2

THE COGNITIVE UNDERPINNINGS OF RELATIVE CLAUSE COMPREHENSION IN CHILDREN

Susan Goldin-Meadow and Annette Karmiloff-Smith

I first met Annette Karmiloff-Smith in 1969 when we were both students at the University of Geneva. It was a life-changing time for us. Annette hadn't yet decided to commit to studying psychology – she had been a simultaneous interpreter at the UN in Geneva but found that the job was not intellectually stimulating, and a chance encounter with Piaget at a bookstore had led her to dabble in psychology. She was working on her licence, equivalent to a master's degree, at the University of Geneva, when we met. I was doing my junior year abroad from Smith College and hadn't committed to anything yet (see Figure 2.1).

Annette and I met in Prof. Mimi Sinclair's lab, the Piagetian expert on language. I didn't know what I was doing, but I knew I was interested in language. Annette and I were part of a team exploring English- and French-speaking children's understanding of the relative clause. The team was supposed to write up a joint report on the project. But the study had too many loose ends to satisfy the two of us. So we went rogue.

We focused on English-speakers and narrowed the window of the study. We redesigned the stimuli, collected new data, and wrote up our own report in June of 1970 (which is now in the Archives de Psychologie in Geneva) – The Relative Pronoun, co-authored by Goldin and Karmiloff (neither of us had hyphens in our names at that point in our lives). I submitted the paper to Smith College to fulfil my junior year abroad requirement; Annette submitted it as a fourth piece of research on the way to obtaining her licence in genetic psychology. We ended our report with a suggestion for future research and I went back to Smith for my senior year and did the project for my honors thesis – our hypotheses were supported by the data I collected in the US.

And there the matter sat. We didn't publish the work, nor did anyone else on the relative pronoun team. When I visited Annette a week before she passed away, in addition to a bright and bold red necklace that to me embodied Annette,

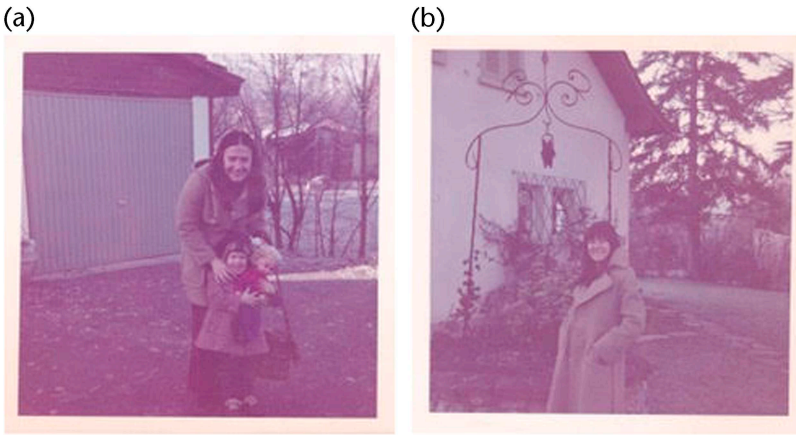

FIGURE 2.1 AK-S with her two-year-old daughter (left) and SG-M (right) in 1969 outside of Annette's house in Geneva where we often worked on our project.

I brought her a copy of the paper that we submitted in 1970. I remarked that we had done good work together when we were kids. Annette's comment was – "We should have published it". And so, at long last, we are.

This paper is a tribute to Annette, who more than anyone else inspired me to go to graduate school and become a developmental psychologist. Although we never worked together after this project, Annette and I were colleagues for each other and, most importantly, close friends for the next 47 years – a lifetime of love and respect.

The linguistic and cognitive underpinnings of relative clause comprehension

The relative clause (RC) is a subordinate clause (SC), which may be embedded within, or placed at the end of, the main clause (MC). The relative pronoun that introduces the SC refers to an antecedent in the MC. The relationship between the antecedent and the relative pronoun forms the link between the two clauses. The RC is defined in grammatical terms as a descriptive clause modifying the antecedent. The pronoun itself may act as either the subject or object of the SC; its antecedent may also assume the role of either subject or object, but of the MC. Our study focused on four types of sentences, each of which contained a transitive MC and a transitive SC (see examples in Table 2.1).

1. The Relative Subject Clause, RSC, where the referent of the relative pronoun *that* (i.e., the CAT in the first example in Table 2.1) is the subject in the SC (the cat is doing the pushing), and the object in the MC (the cat is being licked).
2. The Embedded Relative Subject Clause, [RSC], where the referent of the relative pronoun *that* (i.e., the MONKEY in the second example) is the

TABLE 2.1 Examples of the four types of relative clause tested in the study. The sentences are classified according to whether the relative pronoun *that* plays a subject or object role in the subordinate clause, whether the subordinate clause is embedded or not, and whether the referent of the relative pronoun *that* (the shared semantic element) plays the same role or different roles in the main and subordinate clauses

Type of relative clause (RC) construction	*Examples of relative clause constructions**	*Subject (S) or object (O) in relative clause***	*Relative clause is embedded (+Emb) or not (−Emb)*	*Shared semantic element plays the same roles or different roles in main clause (MC) and subordinate clause (SC)*
1. RSC	The squirrel licks the CAT [that pushes the monkey]	S	−Emb	Different Roles (Patient in MC switches to Agent in SC)
2. [RSC]	The MONKEY [that pushes the cat] licks the squirrel	S	+Emb	Same Roles (Agent in both MC and SC)
3. ROC	The cat licks the BEAR [that the pig pushes]	O	−Emb	Same Roles (Patient in both MC and SC)
4. [ROC]	The SQUIRREL [that the pig pushes] licks the bear	O	+Emb	Different Roles (Agent in MC switches to Patient in SC)

Notes

* The referent in CAPS plays a role in both the Main Clause and the Subordinate Clause; the Subordinate Clause is in brackets; the relative pronoun *that* in the Subordinate Clause refers back to the word in CAPS in the Main Clause.

** S indicates that the referent of the relative pronoun *that* (i.e., the term in CAPS in the Main Clause) plays the Subject role in the Subordinate Relative Clause; O indicates that the referent plays the Object role in the Subordinate Relative Clause.

subject of the SC (the monkey is doing the pushing) and the subject of the MC (the monkey is doing the licking); the square brackets around RSC mark the embedding.

3. The Relative Object Clause, ROC, where the referent of the relative pronoun *that* (i.e., the BEAR in the third example) is the object in the SC (the bear is being pushed) and the object in the MC (the bear is being licked).
4. The Embedded Relative Object Clause, [ROC], where the referent of the relative pronoun *that* (i.e., the SQUIRREL in the fourth example) is the

object in the SC (the squirrel is being pushed) and the subject in the MC (the squirrel is doing the licking); the square brackets around ROC again mark the embedding.

The purpose of our study was to determine whether these four types of RC sentences are acquired (in terms of comprehension) at the same moment in a child's development and, if not, which sentences were more difficult and why. The deeper question was to determine the extent to which the acquisition of these syntactic structures was dependent upon the development of cognitive structures.

In her book *Sentences Children Use*, Menyuk (1969) analysed RC sentences in terms of production. She noted that many children produce RC sentences of the following type (I):

a. I've got the book you want (an ROC sentence)
b. I saw the lady who was here yesterday (an RSC sentence)

However, even at age 7, children rarely produce sentences of this type (II):

c. The book that you want is on the table (an [ROC] sentence)
d. The lady who was here yesterday came back (an [RSC] sentence)

The factor that divides sentences (a) and (b) from (c) and (d) is embedding. The SC is not embedded within the MC in type I sentences, but is in type II sentences. As Menyuk points out, all four sentences contain two underlying sentences, one subordinate to the other, and, in this sense, are recursive. However, the type II sentences involve embedding the relative subordinate clause within the MC, which creates a distance between the subject of the MC (the word in CAPS in examples 2 and 4 in Table 2.1) and its predicate. This distance seems to be a stumbling block for young children, at least in production. Although 87% of Menyuk's participants (ages 3 to 7) used the RC construction, only 46% used the type II construction, and 66% of these children were in the 1st grade, the highest grade level included in the study (see also Limber, 1973). Extrapolating from production data, we might hypothesize that children ought to have particular difficulty understanding sentences in which the RC is embedded, that is, sentences like examples 2 and 4 in Table 2.1, where there is distance between the subject of the MC and its predicate. Indeed, Slobin (1971) hypothesized that this type of interruption in a sentence should make that sentence structure difficult for young children to acquire.

There is, however, another linguistic property that distinguishes these four sentences – whether the relative pronoun *that* is the subject of the subordinate clause (RSC sentences, examples 1 and 2 in the table) or the object of the subordinate clause (ROC sentences, examples 3 and 4). Note that whether the relative pronoun is a subject or object of the subordinate clause has implications for word order within the clause – the RC follows SVO word order in RSC sentences, but OSV word order in ROC sentences. If English-learning children use a linear comprehension strategy (i.e., if they assume that the words in the string reflect an SVO order, the

canonical order in English) to figure out who is doing what in the SC, they will arrive at the correct interpretation in RSC sentences – in sentence 1, the cat is followed by the verb "push" and is, in fact, doing the pushing; similarly in sentence 2, the monkey is followed by the verb "push", and is doing the pushing. In contrast, applying a linear comprehension strategy to ROC sentences does not give a coherent interpretation – the bear is not followed by any verb at all in sentence 3, nor is the squirrel in sentence 4; in both examples, another semantic element (the pig) is doing the action, in this case, pushing. Assuming that children are likely to apply a linear comprehension strategy to the sentences they hear, we might hypothesize that children ought to have particular difficulty understanding sentences in which this strategy results in an incorrect interpretation, that is, in ROC sentences like examples 3 and 4 in Table 2.1. In fact, sentences with object relatives have been found to be more difficult for adults to process than matched sentences with subject relatives (see O'Grady, 2011, for review; and Dick *et al.,* 2001, and Dick, Wulfeck, Krupa-Kwiatkowski, & Bates, 2004, for descriptions of related phenomena in adults with aphasia and children with developmental language impairment).

Finally, we considered another factor, one that reflects the Piagetian tradition in Geneva. Piaget (1967; Piaget & Inhelder, 1966) describes a number of phenomena in which children have difficulty thinking about an entity playing two roles at the same time. For example, children have trouble understanding that object B, which is to the left of A, is, at the same time, to the right of C. Children at this broad developmental stage also have difficulty ordering a set of sticks of different lengths, and treating a particular flower not only as a tulip but also as a flower. If a child has difficulty understanding that an entity can play two different roles at the same time, that child is likely to have trouble interpreting sentences like examples 1 and 4 in Table 2.1. The semantic element that is shared across the MC and SC in example 1 (the cat) plays the subject/agent role in the SC (he's the pusher), but the object/patient role in the MC (he is the lickee). The roles that the shared element plays in the MC and SC are also different in example 4, but they are reversed: the squirrel plays the object/patient role in the SC (he is the pushee), but the agent/subject role in the MC (he is the licker). Sentences containing this type of role-switch are likely to be difficult for a young child to interpret correctly since the situations to which these sentences refer are difficult for the child to conceptualize. In contrast, in sentences 2 and 3, the semantic element shared across the MC and SC plays the same role in both clauses: the subject/agent role in example 2 (the monkey is the pusher and the licker), and the object/patient role in example 3 (the bear is the pushee and the lickee). If role-switch is a factor in children's comprehension of the RC, children should find it easier to understand sentences 2 and 3 than sentences 1 and 4.

These factors lead us to make different predictions about comprehension. If containing an ROC and/or an embedded RC both contribute to comprehension difficulty, example 1 should be the easiest sentence to understand (having neither property) and example 4 the hardest (having both), with example 2 (having Emb but not ROC) and 3 (having ROC but not Emb) somewhere in between. In contrast, if switching roles in the MC and SC contributes to comprehension

difficulty, examples 1 and 4 should both be difficult to understand, and examples 2 and 3 should be relatively easy. Annette and I collected data in Geneva to explore these predictions.

The design of our study in Geneva

We tested 60 children, 10 in each age group: 4–5, 5–6, 6–7, 7–8, 8–9, and 9–10 years. The majority of children were pupils at the International School of Geneva, but 10 4-year-olds and 1 5-year-old attended the United Nations Nursery School, also in Geneva. Each child was presented with six sentences in five random orders. The six sentences included the four sentences with relative clauses displayed in Table 2.1, and two sentences with embedded adjectival clauses ("The monkey next to the cat licks the pig" and "The bear next to the pig pushes the monkey").

In all of the sentences, three animals took part in two actions in which the agent and patient could sensibly be reversed. As a result, the child had to be able to interpret the syntactic structure of the sentence in order to correctly act it out. Children were asked to act out each sentence with a set of stuffed animals; all of the animals could stand alone to avoid manipulation problems that might be caused by having three animals and two actions. Two durative verbs ("to lick" and "to push") were used for all sentences; "lick" was always the verb in the MC, "push" was the verb in the SC. One relative pronoun ("that") was used for all sentences.

The experimenter briefly talked about the toys and asked the child to name them. She then presented two demonstration sentences using "and" and acted out the sentences with the toys, emphasizing two successive actions. All of the verbs in the sentences were in the present tense, but if the child began to act out both parts of the sentence simultaneously, the experimenter repeated the sentence with the verb of the first part in the past tense in order to stress the two distinct and consecutive actions; otherwise, the sentence was presented only once with verbs in the present tense. The experimenter read each sentence according to the random order assigned to the child. Children selected from the five animals (pig, cat, bear, monkey, squirrel) those with which they wished to act out the sentence. After each acting out, the experimenter asked the child to describe what the animals just did.

All of the child's actions, hesitations, requests for repetitions, as well as sentence produced after the action were noted by a second experimenter. The experiment lasted approximately 5 minutes for older children, 15 minutes for the younger ones for whom lengthier presentations were essential as they were slow to respond.

The findings and next steps

Across all ages, children were correct on 71% of the embedded adjectival sentence, and even the 4-year-olds were correct on 65% of these sentences. The children could thus follow the instructions and perform two acts with three animals.

In contrast, across all ages, children were correct on only 42% of the RC sentences displayed in Table 2.1, and there was improvement with age (18%

4-year-olds, 38% 5-year-olds, 40% 6-year-olds, 33% 7-year-olds, 68% 8-year-olds, 55% 9-year-olds). For the most part, children produced verbal responses that mirrored their acting-out responses – they gave correct verbal responses on 35% of the relative clauses sentences (we considered a verbal response to be correct only when the child's action response was also correct; in other words, we did not consider the verbal response to be correct if the child repeated the experimenter's sentence after having acted out the sentence incorrectly).

As expected, performance was not uniform across the four types of RC sentences. Figure 2.2[1] presents the percentage of correct acting-out responses for the four relative clause sentences, classified according to the type of RC. Using a within-groups ANOVA to determine whether correct acting-out responses differed among the four types of sentences, we found a significant effect of sentence type, $F(3,36) = 5.23$, $p < .002$. Tukey HSD pairwise tests reveal significant differences at the $p = .05$ level between sentence types 1 and 2, between sentence types 2 and 4, and between sentence types 3 and 4; no other differences between pairs were reliable. We also used a non-parametric paired-samples sign test to explore differences between pairs of the four types of sentences. Eliminating ties, we found no differences between sentences 2 and 3 ($p = .41$, $N = 18$), nor between sentences 1 and 4 ($p = .50$, $N = 15$). However, sentence 1 differed from sentences 2 ($p = .012$, $N = 16$) and 3 ($p = .026$, $N = 17$), as did sentence 4 ($p = .005$, $N = 18$ and $p = .012$, $N = 16$, respectively).

All three of the factors outlined earlier lead to the prediction that sentence 4 should be difficult to comprehend, and it was. The interesting result is sentence 1, which (under one set of hypotheses) should be the easiest sentence to comprehend since it is an RSC that is not embedded. But, in fact, sentence 1 is difficult for the group as a whole and for each age group (the 4-year-olds produced no correct

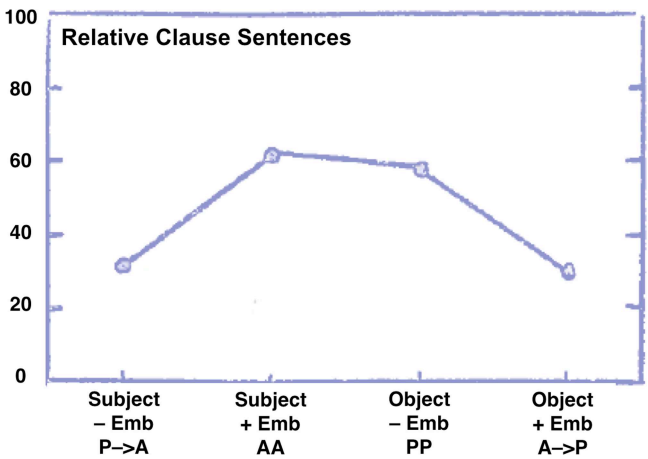

FIGURE 2.2 The percentage of correct acting-out responses produced by the 37 children in the Geneva study, classified according to the four types of relative clauses (see Table 2.1 for description of sentences).

responses on either sentence 1 or 4, but were correct on 30% and 40%, respectively, of sentences 2 and 3). This pattern of results suggests that role-switching is indeed an important factor in a child's comprehension of the relative clause – sentences that referred to a scene in which the shared element played a different role in each clause were more difficult to understand than sentences referring to a scene in which the shared element played the same role in the two clauses.

The role-switch hypothesis assumes that the semantic structure of the to-be-understood relative clause sentence presents a stumbling block for young children, not necessarily the syntactic structure of the sentence. At the end of our 1970 paper, Annette and I suggested that one way to test this hypothesis would be to change the syntactic structure of the four sentences while maintaining their semantic structure. My honors thesis at Smith College was designed to address this question.

Evidence for a cognitive bottleneck from coordinate sentences with passive clauses

We designed a study parallel to the one we conducted in Geneva, and included three different syntactic constructions, each reflecting the four types of semantic structures displayed in Table 2.1: (1) Relative clause sentences identical to the sentences presented to children in Geneva. (2) Coordinate sentences containing active and passive clauses; by using both types of clauses in a coordinate structure, we were able to create the same role structures found in the original relative clauses (see Table 2.2 for examples). Note that the semantic element shared across the two clauses (in CAPS) appears at the beginning of the sentence in each example, which could potentially ease the child's comprehension burden. (3) Coordinate sentences containing only active sentences; these sentences differed from the preceding category in that the semantic element that was shared across clauses (in CAPS) was presented twice, once in each clause, a manipulation that could also ease the child's comprehension burden (see Table 2.2).

Sentences were created by a random selection of animals and verbs for each position in the sentence, with the stipulation that three different animals and two different verbs appeared in each sentence; two sets of sentences were used. The three categories of sentences were not presented in blocks, but were instead presented together in a randomized order; 5 random orders of 12 sentences were used. The procedure was identical to the procedure we used in Geneva, with the exception that the child was not asked to give a verbal account after acting out the sentence with the animals. Because the pattern in Figure 2.2 was strongest in the younger children in our Genevan sample, we focused on children between 4 and 6 years in the US study – 20 children, ages 3.9 to 6.2 (median age = 4.9), were tested. Only two of the older children were attending kindergarten; the rest attended either a bi-weekly daycare center or a private nursery school.

As expected, the 20 children performed best on the coordinate sentences containing only active clauses (60% correct), next best on the coordinate sentences containing both active and passive clauses (44% correct), and least well on the relative

TABLE 2.2 Examples of the four types of coordinate sentences containing active and passive clauses, and the four types of coordinate sentences containing only active sentences. The sentences are classified according to whether the semantic element that appears in both clauses (in CAPS) plays the same roles or different roles in the two clauses

Type of coordinate construction	*Examples of coordinate construction*	*Shared semantic element plays the same or different roles in the two coordinate clauses*
Active and Passive Clauses		
1	The MONKEY licks the pig and is pushed by the mouse	Different Roles (Agent in 1st clause switches to patient in 2nd)
2	The MOUSE pushes the bear and licks the pig	Same Roles (Agent in both clauses)
3	The PIG is licked by the mouse and is pushed by the monkey	Same Roles (Patient in both clauses)
4	The BEAR is pushed by the monkey and licks the pig	Different Roles (Patient in 1st clause switches to Agent in 2nd)
Active Clauses		
1	The MONKEY licks the pig and the bear pushes the MONKEY	Different Roles (Agent in 1st clause switches to patient in 2nd)
2	The PIG pushes the mouse and the PIG licks the bear	Same Roles (Agent in both clauses)
3	The mouse licks the PIG and the monkey pushes the PIG	Same Roles (Patient in both clauses)
4	The pig licks the MOUSE and the MOUSE pushes the monkey	Different Roles (Patient in 1st clause switches to Agent in 2nd)

clause sentences (20%). Using a within-groups ANOVA, we found that children's performance on the three categories of sentences was significantly different, $F(2,19) = 15.02$, $p < .0001$. Tukey HSD pairwise comparisons revealed that performance on the relative clause sentences was significantly different at the $p < .01$ level from performance on the other two categories of sentences; the difference between the two types of coordinate sentences was not significant.

Despite the fact that the US sample performed worse on the relative clause sentences overall than the Geneva sample, they nevertheless displayed the same pattern with respect to the four types of RC sentences: They did better on sentences 2 and 3, the two sentences without role-switch (i.e., AA and PP), than on sentences 1 and 4, the two sentences with role-switch (i.e., P– > A and A– > P) (see Figure 2.3).

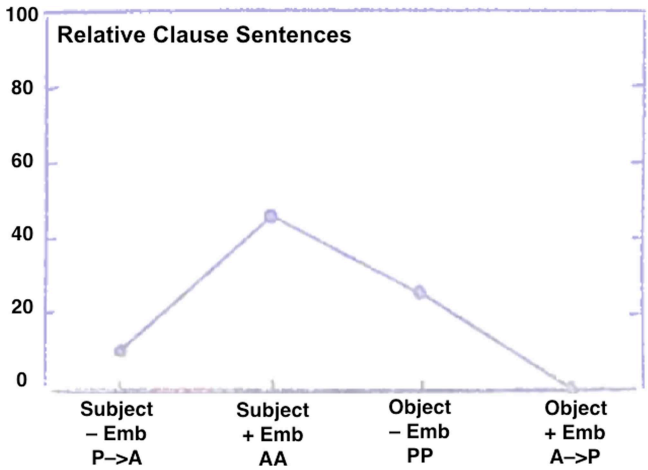

FIGURE 2.3 The percentage of correct acting-out responses produced by the 20 children in the US study, classified according to the four types of relative clauses (see Table 2.1 for description of sentences).

But did the children display this same pattern on sentences with a different syntactic structure? The answer is "yes" for coordinate sentences containing active and passive sentences (see Figure 2.4). Again, we see better performance on the two sentences without role-switch (AA and PP) than on the two sentences with role-switch (A→P and P→A).

However, the children displayed no differences across the four types of co-ordinate sentences containing only active sentences (see Figure 2.5), a surprising result given that the children's responses were not close to ceiling on these sentences.

Using a within-groups ANOVA, we found that the differences among the four sentence types were significant for the relative clause sentences, $F(3,19) = 6.07$, $p = .001$ and the coordinate sentences with active and passive clauses, $F(3,19) = 4.9$, $p = .004$, but not for the coordinate sentences with only active clauses, $F(3,19) = .31$, $p = .81$. Tukey HSD pairwise comparisons revealed differences between sentence types 1 and 2 (at $p < .05$) and between sentence types 2 and 4 (at $p < .01$) for relative clauses, and between sentence types 2 and 4 (at $p < .01$) for the coordinate sentences with active and passive clauses; none of the other pairwise differences was significant. We again used a non-parametric paired-samples sign test to explore differences between pairs of the four types of sentences. In the relative clauses, eliminating ties, we found no differences between the two RC sentences without role-switch ($p = .145$, $N = 8$); we could not carry out the test on the two sentences with role-switch because of the large number of ties (18 of the 20 children responded in the same way to both items, suggesting that responses to the two items did not differ). We did, however, find significant differences between the sentences with and without role-switch (2 vs. 1, $p = .02$, $N = 9$; 2 vs. 4, $p = .005$, $N = 9$; 3 vs. 4, $p = .031$, $N = 5$; the exception was 3 vs. 1, $p = .187$, $N = 5$).

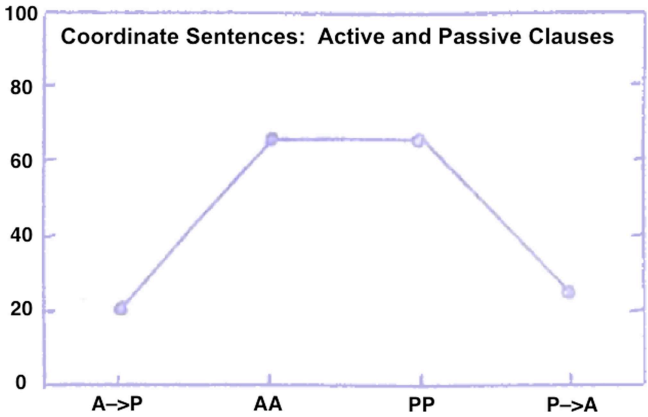

FIGURE 2.4 The percentage of correct acting-out responses produced by the 20 children in the US study, classified according to the four types of coordinate structures (see Table 2.2 for description of sentences).

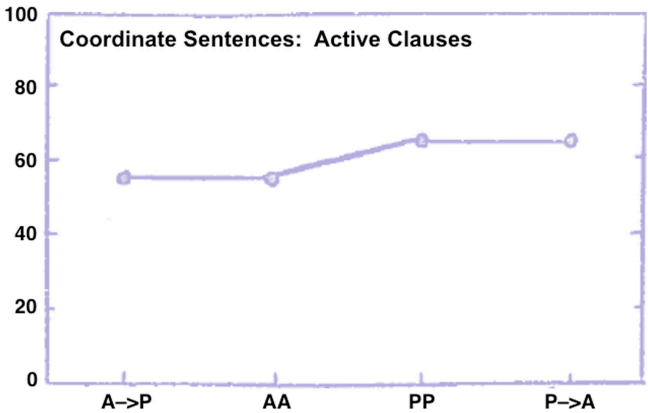

FIGURE 2.5 The percentage of correct acting-out responses produced by the 20 children in the US study, classified according to the four types of coordinate structures (see Table 2.2 for description of sentences).

Similarly, in the coordinate sentences with active and passive clauses, eliminating ties, we found no differences between the two sentences without role-switch (2 vs. 3, $p = .745$, $N = 6$) and no differences between the two sentences with role-switch (1 vs. 4, $p = .50$, $N = 5$). And again, we found a significant difference between the sentences with and without role-switch (2 vs. 1, $p = .005$, $N = 9$; 2 vs. 4, $p = .004$, $N = 8$; 3 vs. 1, $p = .006$, $N = 11$; 3 vs. 4, $p = .011$, $N = 10$).

To summarize, we found that when children responded differently to the four types of sentences within a category (i.e., to the four types of relative clause sentences, and to the four types of coordinate sentences with active and passive clauses), linguistic structure did not predict those differences in comprehension.

Instead, semantic structure – whether an entity plays the same role or switches roles in both clauses – determined sentence comprehension. An obvious follow-up question to ask is whether the US children, as they continued to develop, mastered the relative clause construction and the coordinate clause construction with passives at the same moment in development. If so, the bottleneck to comprehension would appear to be primarily semantic. If not (and this is the more likely outcome, with coordinate sentences containing passive clauses mastered first), the bottleneck to comprehension is likely to involve both semantic and syntactic structure. Overall, our findings underscore how important a sentence's message is to the comprehension of that sentence. This seems like an obvious point, but it can easily be overlooked. If a message is beyond a child's cognitive grasp, we can't even begin to probe the child's comprehension of linguistic structures conveying that message.

Support from the subsequent literature on children and adults

In 1974, Sheldon explored relative clause comprehension in 33 English-speaking children, ages 3.8 to 5.5 years, and manipulated precisely the same three factors that Annette and I had included in our study in Geneva (see Table 2.1): (1) The position of the relative clause, whether the RC was embedded or not. (2) Word order in the relative clause, whether the RC followed SVO order (the order in our RSC sentences) or OSV order (the order in our ROC sentences). (3) Parallel function, whether the noun phrase that appeared in both clauses had the same grammatical function or different grammatical functions (same role or different roles in our terms). Using an acting-out paradigm, Sheldon found that the third factor, parallel function, accounted for the children's responses better than the other two factors. She cites Brown (1971) and Maratsos (1973) as providing additional evidence for the importance of parallel function in young children's language.

If we are correct that children's difficulty with certain types of relative clause sentences stems from their inability to envision the semantic element that is shared across clauses in two different roles, then this problem should be short-lived, resolved once children are able to easily conceptualize two facets of an object at the same time. Interestingly, Sheldon (1977) explored the same three factors in a sentence processing study in adults and found strong evidence for the effects of the first two factors (RC position, and word order in the RC), but not for the third factor (parallel function), providing support for the hypothesis that this factor is a product of the cognitive constraints of childhood.

The long reach of the relative clause

In hindsight I can see that the project I did with Annette in 1970 set the stage for the research program that I began in graduate school and am still pursuing. Another way to explore the impact, or lack of impact, that linguistic structure has

on children's communicative development is to observe children who have not been exposed to linguistic input. My dissertation took this path by studying deaf children whose hearing losses prevented them from making use of the spoken language input that surrounded them, and whose hearing parents had not yet exposed them to sign language. We might guess that children in this situation would fail to communicate simply because they have no model for language. But this guess would be wrong – deaf children not exposed to a usable linguistic model communicate with their hearing family members, and use gesture to do so. Moreover, these gestures – called *homesigns* – display many of the structural properties found in natural language (Goldin-Meadow, 2003).

For example, homesign contains lexical markers that modulate the meanings of sentences (negation and questions, Franklin, Giannakidou, & Goldin-Meadow, 2011), grammatical categories such as nouns, verbs (Goldin-Meadow, Butcher, Mylander, & Dodge, 1994) and subjects (Coppola & Newport, 2005), and devices that refer to non-present events (i.e., that allow displacement, Butcher, Mylander, & Goldin-Meadow, 1991; Morford & Goldin-Meadow, 1997). Homesign gestures are also composed of parts, akin to a morphological system (Goldin-Meadow, Mylander, & Franklin, 2007), and those gestures combine to form structured sentences, akin to a syntactic system (Feldman, Goldin-Meadow, & Gleitman, 1978). Homesign is thus characterized by levels of structure, and those levels are organized hierarchically. For example, homesigners use multi-gesture combinations – a demonstrative gesture plus a noun gesture – to serve the same semantic and syntactic functions as either the demonstrative gesture or the noun gesture used on its own. The larger unit can thus substitute for the smaller units and, in this way, functions as a complex nominal constituent embedded within a sentence (i.e., a sentence with hierarchical structure [[[that] [bird]] [pedals]], rather than flat structure [[that] [bird] [pedals]] (Hunsicker & Goldin-Meadow, 2012; Flaherty, Hunsicker & Goldin-Meadow 2021).

The structures found in homesign have not been copied from a conventional language model, nor can they be traced back to the co-speech gestures that the homesigners' hearing family members used when interacting with them (Goldin-Meadow & Mylander, 1983, 1984, 1998; Goldin-Meadow et al., 2007; Flaherty, Hunsicker, & Goldin-Meadow, 2019). Moreover, there is no evidence that the way in which the hearing family members respond to their homesigner's gestures plays a role in shaping the structure of those gestures (Goldin-Meadow & Mylander, 1983; 1984). These structures, therefore, come as close as we can currently envision to revealing the human child's predispositions to communicate in a structured way. Because they have not been influenced by an established language model, the structures in homesign may be a relatively straightforward reflection of the cognitive structures children bring with them to language-learning.

Returning to the relative clause, if role-switch is cognitively difficult for children learning language from a model, it is likely to be just as difficult (maybe more so) for children who are creating their own linguistic structures. We would then expect that, when homesigners produce sentences with two clauses and a semantic element shared across those clauses, they should be biased toward

producing sentences in which the shared element plays the same semantic role in the two clauses. This prediction is, in fact, supported by the homesign data.

The shared semantic element in a relative clause sentence is marked by the relative pronoun (*that* in the study Annette and I did together), which is either the subject or object of the subordinate clause. But as the examples in Table 2.2 illustrate, sentences that have coordinately conjoined clauses (as opposed to subordinately conjoined clauses) can have shared elements too. Sometimes the shared element is repeated in the surface structure of the sentence (e.g., The PIG pushes the mouse and the PIG licks the bear) and sometimes it is omitted (e.g., The PIG pushes the mouse and licks the bear).

We analysed all of the gesture sentences containing more than one clause produced by a US homesigner between the ages of 2 years;10 months and 4 years; 10 months. The homesigner produced 267 two-clause sentences (with either coordinate or subordinate sentence structure), and 80% of these sentences contained shared elements. The *horse* is the shared element in example (1) and the *village* is the shared element in example (2) (Goldin-Meadow, 1982). Iconic gestures are in CAPS in the examples, pointing gestures are in lower case; a gloss of the sentence is in parentheses.

1. CLIMB–SLEEP–horse (horse climbs and then sleeps, describing a picture of a horse sleeping on top of a house)
2. toy1–village–toy2–village (you put toy1 in village and toy2 in village, requesting the experimenter to put the toys in the village).
   A shared semantic element can play the same role in the two clauses, as in these examples. In (1) the *horse* is an actor in both clauses, and in (2) the *village* is a locative recipient in both clauses. But a shared element can also switch roles, as in example (3).
3. PUSH–truck–CIRCLE–truck (I push the truck and then the truck circles, describing his own actions on the truck).

Here the shared element, the *truck*, is the patient of the pushing action and the actor of the circle action.

The interesting question given the theory that Annette and I constructed concerns the distribution of shared elements that play either the same or different roles in the two clauses of a complex sentence. Consistent with our theory, the homesigner produced significantly more sentences in which the shared semantic element played the same role in the two clauses (N = 112, 85% of complex sentences containing two action propositions) than sentences in which the shared element played different roles (N = 20, 15%) ($p < .0001$, binomial test, two-tailed).

A child who is not exposed to a language model can nevertheless produce two-clause sentences in which a semantic element appears in both clauses. More to the point for our question, the child seems to be biased against producing two-clause sentences in which the shared semantic element plays a different role in each of the two clauses. The linguistic structures that homesigners display in

their sentences are good candidates for cognitive structures that exert an influence on language development, consistent with Piagetian theory (see Sinclair, 1967). The homesign findings, thus, lend support to the hypothesis that at least one of the difficulties children face in comprehending relative clauses is cognitive and not purely linguistic.

Annette and I set out in 1969 to determine whether Piaget's theory had anything say about children's acquisition of the relative clause, and found that it did. But the truly important aspect of the experience for me was that I got to work with Annette, who was (even then) a gifted researcher. And I got to watch first hand as Annette managed being a young mother and a student, and did it with her characteristic excellence – the beginning of one of the important themes in Annette's life – achieving a sensible work-life balance.

As I look back on my work, I now see many places where Annette's work had an important influence on me. For example, her belief in the value of the microgenetic method was instrumental in getting me to do my own microgenetic study of the role that spontaneous gestures can play in learning math (Alibali & Goldin-Meadow, 1993), and her ideas about *representational redescription* provided a framework for the theory my students and I are building on the role that gesture plays in the transition from concrete action to abstraction (Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014; Goldin-Meadow, 2015; Wakefield, Hall, James, & Goldin-Meadow, 2018) – gesture turns out to be a viable vehicle for the redescription that propels developmental change (Goldin-Meadow & Alibali, 1994). And then there is my work on homesign, which addresses questions that Annette and I asked together. Much to my surprise, the homesign data corroborate the theory that Annette and I proposed back in 1970, a realization that I came to in writing this chapter, and am saying out loud for the first time. I have come full circle and only wish that I could discuss it all with Annette, who would know just how to put the insight into perspective and creatively build on it.

Note

1 The graphs in this paper are taken from my 1971 honors thesis and thus were constructed by hand (as graphs were at that time), which accounts for their home-grown feel.

References

Alibali, M. W., & Goldin-Meadow, S. (1993). Gesture-speech mismatch and mechanisms of learning: What the hands reveal about a child's state of mind. *Cognitive Psychology*, 25, 468–523.

Brown, H. D. (1971). Children's comprehension of relativized English sentences. *Child Development*, 42, 1923–1926.

Butcher, C., Mylander, C., & Goldin-Meadow, S. (1991). Displaced communication in a self-styled gesture system: Pointing at the non-present. *Cognitive Development*, *6*, 315–342.

Coppola, M., & Newport, E. (2005). Grammatical Subjects in homesign: Abstract linguistic structure in adult primary gesture systems without linguistic input. *Proceedings of the National Academy of Sciences*, *102*, 19249–19253.

Dick, F., Bates, E., Wulfeck, B., Aydelott, J., Dronkers, N., & Gernsbacher, M. (2001). Language deficits, localization, and grammar: Evidence for a distributive model of language breakdown in aphasic patients and neurologically intact individuals. *Psychological Review*, *108*(3), 759–788.

Dick, F., Wulfeck, B., Krupa-Kwiatkowski, M., & Bates, E. (2004). The development of complex sentence interpretation in typically developing children compared with children with specific language impairments or early unilateral focal lesions. *Developmental Science*, 7(3), 360–377.

Feldman, H., Goldin-Meadow, S., & Gleitman, L. (1978). Beyond Herodotus: The creation of language by linguistically deprived deaf children. In A. Lock (Ed.), *Action, symbol, and gesture: The emergence of language* (pp. 351–414). New York: Academic Press

Flaherty, M., Hunsicker, D., & Goldin-Meadow, S. (2021). Structural biases that children bring to language learning: A cross-cultural look at gestural input to homesign. Revision under review.

Franklin, A., Giannakidou, A., & Goldin-Meadow, S. (2011). Negation, questions, and structure building in a homesign system. *Cognition*, *118*, 398–416.

Goldin-Meadow, S. (1982). The resilience of recursion: A study of a communication system developed without a conventional language model. In E. Wanner & L. R. Gleitman (Eds.), *Language acquisition: The state of the art* (pp. 51–77). New York: Cambridge University Press.

Goldin-Meadow, S. (2003). *The resilience of language: What gesture creation in deaf children can tell us about how all children learn language*. New York: Psychology Press.

Goldin-Meadow, S. (2015). From action to abstraction: Gesture as a mechanism of change. *Developmental Review*, *38*, 167–184, doi: 10.1016/j.dr.2015.07.007.

Goldin-Meadow, S., & Alibali, M. W. (1994). Do you have to be right to redescribe? *Behavioral and Brain Sciences*, *17*, 718–719.

Goldin-Meadow, S., Butcher, C., Mylander, C., & Dodge, M. (1994). Nouns and verbs in a self-styled gesture system: What's in a name? *Cognitive Psychology*, *27*, 259–319.

Goldin-Meadow, S., & Mylander, C. (1983). Gestural communication in deaf children: The non-effects of parental input on language development. *Science*, *221*, 372–374.

Goldin-Meadow, S., & Mylander, C. (1984). Gestural communication in deaf children: The effects and non-effects of parental input on early language development. *Monographs of the Society for Research in Child Development*, *49*, 1–121.

Goldin-Meadow, S., & Mylander, C. (1998). Spontaneous sign systems created by deaf children in two cultures. *Nature*, *391*, 279–281.

Goldin-Meadow, S., Mylander, C., & Franklin, A. (2007). How children make language out of gesture: Morphological structure in gesture systems developed by American and Chinese deaf children. *Cognitive Psychology*, *55*, 87–135.

Hunsicker, D., & Goldin-Meadow, S. (2012). Hierarchical structure in a self-created communication system: Building nominal constituents in homesign, *Language*, *88*(4), 732–763.

Limber, J. (1973). The genesis of complex sentences. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language*. New York: Academic Press.

Maratsos, M. (1973). The effects of stress on the understanding of pronominal coreference in children. *Journal of Psycholinguistics*, *1*, 1–8.

Menyuk, P. (1969). *Sentences Children Use*. Research Monographs No. 52. Cambridge, MA: MIT Press.

Morford, J. P., & Goldin-Meadow, S. (1997). From here to there and now to then: The development of displaced reference in homesign and English. *Child Development*, *68*, 420–435.

Novack, M. A., Congdon, E. L., Hemani-Lopez, N., & Goldin-Meadow, S. (2014). From action to abstraction: Using the hands to learn math. *Psychological Science*, *25*(4), 903–910. doi: 10.1177/0956797613518351

O'Grady, W. (2011). Relative clauses: Processing and acquisition. In E. Kidd (Ed.), *The acquisition of relative clauses: Processing, typology and fFunction* (pp. 13–38). Amsterdam: John Benjamins.

Piaget, J. (1967). *La Psychologie de l'Intelligence*. Paris: Librare Armand Colin.

Piaget, J., & Inherlder, B. (1966). *La Psychologie de l'Enfant*. Paris: Pressess Universitaires de France.

Sheldon, A. (1974). The role of parallel function in the acquisition of relative clauses in English. *Journal of Verbal Learning and Verbal Behavior*, *13*, 272–281.

Sheldon, A. (1977). On strategies for processing relative clauses: A comparison of children and adults. *Journal of Psycholinguistic Research*, *6*(4), 305–318.

Sinclair, H. (1967). *Acquisition du langage et développement de la pensée: Sous-systèmes linguistiques et opérations concrètes*. Paris: Dunod.

Slobin, D. I. (1971). Developmental psycholinguistics. In W. O. Dingwall (Ed.), *A survey of linguistic science*. Linguistics Program, University of Maryland.

Wakefield, E. M., Hall, C., James, K. H., & Goldin-Meadow, S. (2018). Gesture for generalization: Gesture facilitates flexible learning of words for actions on objects, *Developmental Science*, *21*(5), DOI: 10.1111/desc.12656