisher, 2009), studies on the English conjoined agent intransitive have yielded inconsistent results. Naigles (1990) found that 25-month-old children interpret novel verbs in conjoined agent intransitive frames (e.g., *The duck and the bunny are gorping*) as referring to non-causal synchronous actions (not causal actions) and Kidd et al. (2001) found a similar effect, although not until 30 months. However, Naigles and Kako (1993) failed to replicate the findings with 27-month-olds and Hirsh-Pasek et al. (1996) reported an unexpected significant preference for the *non*matching scene when children were presented with a ''with intransitive'' (e.g., *Big Bird is glorping with Cookie Monster*). Furthermore, they reported that it was difficult to find an effect even with real verbs.

More recently, in a series of experiments, Yuan and Fisher (2009) used a slightly modified IPLP in which children aged 28 months were exposed to either two-participant transitive or one-participant intransitive dialog prior to the test trial, and then presented with one- and two-participant event scenes.[2] In Study 1, children who were exposed to transitive dialog looked significantly longer at a two-participant event than children exposed to one-participant intransitive dialog. However, the difference in looking time to a one-participant event was not significantly different between the two different dialog conditions. Study 2 replicated the findings and showed a significant effect of dialog in looking times to the two-participant event but a nonsignificant effect of dialog in looking times to the one-participant event. In other words in both experiments, children did not look significantly longer to the one-participant event in the one-participant dialog condition than children in the transitive dialog condition (see Yuan & Fisher, 2009, p. 624, table 3).

Arunachalam and Waxman (2010) also used the dialog method but in a FCPP rather than a preferential looking paradigm. Children aged 2;3 were presented with transitive or conjoined agent intransitive dialog rather than one-participant intransitive dialog. The results indicated that (a) children in the transitive dialog condition were more likely to point to the causative scene than children in the intransitive dialog condition and (b) children in the transitive condition pointed to the matching causal scene significantly more than would be expected by chance. In contrast, children exposed to conjoined agent intransitive dialog did not point to the matching noncausal scene significantly more than would be expected by chance.

In sum, the results from previous studies do not provide conclusive or uncontroversial evidence for adult-like ability across the board. In particular, although there is robust evidence that children aged 2 can associate transitive argument structure with causal events, studies using the same methodology investigating 2-year-old children's knowledge of the conjoined agent intransitive and of semantic role assignment have reported inconsistent findings. This evidence thus leaves two important questions unanswered—(a) Do children develop the ability to comprehend different aspects of argument structure at different ages? and (b) If so, what consequences does this have for the nature of their early knowledge and the pattern of development?

If children develop different aspects of argument structure understanding at different ages, the pattern of acquisition could be highly informative about what form their early knowledge takes. For example, early acquisition of the ability to assign the agent and patient roles in transitives may indicate that the children know that the first-named noun in a sentence tends to refer to the agent of a causal action (see Slobin, 1966). Early acquisition of transitive (but not conjoined agent intransitive) argument structure may indicate that the children know that the number of nouns in a sentence is a reliable cue to the number of semantic roles required by the verb (Lidz, Gleitman, & Gleitman, 2003). While this type of knowledge will allow the child to infer the meaning of some sentence structures (e.g., the transitive), it would not allow them to correctly interpret all sentence structures (e.g., the conjoined agent intransitive). This would rely on further learning and development, with the child's early verb-general knowledge interacting with the language specific environment—the input (see Chang, Dell, & Bock, 2006, for a model of how this might occur).

The aim of this article is to use a new paradigm—the FCPP—to assess English-learning children's early knowledge of argument structure. The FCPP presents the child with two visual scenes and an accompanying sentence, and then requires the child to point to the visual scene that matches the presented sentence. By pointing or gesturing to one of the visual scenes, the child provides an overt behavioral response, which can be easily coded. Although the requirement to provide an overt response has the disadvantage that it introduces additional task demands, it has the important advantage that it provides a much more direct, and hence less noisy, measure of children's knowledge than the IPLP. It also places fewer demands on the children than production and other comprehension methods, meaning that the child's ability to demonstrate her knowledge will be much less likely to be masked by task demands. The FCPP has already been used successfully to measure comprehension of argument structure in children aged 2;6 and above (see, e.g., Fernandes, Marcus, Di Nubila, & Vouloumanos, 2006; Fisher, 1996; Rowland & Noble, 2011). In this study, we modified the procedure to make it suitable for children at the critical age for the investigation of children's knowledge of transitive and intransitive argument structure (i.e., 2 years of age).

In addition to providing more direct measures of children's performance, the FCPP has two further advantages. First, it allows for the investigation of the nature of children's knowledge of argument structure across a much wider age range. Thus, unlike the IPLP (which is difficult to use successfully with older children), the FCPP can be used with children of any age (and, in fact, even with adults), which allows for the investigation of developmental differences. Second, since the FCPP is easier to administer than the IPLP, it can be readily used to compare the performance of the same children on a number of different tasks. This within-subjects approach makes it possible to investigate whether children have verb-general knowledge of a range of different structures at a given point in development. Additionally, this approach makes it possible to tease apart whether, if children fail to identify the correct referent, this failure is because of task demands or a lack of relevant linguistic knowledge. For example, while poor performance on the task across a range of structures is consistent with an explanation in terms of high task demands, failure on one structure but not another suggests a lack of knowledge of how that particular structure constrains meaning (cf. Abbot-Smith, Lieven, & Tomasello, 2008 who used a similar strategy, albeit cross-linguistically, to distinguish between lack of knowledge and task demand explanations).

The primary aim of this study was to establish at what age English-learning children have verb-general knowledge of both transitive and conjoined agent intransitive argument structure using a new method: the FCPP. We used a mixed design to investigate three aspects of children's knowledge of syntactic structure. First, we investigated whether young children at four different ages (2;3, 2;7, 3;4, and 4;3) could use the syntactic structure of English transitives (e.g., *The bunny is glorping the duck*) to infer that a novel verb must refer to a causal action (with one referent acting on another), correctly rejecting a noncausal scene (in which two referents acted independently side by side, cf. Naigles, 1990). Second, we investigated whether the same children could use the structure of a conjoined agent intransitive (e.g., *The bunny and the duck are glorping*) to identify the referent of a novel verb as a noncausal (or internally caused) action (cf. Naigles, 1990). Third, we investigated whether the same children could use the structure of the transitive to identify agent and patient semantic roles correctly (cf. Gertner et al., 2006). In sum, we used the FCPP to test, developmentally, three critical aspects of children's knowledge of syntactic structure that have until recently only been demonstrated in children as young as 2 years using the IPLP.

2. Method

2.1. Participants

Twenty-nine 2-year-olds, twenty-one 2½-year-olds, twenty-three 3-year-olds, and twenty 4-year-olds participated in a language comprehension task using the FCPP. All were native speakers of British English who had no language difficulties. A further 11 participants were excluded because of failure to complete the task (7), failure to pass the screening trials (3), and always pointing left (1). The final sample comprised twenty-one 2-year-olds (mean age: 2;3; SD: 1.84 months; range: 1;11–2;4), twenty 2½-year-olds (mean age: 2;7; SD: 1.70 months; range: 2;5–2;10), twenty-one 3-year-olds (mean age: 3;4; SD: 4.10 months; range: 2;11–3;10), and twenty 4-year-olds (mean age: 4:3; SD: 3.16 months; range: 3;11–4;10).

2.2. Design

The FCPP is a comprehension method based on pointing, similar to the method used by Fisher (2002). The study comprised two types of tasks: an argument structure task and a semantic roles task. The argument structure task employed a 4 × 2 mixed design with two independent variables: Age, with four levels (2-year-olds/2½-year-olds/3-year-olds/4-year-olds), and transitivity, with two levels (intransitive argument structure/transitive argument structure). The semantic roles task had a between subjects design with one independent variable: Age, with four levels (2-year-olds/2½-year-olds/3-year-olds/4-year-olds). The dependent variable for both tasks was the number of correct points to the target screen (that matched the spoken sentence). In total, each participant completed three screening trials, two real verb practice trials, and eight test trials. Four of the trials tested knowledge of conjoined agent intransitive and transitive argument structure (the argument structure task) and four of the trials measured knowledge of semantic roles (the semantic roles task). In the argument structure task, the maximum possible score was 2 for the transitive argument structure trials and 2 for the intransitive argument structure trials. In the semantic roles task, the maximum score was 4.

2.3. Materials

2.3.1. Visual stimuli

The visual stimuli consisted of cartoon animations of ducks, rabbits, sheep, teddies, and frogs performing novel actions. These were created in Anime Studio Pro and exported as movies to QuickTime. The movies were presented on a laptop and showed two animations side by side, one of which was the target scene. The movies lasted 12 s during which the actions were presented twice. In the argument structure task, one scene showed a causal action (e.g., a rabbit acting on a duck) and the other scene showed a noncausal action (e.g., both the rabbit and the duck performing the same action independently). In the semantic roles task, one scene showed a causal action with the teddy as the agent and the other scene showed a different causal action with the frog as the agent. Table 1 gives details of the novel action pairs.

2.3.2. Audio stimuli

A female native British English speaker recorded the audio stimuli, which were edited in Audacity and exported into the QuickTime movies. A toy rabbit with speakers hidden inside was used to play the audio stimuli to create the effect of the rabbit speaking. In the argument structure task, children heard two transitive sentences (e.g., *The duck is daxing the bunny*) and two conjoined agent intransitive sentences (e.g., *The duck and the bunny are blicking*). In line with previous studies, we used conjoined agent intransitives to ensure that the number of participants on both screens (and the number of characters mentioned in each sentence) always remained the same. This ensures that any observed effects can be attributed to the child's understanding of the syntax rather than to her mapping the number of entities on the screen to the number of characters mentioned in the sentence. The four novel verbs used in the argument structure trials were *dax*, *blick*, *glorp*, and *krad*. In the semantic roles trials, the children heard four simple reversible transitive sentences (e.g., *The teddy is wugging the frog*). The four novel verbs used in the semantic roles test trials were *wug*, *klimp*, *meek*, and

Table 1
Descriptions of the target and foil actions for the test stimuli and associated novel verbs

Argument Structure			Agent and Patient Roles		
	Left Screen	Right Screen		Left Screen	Right Screen
Blick	The bunny and duck circle one of their arms	The duck pushes the bunny into a squat position	Jemm	The teddy rocks the frog by his feet	The frog lifts the teddy up into the air and back down again
Dax	The duck and the bunny flex one of their arms out in front of them	The duck bends the bunny forward by pushing the bunny's head	Wug	The teddy makes the frog hop by pulling the frog's foot	The frog makes the teddy squat by pushing down on the teddy's head
Glorp	The duck and the bunny cover one of their eyes with their hand	The bunny tips the duck forward by pushing on the duck's bottom	Klimp	The frog rocks the teddy back and forwards by his head	The teddy pushes the frog on the trolley
Krad	The bunny and the duck swing one of their legs	The bunny lifts the duck up into the air and back down again	Meek	The frog rocks the teddy back and forward on a chair	The teddy lifts the frog's leg and tips the frog backwards

jemm. In each test trial, the novel verb was presented three times in three different sentence structures. First, the novel verb was presented in the future ''going to'' tense (e.g., *The duck is gonna dax the bunny*); then the children heard the present tense test sentence (e.g., *The duck is daxing the bunny*); and finally the test sentence was repeated with the addition of the pointing command (e.g., *Point to where the duck is daxing the bunny*).

2.4. Counterbalancing

The order of the testing block was counterbalanced (semantic roles test trials first vs. argument structure test trials first). The visual stimuli for the semantic roles block were counterbalanced for order of novel verb and target animal. Target side was balanced within each condition. The visual stimuli for the argument structure block were counterbalanced for order of verbs, and order of conjoined agent intransitive and transitive test trials. Target side was counterbalanced within each condition. Participants were randomly assigned to one of eight counterbalance conditions.

2.5. Procedure

Testing took place in the Child Language Study Centre at the University of Liverpool or in a quiet room in the children's nursery. All children were given the option of being accompanied by a familiar adult who sat to the side of the laptop and interacted minimally with the child. During all trials, the experimenter sat beside the child. Once the trial had started the experimenter focused his or her gaze on the child, not the scenes, so that the child could not use the experimenter's eye gaze to locate the correct scene. The order of the trials was as follows: Character identification > Screening trials > Real verb practice trials > Test trials.

2.5.1. Character identification

The investigator told the child they were going to play a pointing game. The child was shown a still picture of the five characters (duck, teddy, frog, rabbit, sheep) and asked to point to each one in turn (e.g., *Point to the frog!*). All children correctly identified all characters.

2.5.2. Screening

Next each child completed three screening trials in a random order. These trials consisted of an animal performing an action in one scene and the same animal standing still in the other scene. The accompanying audio was a simple intransitive sentence. For example: The left-hand image showed a duck standing still and the right-hand animation showed the duck waving one of its arms. The accompanying audio was *The duck is gradding. Point to where the duck is gradding!*

The investigator informed the child that there were now two animations to watch but that Flopsy the rabbit was only going to talk about one of the pictures. The child was told s/he must listen to what Flopsy said and watch the pictures and then point to the matching picture. If the child did not point during the movie, the investigator prompted her/him by asking, *Which picture?* or *Can you point to the picture Flopsy was talking about?* The movie was repeated if the child still failed to point. If the child still did not point, the investigator asked the child to stick a sticker on the correct picture and the movie was run again. If the child pointed to the incorrect picture in the screening trials, s/he was praised for pointing but told that the other picture was actually the matching scene and given another opportunity to see the movie. All participants then pointed to the correct picture.

The child's first accurate point was always taken as their response unless s/he changed his/her mind and expressed this clearly. If the child's point was ambiguous (e.g., s/he pointed to the center of the two animations or pointed to both animations), the trial was rerun and the child was reminded to point to only one of the pictures. Only four children (all in the 2;0 age group) had to be reminded to point to only one picture. This procedure was repeated for all three screening trials.

As the aim of the study was to investigate whether children could interpret conjoined agent intransitive and transitive sentences, it was necessary to exclude participants who could not pass a simple screening test which required them to point to a figure that was performing an action. To pass the screening trials, the children had to get two or more of the three screening trials correct.

2.5.3. Real verb practice trials

These trials were included to give the child further practice on the task before the test trials began. The procedure for these trials was the same as the screening trials, with two changes. First, there were now two animals present in each animation and second, to avoid further training on intransitive sentences, transitive sentences were used. The movie always showed an animal performing an action in one scene and the same animal performing a different action in the other scene. The movies were accompanied by a simple transitive sentence containing a real verb. For example, the left-hand animation showed a teddy tickling a frog and the right-hand animation showed a teddy feeding a frog. The accompanying audio for half of the participants was *The teddy is tickling the frog! Point to where the teddy is tickling the frog!* and for the other half was *The teddy is feeding the frog! Point to where the teddy is feeding the frog!* As the agent was the same animal in both scenes and the audio contained a real verb, these trials were a test of the child's real verb knowledge. Each child completed two real verb practice trials in a random order.

2.5.4. Test trials

The test trials followed the real verb practice trials. Each participant completed eight novel verb test trials; a block of four semantic roles trials and a block of four argument structure trials. Within the argument structure trials, each child completed two transitive and two conjoined agent intransitive test trials.

The argument structure test trials consisted of one animation showing one animal performing a causal action on another animal and one animation of the same animals both performing a noncausal action. Either a simple transitive sentence or a conjoined agent intransitive accompanied the movies. For example, the left-hand animation showed a noncausal action and the right-hand animation showed a causal action and the accompanying audio was either *The duck and the bunny are blicking! Point to where the duck and the bunny are blicking!* or *The duck is blicking the bunny! Point to where the duck is blicking the bunny!*

The semantic role test trials consisted of one animation showing one animal as the agent of a causal action and one animation showing the other animal as the agent of a causal action. The animation was accompanied by a simple reversible transitive sentence. For example, the left-hand animation showed a causal action with teddy as the agent, the right-hand animation showed a causal action with the frog as the agent, and the accompanying audio was either *The frog is jemming the teddy! Point to where the frog is jemming the teddy!* or *The teddy is jemming the frog! Point to where the teddy is jemming the frog!*

The procedure for the test trials was identical to that for the real verb practice trials except the child was not corrected if s⁄he pointed to the incorrect picture. The child was instead praised for pointing regardless of whether s⁄he pointed to the correct picture. Fig. 1 illustrates the stimuli and sequence of events.

Fig. 1. Example stimuli and sequence of trials.

2.6. Coding

The trials were coded online and the investigator recorded the child's first point in all of the trials as correct or incorrect. An additional investigator was present for 13% of the children tested and also coded the children's responses online. Inter-rater reliability was 100%.

3. Results

All analyses were conducted on the 82 children who had passed the screening trials. The first analysis investigated performance on the screening and real verb practice trials to explore whether there were any overall age differences in performance that could be attributed simply to the difficulty of the pointing task. Table 2 shows the mean number of correct points to the target screen in the training and screening trials. A one-way ANOVA was run, with age (2;3, 2;7, 3;4, 4;3) as the independent variable and mean rate of pointing to the matching scene in the screening and real verb practice trials as the dependent variable. Although the means show that performance improved slightly with age, there was no main effect of age, $F(3, 78) = 1.241$, $p = .301$, indicating that there was no significant difference in performance on the screening and real verb practice trials between the four age groups. A series of one-sample t-tests also established that the children at all ages were pointing to the matching scene significantly more than would be expected by chance (all ps $\leq .001$). The results indicated that children at all ages were aware of what was required of them in the task and were able to use their knowledge of real verbs to locate the matching scene in the real verb trials. In other words, all age groups understood the requirements of the pointing task and were able to produce sensible, correct responses.

Analysis 2 investigated whether there were developmental differences in performance across the three different tasks; the transitive argument structure test trials, the intransitive argument structure test trials, and the semantic roles test trials. Table 3 shows the mean number of correct points for each test trial type and for each age group.

As there were unequal numbers of each test trial type (transitive argument structure test trials = 2, intransitive argument structure test trials = 2, and semantic roles test trials = 4), the data were proportionalized to allow comparison across all three test trial types.[3] A mixed-effect model was run with age in months (23–58 months), task type (argument

Table 2
Mean number of correct points to target screen (SD) in the screening and training trials

Age Group	Mean	SD	t	p
Screening trials and training trials (number of trials = 5)				
2;3	4.15	0.85	8.82	.001
2;7	4.25	0.85	9.20	.001
3;4	4.43	0.68	13.07	.001
4;3	4.55	0.51	17.96	.001

Table 3
Mean number of correct points to the target screen (SD) for each test trial type for each age group

	Age			
	2;3	2;7	3;4	4;3
Argument structure task				
Transitives (two trials)	1.62 (0.67)	1.60 (0.60)	1.57 (0.75)	1.75 (0.55)
Intransitives (two trials)	0.86 (0.79)	1.10 (0.79)	1.38 (0.74)	1.40 (0.68)
Semantic roles task (four trials)	2.67 (0.66)	3.10 (0.72)	2.71 (0.96)	2.95 (1.05)

structure vs. semantic roles)[4] and transitivity (transitive vs. intransitive)[5] as fixed effects, and subject as a random effect. We used the empirical logit as the predicted variable (= log[(points to target + 0.5)/(points to foil + 0.5)]) to map the data into the range of the real numbers.

The model showed that transitivity significantly predicted performance on test trials: participants performed better on the test trials with transitive argument structure than the test trials with intransitive argument structure, $\beta = 1.78$ (SE = 0.63), $t = 2.82$, $p = .005$. Task type did not significantly predict performance on test trials: participants performed equally on the argument structure test trials and the semantic roles test trials, $\beta = 0.20$ (SE = 0.63), $t = 0.31$ $p = .73$. The model showed a nonsignificant trend for age to predict performance on the test trials: older participants tended to perform better on all test trials types than younger participants, $\beta = 0.03$ (SE = 0.02), $t = 1.71$ $p = .09$. The model showed no interaction between age and task type: participants of all ages performed equally on the argument structure test trials and the semantic roles test trials, $\beta = -0.01$ (SE = 0.02), $t = -0.05$, $p = .95$. The model, however, showed a near significant interaction between age and transitivity: $\beta = -0.03$ (SE = 0.02), $t = -1.76$, $p = .076$.

To investigate the main effect of transitivity and the near significant interaction between age and transitivity, a simple regression model was run for each test trial type (intransitive argument structure, transitive argument structure, and semantic roles) with age in months (23–58 months) as the fixed effect and empirical logit as the predicted variable (points to the target + 0.5/points to the foil + 0.5). Age did not significantly predict performance on the transitive argument structure trials, $\beta = 0.004$ (SE = 0.01), $t = 0.40$, $p = .69$, or on the semantic roles trials, $\beta = 0.005$ (SE = 0.01), $t = 0.53$, $p = .60$. In other words, children of all ages performed equally well on the transitive argument structure and semantic roles test trials. Age, however, was a significant predictor of performance on the intransitive argument structure trials, $\beta = 0.03$ (SE = 0.01), $t = 2.54$, $p = .01$. In other words, older children performed better on the intransitive argument structure trials than younger children.

To establish in which age groups and on which type of test trials children were able to interpret the sentences correctly, analysis 3 investigated whether their performance was significantly different to the performance we would expect by chance.[6] We used a series of one-sample *t*-tests with mean rate of pointing to the matching scene as the dependent variable and chance set at 50% (this is a similar to the analysis used by Gertner et al., 2006).

The analysis revealed that children in all age groups pointed to the matching scene significantly more than would be expected by chance in the semantic roles test trials (all *p*s ≤ .003, two-tailed) and in the transitive argument structure test trials (all *p*s ≤ .002, two-tailed). In contrast, only children in the oldest two age groups pointed to the matching scene significantly more often than chance in the intransitive argument structure test trials (3-year-olds: $p = .03$; 4-year-olds $p = .02$, all other *p*s = n.s., two-tailed).[7] In sum, both 3- and 4-year-olds were able to assign the correct meaning to the novel verb based on the structure of transitive and intransitive constructions. Both 3- and 4-year-olds were also able to assign semantic roles correctly based on the syntactic structure of the transitive. Both 2- and 2½-year-olds were able to assign the correct meaning to the novel verb based on the transitive structure, and were also able to assign semantic roles correctly. However, neither 2- nor 2½-year-olds were able to interpret the novel verb correctly based on the conjoined agent intransitive structure.

4. Discussion

The primary aim of this study was to establish at what age English-learning children can demonstrate verb-general knowledge of both transitive and intransitive argument structure using a new method: the FCPP. The study used a mixed subjects design to investigate three critical aspects of children's knowledge of syntactic structure. There were two main findings. First, children as young as 2;3 were able to associate transitive argument structure with causal events and could use transitive argument structure to assign agent and patient roles correctly. However, second, children were unable to associate the structure of conjoined agent intransitives with noncausal events until 3;4.

Our results are the first to show that English-learning children as young as 2;3 have verb-general knowledge of two aspects of transitive syntax that is robust enough to support an overt behavioral response. The results extend and confirm the IPLP findings by showing that children have sufficient verb-general knowledge early in development to allow them to infer the meaning of transitive syntax correctly. The findings, therefore, contradict those of previous studies using production methodologies (e.g., Akhtar & Tomasello, 1997; Dodson & Tomasello, 1998; Olguin & Tomasello, 1993), which also require an overt behavioral response, but have tended to report that children aged 2 years do not have verb-general knowledge of transitive argument structure. These findings, in conjunction with previous IPLP findings (Gertner et al., 2006; Naigles, 1990), provide further evidence that act-out and production methodologies may underestimate young children's knowledge of syntactic structure.

Our results also confirm that there is a developmental asynchrony in the acquisition of verb-general knowledge of transitive and conjoined agent intransitive argument structure.[8] By using the FCPP, it was possible to test across a much wider age range than in previous IPLP studies which allowed us to show that children's verb-general knowledge of transitive argument structure is initially better than their knowledge of the conjoined agent intransitive.[9] In other words, our results suggest that children may develop the ability to comprehend different aspects of argument structure at different ages. We suggest that this pattern of results indicates that English-learning children's verb-general knowledge of transitive and intransitive argument structure is continuing to develop between 2 and 3 years of age. This argument is made on the basis that, if children have fully developed verb-general knowledge of argument structure, their verb-general knowledge should not be restricted to the transitive, but should extend to all structures.

Given this, what consequences do our results have for the nature of children's early knowledge and the pattern of development? One possibility is that the asynchrony seen in the acquisition of transitive and intransitive argument structure is because of the fact that intransitives are not necessarily noncausal but can be interpreted as referring to causal actions. For example, in our task, the younger children may have thought the conjoined agent intransitive described the causal event in terms of ''fighting'' or ''playing'' (*The bunny and the duck are glorping [playing]*). To succeed on the intransitive task the participants needed to realize that the preferred interpretation of the conjoined agent intransitive sentence was noncausal. In contrast, to succeed on the transitive task, the child simply had to interpret the grammar correctly—no such additional inference was needed, as the transitive sentence could not have plausibly related to the noncausal scene. However, while this explanation could explain the asynchrony in the acquisition of the transitive and intransitive, it does not provide a direct explanation for the developmental pattern in the acquisition of the conjoined agent intransitive. It is unclear, on this account, why the older children associated the conjoined agent intransitive with the noncausal scene but the younger children did not.

A related possibility, which could account for the developmental asynchrony, is that older and younger children make different assumptions about the motivation behind the task. Older children may be aware that while both the causal and the noncausal scenes are plausible interpretations of the conjoined agent intransitive if the speaker had wanted to describe the causal scene they would have used a transitive. On this basis the older, but not younger, children would therefore choose the noncausal scene when presented with a conjoined agent intransitive. Although this may account for the developmental asynchrony, we are not aware of any evidence that this type of sophisticated intention-reasoning develops between 2;6 and 3 years. Further research would be needed to assess this possibility.

A second possibility that can account for the full pattern of results is that the children's early ability with transitives can be attributed to them paying attention to very specific cues to meaning present in the surface structure of sentences. There are many such cues, all of which could be informing the child's choice of scene (e.g., number of nouns, position of agent with respect to verb, position of patient with respect to verb or perhaps using the second noun as a patient strategy or a first noun as agent strategy). Two of the most promising explanations focus on two of these cues; the relationship between the number of nouns and semantic roles in a transitive sentence and the role that the first-named noun in a transitive sentence performs. In both explanations, the child is assumed to have a verb-general bias to attend to an aspect of the surface structure of sentences early in development. This bias interacts with the child's exposure to her language-specific environment to result in fully developed verb-general knowledge of argument structure, but only later in development.

According to the first explanation, early in development the child has verb-general knowledge in the form of a bias to treat each noun phrase as a distinct semantic role (Fisher, 1994, 1996, 2002; Lee & Naigles, 2008; see Lidz et al., 2003 for a similar account). This bias to attend to the number of nouns in a sentence allows the child to interpret transitive and intransitive sentences differently by assigning a distinct semantic role to each noun in the sentence. It, therefore, allows the child to infer the meaning of sentences in which the number of nouns and semantic roles are aligned. However, it also leads to errors in the interpretation of sentences in which the number of nouns and semantic roles are not aligned, such as the conjoined agent intransitive. In the conjoined agent intransitive, there are two nouns (e.g., the bunny and the duck in; *the bunny and the duck are glorping*) but only one semantic role (the conjoined agent). As the bias leads the child to assign a distinct semantic role to each noun in a sentence, the child is predicted to associate the conjoined agent intransitive with the causal scene in which there are two semantic roles (agent and patient).

There is already evidence from a range of methodologies that children as young as 28 months use the number of nouns in a sentence as a cue to its semantic predicate argument structure (Fisher, 1994, 1996, 2002). In addition, there is also some evidence that sensitivity to this cue results in errors when interpreting conjoined agent intransitives. Gertner and Fisher (2006) found that children aged 21 months interpreted conjoined agent intransitives as transitives. To overcome these errors, the child must at some point develop more sophisticated syntactic representations which allow the correct interpretation of all sentences structures. According to this explanation, to do this the child must add new features to his or her syntactic representations. These additional features presumably come from the input and could include any aspect of the surface structure that the child is sensitive to, such as noun and verb phrase morphological features and word order features (Connor, Gertner, Fisher, & Roth, 2008). For example, the word order cue of verb position would allow the child to distinguish between transitive argument structure in which the verb occupies a sentence medial position and conjoined agent intransitive argument structure in which the verb occupies a sentence final position. This demonstrates how early verb-general biases may interact with a role for learning from the input to result in fully developed knowledge of argument structure. Further investigation and explanation is needed to determine what the critical features are and how the child incorporates them from the input and uses them to refine his or her early verb-general knowledge.

A second explanation for the asymmetry between the transitive and intransitive findings is that, early in development, the child has a verb-general tendency to treat the first-named noun as the agent of a causal action, perhaps as an innate bias or perhaps because of the presence in the input of a large number of constructions in which the first-named noun maps to the causative agent (e.g., the transitives, datives, etc.). Children with this bias would be able to correctly interpret many structures in which the first-named noun is a causal agent. However, they would also incorrectly interpret structures in which the first-named noun is not a causal agent, structures like the conjoined agent intransitive. Only later in development, once the child has more linguistic experience, especially of utterances in which the first noun is not the agent, is the bias revised and overridden to allow the child to correctly interpret all sentence structures.

Chang et al. (2006) have shown how this bias could emerge and develop from the input. Chang et al. used a dual route connectionist network that incorporated a meaning system (for encoding concepts and thematic roles) and a sequencing system (a simple recurrent network that learned to predict the next word in a sentence), to successfully model the asymmetry between the acquisition of transitive and intransitive argument structure found in this study. Chang et al.'s connectionist simulation failed at first to recognize the ''with'' intransitive (e.g., the bunny is glorping with the teddy) as referring to a noncausal action, succeeding only later in the learning process. The failure in the first stage of learning was caused by a bias to treat first-named nouns as agents of causal actions, learned because most utterances correspond to this pattern. As the model was exposed to more utterances, it began to learn from the more infrequent constructions in its input (e.g., passives and intransitives) that the first-named noun is not always the agent of a causal action, which resulted in correct performance.

An additional advantage of Chang et al.'s model is that, by building in a developmental component, the model can account not only for the pattern of results from transitive and intransitive comprehension studies but also the asymmetry in results from production and comprehension studies. The model succeeded in the IPLP task at an earlier stage of learning than in the production task solely because of the level of knowledge required to succeed in each task. To succeed on the production task, the model had to make a series of correct predictions about what word should come next in the sentence; any error at any point produced an incorrect utterance. In contrast, to succeed on the preferential looking task, the model only needed to make more correct decisions than incorrect decisions (i.e., to have a slight preference for the sentence that matched the scene). Thus, the model could use immature knowledge to successfully make a choice between two interpretations as in a preferential looking task, but not to produce full transitives in a production task. It is important to note that at any given time point, what the model knows when performing these tasks is exactly the same, only the knowledge needed for successful performance on the two tasks is different.

To summarize, both proposed biases could explain the pattern of results in this study and previous IPLP findings. While the explanations suggest different biases as the cause of the asynchrony in findings between the transitive and the conjoined agent intransitive, both share a common developmental perspective. Both accounts demonstrate how early verb-general biases may interact with input-driven learning to result in fully developed knowledge of argument structure. The biases in both explanations represent verb-general knowledge of argument structure, but this knowledge is not assumed to be adult-like. Instead, the biases represent sensitivities to particular cues to meaning present in the surface structure of certain constructions. Cross-linguistic work (cf. Chang, 2009) will make it possible to determine whether children learning other languages have the same or different biases to English-learning children and how these biases interact with the language specific environment to develop in each language. Therefore, the issue that faces the field is to establish which cues children are sensitive to in different languages and to chart how these sensitivities change during development.

In conclusion, this study found evidence that young English-learning 2-year-olds can associate transitive structures with causal (or externally caused) events and can use transitive structure to assign agent and patient roles correctly. However, the same children were unable to associate the conjoined agent intransitive with noncausal events until aged 3;4. The results confirm that young 2-year-old English-learning children have some form of verb-general knowledge and are learning the form-function mappings of English from a very early age. However, the more interesting issues concern what type of knowledge underlies these abilities and, in particular, what cues, present in the surface structure of the sentences, children are using to interpret sentences correctly. Consequently, the question for future research is not whether children have verb-general knowledge but what kind of verb-general knowledge they have and what cues they are using to parse sentences at different stages of development.

Finally, we have demonstrated that the FCPP is a suitable tool for investigating children's understanding of form-meaning mappings across a range of different structures and across a range of different ages. The FCPP made it possible to provide converging evidence from a measure other than the IPLP that young 2-year-olds have verb-general knowledge of the transitive, and to identify a developmental asynchrony in the acquisition of transitive and intransitive argument structure. These methodological factors make the FCPP a valuable tool, allowing us to go beyond simply establishing at what age children are sensitive to the constraints of argument structure, and allowing us to investigate what cues to meaning children are sensitive to and how their sentence interpretation strategies may change throughout development.

Notes

1. Although see Budwig, Narasimhan, and Srivastava (2006), who suggest these abilities may emerge earlier in children learning other languages.
2. The results for the intransitive are a little hard to interpret as raw looking time to the two-participant event and to the one-participant event had to be analyzed because of methodological reasons rather than the more conventional single measure of proportion of looking time to one event out of total looking time to both events.
3. To ensure that there was no difference in performance between the first two and last two trials in the semantic roles task, we ran a paired sample *t*-test with mean number of points to the matching scene as the dependent variable. There was no significant difference between performance on the first two trials and the second two trials; $t(82) = -0.867$, $p = .39$. For this reason, all four trials were used in the analysis of the semantic roles task.
4. For the task variable, the intransitive and transitive argument structure test trials were coded as similar (i.e., argument structure test trials) and the semantic roles test trials were coded as dissimilar to the argument structure test trials (i.e., semantic roles test trials). For the transitivity variable, the transitive argument structure test trials and the semantic roles test trials were coded as similar (i.e., transitive) and the intransitive argument structure test trials were coded as dissimilar to the transitive argument structure test trials and the semantic roles test trials (i.e., intransitive).

5. The transitive argument structure task and the semantic roles task were coded as transitive, and the intransitive argument structure task was coded as intransitive.
6. In response to a reviewer comment, an additional set of analyses were run using a different dependent variable to investigate whether the younger children's lack of tendency to associate the conjoined agent intransitive structure with a noncausal meaning was because of a bias to attend to and thus choose the causal event either as a baseline bias, or because of the less constraining nature of the conjoined agent intransitive. For the conjoined agent intransitive test trials, the dependent variable was recoded as mean rate of pointing to the causal scene. A two-way ANOVA was run with, age (2;3, 2;7, 3;4, 4;3) and transitivity (transitive argument structure test trials vs. intransitive argument structure test trials) as the independent variables and mean rate of pointing to the causal scene as the dependent variable. Recoding the dependent variable as the mean rate of pointing to the causal scene had no effect on the pattern of results seen in the main analyses. There was a main effect of transitivity, $F(1, 78) = 84.30$, $p = .001$, children pointed to the causal scene significantly more in the transitive test trials than in the intransitive test trials. There was no main effect of age, $F(3, 78) = 0.94$, $p = .43$, but there was a significant interaction between age and transitivity, $F(3, 78) = 2.71$, $p = .05$. Pairwise comparisons revealed that in the transitive argument structure test trials, there was no significant difference in the rate of pointing to the matching causal scene between any of the age groups. In contrast, in the intransitive test trials, children in the oldest two age groups pointed to the nonmatching causal scene significantly less than children in the youngest age group (2;3—mean: 1.14, SE: 0.24; 3;4—mean: 0.62, SE:0.23, $p = .027$; 4;3—mean: 0.60, SE: 0.24, $p = .024$). The mean rate of pointing to the causal scene in the youngest two age groups on the intransitive test trials was close to chance (chance = 1; 2;3, mean: 1.14, SD: 0.79; 2;7, mean: 0.90, SD:0.79). A paired sample *t*-test was run for each age group with argument structure test trial type as the independent variable (transitive vs. intransitive) and mean rate of pointing to the causal scene as the dependent variable. The analysis revealed that children in all age groups pointed the causal scene significantly more in the transitive task than in the intransitive task (all ps $\leq .004$, two-tailed). Our interpretation of these analyses is that children did not have a bias for the causal scene. However, a baseline condition should be included in future studies to be certain that children do not have an intrinsic bias for either visual scene.
7. If the level of significance was changed to .02 to compensate for the number of tests, the results would be identical except that the 3-year-olds would now no longer pass the intransitive task. We have chosen not to change the p-value as we are reporting two-tailed, not one-tailed, effects.
8. Conjoined agent intransitives were used in this study for methodological reasons. It is important to note that children may learn other kinds of intransitives earlier and the current study relates specifically to the acquisition of the conjoined agent intransitive. For example, in line with research which claims children learn patient subjects earlier than actor subjects, children may acquire unaccusative intransitives in which the patient is promoted to subject position (*It drives easily, It cleans quickly*) earlier than

conjoined agent intransitives (see Budwig, Stein, and O'Brien (2001), for a review of nonagent subjects in early child language).

9. To account for instances when children do not display knowledge, which is hypothesized to be innate, early abstraction accounts often cite task demands or performance limitations as an explanation. However, the within-subjects design of this study allows us to rule out this possible explanation for the pattern of results. The task demands were equal between all tasks with the only difference between the tasks being the linguistic material presented. Only poor performance across all three structures by the younger children would have been consistent with an explanation in terms of task demands. As the children failed on one structure but not the other two, this suggests a lack of linguistic knowledge (cf. Abbot-Smith et al., 2008).

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