

# 18

## Sentence processing

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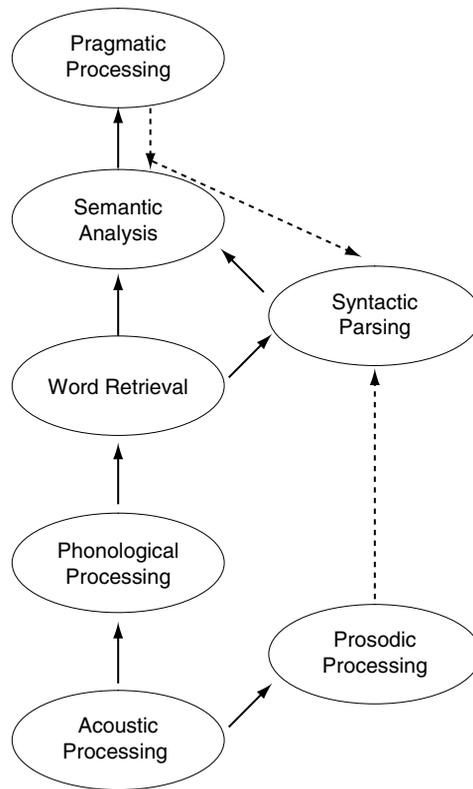
### 18.1 Introduction

Human language comprehension is so effortless that it often appears instantaneous. Someone speaks, and we understand them without any awareness of how. It is only when we step back and examine the structure of language that it becomes clear just how complex this ability is. To understand speech, we must: transform the acoustic input into a phonological representation, identify each word that is spoken, integrate these words into a structured syntactic and semantic representation and then use that representation to determine what the speaker intended to convey.

Figure 18.1 illustrates these processes and how they might be connected. The solid arrows represent a pared-down theory of how information flows through the system during comprehension. Most theorists posit additional connections between the different levels of processing but they disagree about whether these instructions are immediate or delayed.

The field of sentence processing examines the combinatorial processes that follow word identification – syntactic analysis, semantic interpretation and pragmatic processing. Until recently there was little research that examined children’s sentence processing. This was largely attributable to a lack of appropriate paradigms. Research on adult language comprehension had relied on reading paradigms, dual-task studies and metalinguistic judgments of words or utterances. While these methods provided substantial insight into the mature processing system, the findings for young children were often difficult to interpret. In recent years a number of new techniques have been developed which allow us to study how children comprehend spoken language with more natural tasks.

There are several reasons for studying children’s sentence processing. First, it is a critical but poorly understood aspect of child development. By four or five years of age, children have mastered the basics of their native language and amassed an impressive vocabulary. But we know little about



**Figure 18.1** A sketch of the processes involved in comprehending spoken language. The solid arrows represent the bottom-up connections that are a part of all theories. The dotted arrows represent the pathways explored in section 18.4.

how they employ this knowledge as they are listening. Are young children able to understand sentences as rapidly as adults? Or is it wiser to slow down when we speak to them? Do they arrive at essentially the same interpretation as adults? Or is our communication with children jeopardized by systematic differences in how we resolve linguistic ambiguity? Mapping the development of language processing could also shed light on some developmental disorders. For example, many children with Asperger's syndrome and Attention Deficit Disorder have problems following spoken instructions, despite average or even superior performance on standardized tests of lexical and grammatical abilities. Sensitive measures of online comprehension could allow us to explore whether these problems stem from deficits in language processing, in contrast with deficits in pragmatic abilities, attention or motivation.

Studying children's language processing may also provide insight into the architecture of the adult language comprehension system. There is general consensus that adults are able to rapidly integrate many sources of information to arrive at a syntactic and semantic analysis of an utterance. But there is considerable controversy about precisely how this is done. Some theorists

believe that adult language processing is massively interactive (that every process in Fig. 18.1 connects with and directly influences every other process). Others believe that the flow of information through the system is more constrained (or modular). For example, some theorists propose that during initial comprehension, information from one level flows solely to the level immediately above it. In these modular theories, there is typically a second stage of processing in which a wider range of information sources is used to refine and revise the initial analysis. With experience these revision processes may become so rapid and automatic that it becomes difficult to find evidence of the initial modular stage. Tracing the development of language comprehension in developmental time could help resolve this debate. In the absence of a blueprint, we may be able to discover the underlying structure of sentence processing by watching the building go up.

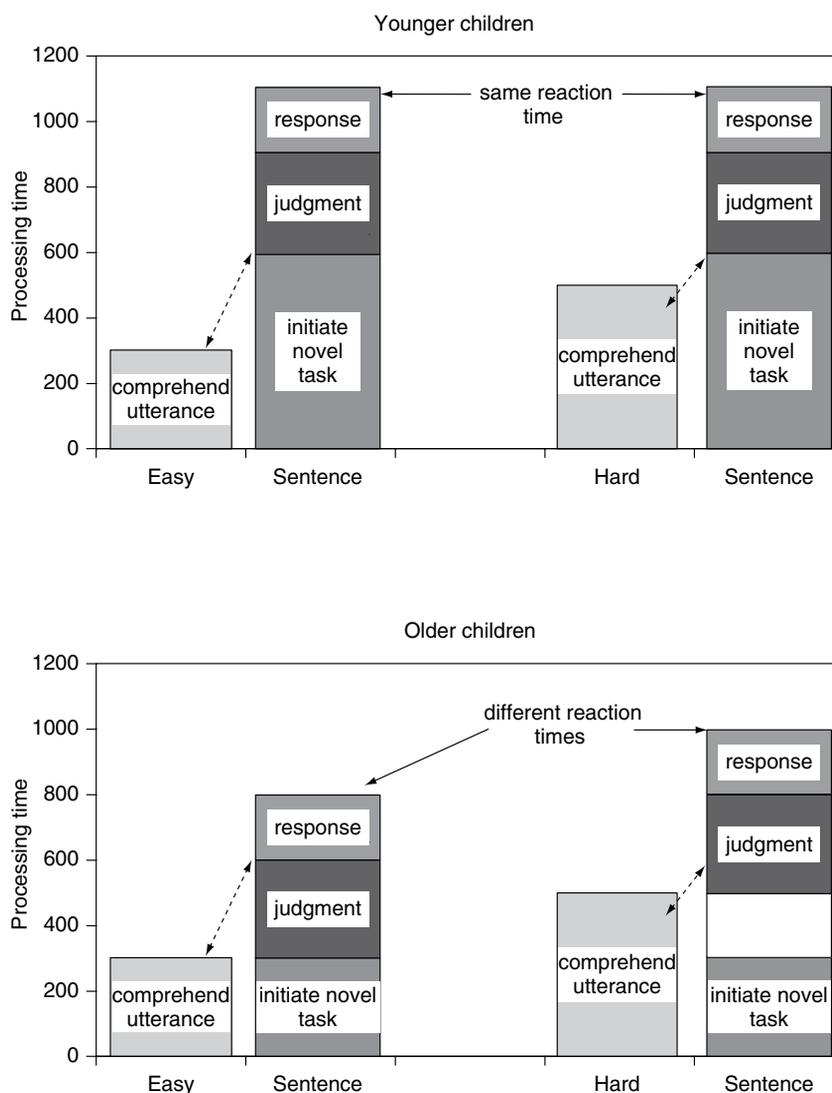
Finally, studies of children's sentence processing inform the study of language acquisition. As we will see in section 18.5, processing studies can provide data on the nature of children's linguistic representations which bear directly on theories of acquisition. In addition, sentence processing constrains language acquisition. Children acquire language in part on the basis of the utterances they hear. What they learn from an utterance will depend on how they represent it, which in turn will depend on the comprehension process itself (Fodor 1998b).

In this chapter I will briefly describe what we know about adult sentence processing and introduce some of the methods that are used in children's sentences processing. Then I will review two lines of work: one on ambiguity resolution and one on syntactic priming. I will conclude with a discussion of recent directions in the field.

## 18.2 Methodological issues

Speech gallops along at about 2.5 words per second. To keep pace language comprehension must be both rapid and incremental. In other words, we begin analysing each word as we hear it, rather than waiting until the word or the sentence is complete. For this reason the study of language comprehension requires tools with fine temporal resolution: tools that give us insight into the moment-to-moment changes in cognitive processes rather than merely showing us the final product. These methods are called online comprehension tasks, to distinguish them from the offline tasks used to study children's grammatical knowledge.

For many years research on adult language comprehension primarily examined the comprehension of written language. Text was preferred to speech both because it was much easier to present and because the presentation of each word or phrase could be yoked to the participant's response, providing fine-grained information about processing time. Many paradigms combined reading or listening with a secondary task,



**Figure 18.2** Hypothetical example of a reaction-time task in two groups of children. To respond, children must both initiate the novel task and comprehend the sentence. If task initiation is slow (as in the younger children) then differences in linguistic processing will not affect reaction times.

like judging whether the sentence was grammatical or whether a string of letters formed a word. These secondary tasks were used to make inferences about the processing load at different points in an utterance and the kinds of interpretations that were being entertained.

Because these paradigms provided a rich and detailed picture of adult language comprehension, several creative experimenters adapted them for use with children (for reviews see Clahsen 2008, McKee 1996). The results of such studies can be difficult to interpret, primarily because these tasks

require abilities – such as reading, executive functions and metalinguistic reasoning – which continue to develop throughout childhood (see e.g. Gombert 1992, Welsh *et al.* 1991). Often in reaction or reading time tasks young children appear to be insensitive to information sources or constraints that guide sentence processing in adults and older children (Kidd 2003, Traxler 2002). But typically the younger children have much longer reading or reaction times in all conditions, suggesting that they find the task more difficult than do older children. Under these circumstances, response times may not be a sensitive measure of language processing. As the response time increases the noise in the data increases as well, making it more difficult to detect effects of a given size. As figure 18.2 illustrates, the presence of a secondary task – like a judgment or button press – further complicates the picture. If young children are slower at initiating the secondary task, that delay can mask any differences in difficulty of the linguistic task. Cognitive psychologists would say that the effect is absorbed into the slack, and thus is not apparent in the reaction time (see Sternberg 1998).

These difficulties led researchers to conclude that children's language processing is best studied with spoken language and no overt task. The challenge, of course, is to figure out how we can get data on online processing under these conditions. Over the past decade two solutions have emerged. First, we can examine the neural correlates of sentence processing using neuro-imaging techniques. The most popular imaging technique for studying children's sentence processing is the measurement of event-related potentials (or ERPs, see Ch. 4). ERPs provide less information about the location of a neural process than methods like fMRI, but they have the temporal resolution necessary for studying language processes, are safe for use with children, and are inexpensive compared to other imaging techniques. Our interpretation of ERP data in children is largely based on what we know about particular ERP effects in adults. One limitation of the technique is that most research designs examine neural responses to anomalous utterances, and thus provide limited information about the evolving interpretation of well-formed utterances.

Recently many researchers have been studying children's online language processing by examining what they look at as they are listening to an utterance (Fernald *et al.* 1998, Nation *et al.* 2003, Song & Fisher 2005, Swingley & Aslin 2002, Swingley & Fernald 2002, Trueswell *et al.* 1999). These methods stem from the intermodal preferential looking paradigm which was developed to study intermodal perception (Spelke 1979) and offline language comprehension (Golinkoff *et al.* 1987), and from the visual world paradigm that was developed by Michael Tanenhaus and his colleagues to study online spoken language comprehension in adults (Tanenhaus *et al.* 1995).

In eye-gaze studies exploring online language processing, children hear a word or a sentence that refers to the visual scene that accompanies it. The visual scene can be a video, a still picture, or a set of objects placed on a tabletop. As the child is listening to the sentence, her gaze direction is recorded. Later the child's eye-movements are analysed with respect to the

accompanying utterance, allowing researchers to make inferences about the child's evolving interpretation of the utterance. Eye gaze can be measured in several ways. Some researchers use automated eye-trackers which record an image of the eye and use computer algorithms to infer the direction of gaze. Other researchers simply use a camera which is pointed at the child's face and then code the video by hand. The two methods produce quite similar results (Snedeker & Trueswell 2004).

Why might eye movements be a useful measure of language processing? Because visual acuity is much greater in the fovea (the centre of the retina), we tend to move our eyes to fixate objects that we are attending to. These eye movements are quick, frequent and largely unconscious. Language in turn is a remarkably effective way of altering someone's attentional state. If I say "telephone" you are likely to find yourself thinking of telephones. If there is a telephone nearby that I might be referring to, your eyes will tend to rest on this telephone shortly after the word begins. Eye-gaze paradigms have several advantages for studying children's comprehension. The tasks are simple to administer and typically enjoyable for children. We can examine the comprehension of naturalistic spoken utterances which do not contain anomalies. The measure of interest is based on a spontaneous behaviour which requires no training on the part of the participant. Finally, because the eyes can move several times a second, eye-gaze paradigms provide fine-grained temporal information.

In adults these methods are sensitive to language processing at multiple levels and have been successfully used to explore such diverse issues as: the time course of lexical activation (Allopenna *et al.* 1998, Magnuson *et al.* 2003); the integration of syntactic and semantic constraints during sentence processing (Boland 2005, Kamide *et al.* 2003); and the role of contextual cues in resolving referential and syntactic ambiguities (Chambers *et al.* 2004). Much of the developmental work has focused on word recognition, demonstrating that one and two-year-old children rapidly and incrementally map phonological input onto lexical entries (Fernald *et al.* 2006, 1998, Swingley & Aslin 2002, Swingley & Fernald 2002). However several researchers have also examined higher-level processes such as pronoun interpretation (Arnold *et al.* 2000, Sekerina *et al.* 2004, Song & Fisher 2005), incremental semantic analysis (Sedivy *et al.* 2000) and syntactic ambiguity resolution (Snedeker & Trueswell, 2004, Trueswell *et al.* 1999). While this field is still in its infancy, it has already provided some insights into the origins and development of the language comprehension system and the grammatical representations that underlie it.

### 18.3 The adult comprehension system

Half a century of systematic exploration has led to a rich (albeit incomplete) understanding of how adult listeners interpret spoken language. While there is still considerable controversy in this field, there is broad agreement on three

basic issues (see Altmann 2001, Elman *et al.* 2005, Treiman *et al.* 2003 for reviews). First, language comprehension involves a series of processes which are ordered with respect to one another (see figure 18.1). Phonological processing must begin before words can be recognized. Lexical processes provide semantic and syntactic information which is integrated into structural representations which in turn encode the relations between words. Structured semantic representations are enriched and disambiguated by pragmatic inferences that are guided by information about communication and the context of language use.

Second, each of these processes is incremental. This means that processing at higher levels begins before processing at the lower levels is completed. Many theorists use the metaphor of spreading activation (or cascading water) to capture this relation. As soon as activation (information) begins to accumulate at one level of analysis, it is propagated on to the next level, initiating the higher level process while the lower one is still in progress. Thus word recognition is underway by the time the first phoneme has been heard, syntactic and semantic processing begin as soon as candidate word forms become active (often leading to expectations about words that have yet to be heard), and pragmatic inferences can be made before a clause is completed.

Third, processing at a given level can be influenced by information from other levels, both higher and lower, in the linguistic system. For example, word identification is rapidly influenced by top-down information about the syntactic and semantic context in which that word appears, as well as bottom-up information about the phonological and prosodic form of the word.

To explore this in more detail, let's focus on the syntactic level. In adults syntactic parsing has primarily been investigated by examining the way readers initially interpret, and misinterpret, syntactically ambiguous phrases. For example, consider the sentence fragment (1):

(1) Mothera destroyed the building with ...

At this point in the utterance the prepositional phrase (PP) beginning with *with* is ambiguous because it could be linked to the verb *destroyed* (VP-attachment), indicating an instrument (e.g. *with her awesome powers*); or it could be linked to the definite noun phrase *the building* (NP-attachment) indicating a modifier (e.g. *with many balconies*). In adults, several different kinds of information rapidly influence the interpretation of ambiguous phrases.

First, knowledge about the particular words in the sentence constrains online interpretation of ambiguous phrases (Taraban & McClelland 1988, Trueswell *et al.* 1993). For instance, the sentence in (1) favours the instrument analysis but if we change the verb from *destroyed* to *liked* the preference flips and the modifier analysis, or NP-attachment, is favoured. This kind of information is often called 'lexical bias' or 'verb bias'. The observed change in preferences could reflect knowledge about the kinds of structures in which each verb is likely to appear (information accessed during word retrieval and then passed on to the syntactic parser), it could reflect semantic knowledge

about the arguments of the verb (accessed during word retrieval and passed on to semantic analysis), or it could reflect a more global analysis of the plausibility of different events (pragmatic processing), which influences the relations posited during semantic analysis, which in turn constrains syntactic parsing. All three pathways are shown in Figure 18.1.<sup>1</sup>

Second, adults can use intonation or prosody to resolve attachment ambiguities. If we hear a pause before the preposition (*destroyed the building ... with the tower*), we are more likely to assume that the prepositional phrase is attached to the verb phrase and interpret it as an instrument. In contrast, a pause or intonational break before the direct object (*destroyed ... the building with the tower*) favours NP-attachment (Pynte & Prieur 1996, Schafer 1997). In Figure 18.1, the pathway by which prosody might influence syntax is shown by the dashed line coming up from prosodic processing to syntactic parsing.

Finally, the situation in which the utterance is used can influence our interpretation (Crain & Steedman 1985). For example, if only one building is under consideration, VP-attachment is likely to be preferred, but if multiple buildings are available then we are more likely to initially interpret the ambiguous phrase as a modifier specifying the building in question (Altmann & Steedman 1988). This type of information is often called referential context. In a reading task the referential context depends upon the information provided in the passage (and the reader's knowledge of the world). In some studies of spoken language comprehension the referential context is limited to the set of objects that the participant can act on. In figure 18.1 the pathway by which referential context might influence parsing is shown by the dashed line coming down from pragmatic processing to semantic analysis and then to syntactic parsing.

The bulk of the evidence suggests that adults rapidly integrate these different information sources to arrive at the analysis that best meets the constraints they have encountered (for a review see Altmann 1998). But disputes continue about the details of this process: do some sources of information establish the candidate analyses while other sources of information weigh in at a later stage (Boland & Cutler 1996, Pynte & Prieur 1996)?

## 18.4 Syntactic ambiguity resolution in children

The introduction of eye-gaze paradigms enables us to ask parallel questions about the development of online parsing. Trueswell and colleagues (1999) first explored this in a study examining whether children, like adults, can use referential constraints to guide online parsing. Children were given spoken instructions to move objects about on a table while their eye movements were recorded. The critical trials contained a temporary

<sup>1</sup> If verb bias effects are actually based on plausibility, then the pathway by which they influence syntactic analysis is the same as the pathway by which referential context has its effect (shown with a dashed line from pragmatics to semantics to syntax).

PP-attachment ambiguity, see (2) below. The verb (*put*) was one that typically appears with a PP argument encoding the destination of the action, thus supporting an initial analysis of the phrase *on the napkin* as VP-attached.

(2) Put the frog on the napkin in the box.

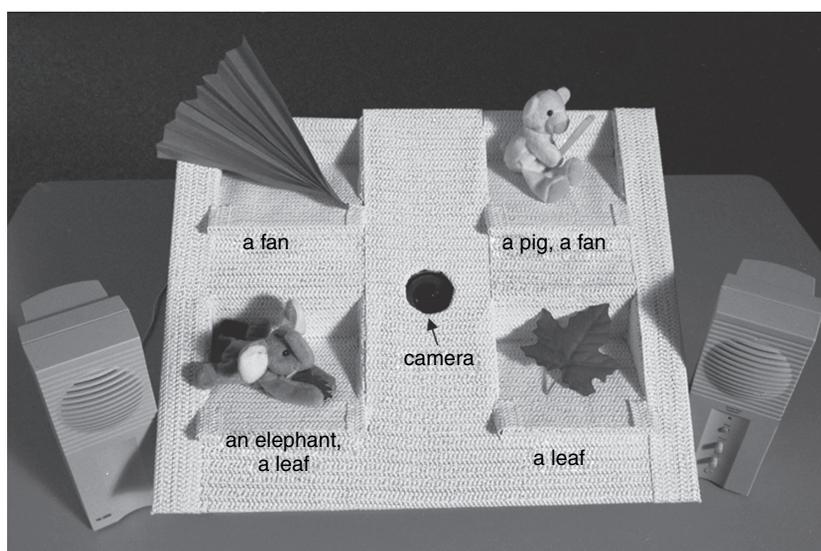
In contexts with just one frog, adults initially looked over to the incorrect destination (the empty napkin) suggesting that they were misanalysing the first prepositional phrase (*on the napkin*) as a VP-attached destination (Tanenhaus *et al.* 1995). But when two frogs were provided (one of which was on a napkin) the participants were able to immediately use the referential context to avoid this garden path, resulting in eye movements similar to unambiguous controls (e.g. *Put the apple that's on the napkin ...*).

In contrast five year olds were unaffected by the referential context. In both one-referent and two-referent contexts, children frequently looked at the incorrect destination, suggesting that they pursued the VP-attachment analysis regardless of the number of frogs. In fact, the children's actions suggested that they never revised this misanalysis. On over half of the trials, their actions involved the incorrect destination. For example, for the utterance in (2) many children put the frog onto the napkin and then placed it in the box. By age eight, most children acted like adults in this task, using referential context to guide their parsing decisions about ambiguous phrases.

There are two plausible explanations for this overwhelming preference for the VP-attachment. First, children's parsing preferences could be driven by their statistical knowledge of the verb *put*, which requires the presence of a PP-argument (the destination). Second, children could have a general structural preference for VP-attachment. Such a preference would be predicted by theories of acquisition and parsing that favour simple syntactic structures (i.e. a Minimal Attachment strategy, Frazier & Fodor 1978, Goodluck & Tavakolian 1982) or that ban complex syntactic operations entirely in early stages of development (e.g. Frank 1998). On such a theory, parsing revisions that are based on lexical or referential sources might simply get faster over the course of development (Goodluck & Tavakolian 1982), until the erroneous analyses become undetectable to experimenters measuring adult comprehension (Frazier & Clifton 1996).

Snedeker and Trueswell (2004) explored these two possibilities by manipulating both the bias of the verb and the referential context in which the utterance was used. In this study, children and adults heard globally ambiguous prepositional phrase attachments, as in (3). These sentences were presented in contexts that provided distinct referents for the prepositional object under the two analyses. For example in (3c) both a large fan and a pig holding a fan were provided (see figure 18.3).

- (3) a. Modifier Biased: Choose the cow with the fork  
 b. Unbiased: Feel the frog with the feather  
 c. Instrument Biased: Tickle the pig with the fan



**Figure 18.3** Example of a display for the verb bias and prosody experiments (Snedeker & Trueswell 2004, Snedeker & Yuan 2008). The critical utterance was: *Tickle the pig with the fan.*

Both adults and five-year-old children were strongly swayed by the type of verb that was used in the instructions. When the verb was one that frequently appeared with an instrument phrase (3c), participants began looking at the potential instrument (e.g. a large fan) shortly after the onset of the prepositional object. When the verb was strongly biased to a modifier analysis (3a), participants focused in on the animal holding the object instead. In addition, verb biases strongly shaped the ultimate interpretation that the adults and children assigned to the prepositional phrase: instrument biased verbs resulted in actions involving the target instrument while modifier biased verbs resulted in actions on the target animal. Adults also incorporated referential constraints into their analyses, children showed little sensitivity to the referential manipulation. Although there was a weak effect of referential context on children's eye movements, their ultimate interpretation of the prepositional phrase was based exclusively on verb bias.

Recently Snedeker and Yuan (2008) built upon these findings by using the same sentences and paradigm to explore young children's and adults' use of prosody in online parsing. While prior studies of adult comprehension had found rapid effects of prosody on ambiguity resolution (Kjelgaard & Speer 1999, Snedeker & Trueswell 2003, Steinhauer *et al.* 1999), there was little information available about how adults combined prosodic and lexical cues and no evidence that young children made use of prosody to resolve syntactic ambiguity (Choi & Mazuka 2003). Two prosodic variants of each sentence were created. The modifier prosody had an intonational phrase (IP) break after the verb (*You can tap ... the frog with the flower*) while the instrument prosody had an IP break after the noun (*You can tap the*

*frog ... with the flower*). The prosody of the sentence was fully crossed with the verb bias manipulation described above, resulting in six different conditions.

When large numbers of participants are tested, paradigms like these can provide detailed information about the time course of language processing. In this study we were able to look at how eye movements changed in 100 ms intervals starting at the beginning of the critical word (e.g. *fork* in 3a). We found that both the children and the adults made rapid use of prosody to interpret the ambiguous phrase. By 200 ms after the critical word began, adults who heard instrument prosody were already looking at the instrument more than those who heard modifier prosody. In children these effects were smaller and emerged a bit later (500 ms after the onset of the critical word). The effects of verb bias were also robust and rapid, indicating that lexical information plays a central role even when strong prosodic cues are present. In children the effect of verb bias appeared as soon as the critical word began (at 0 ms). Since eye movements take approximately 200 ms to programme and execute, this indicates that the children were using information about the verb to guide syntactic analysis immediately after encountering the preposition.

Taken together this set of studies suggests that children's online parsing is rapidly influenced by lexical and prosodic cues but is relatively impervious to referential cues. Snedeker and Yuan suggest that this pattern could reflect either (1) a developmental difficulty in employing top-down cues during comprehension; or (2) the failure of the parsing system to acquire a constraint which is only a weak predictor of syntactic structure (see Trueswell & Gleitman 2004 for discussion).

## 18.5 Syntactic priming

While most researchers have used online methods to explore the processes that are involved in language comprehension, these methods can also give us insight into the nature of children's linguistic representations. In our recent work on priming, Malathi Thothathiri and I have used an eye-movement paradigm to explore how children represent argument structure.<sup>2</sup>

Languages have systematic correspondences between syntactic relations, such as subject and object, and semantic categories, such as agent and patient or theme. These correspondences allow us to interpret who did what to whom, even when the verb in the sentence is novel. For example, in (4) we all know who the culprit is – even if we never encountered this particular verb and harbour no prejudices against motorists.

<sup>2</sup> Allen discusses argument structure in Ch. 13.

## (4) The driver doored the cyclist

Tomasello and colleagues have suggested that young preschoolers use templates based on the behaviour of individual verbs to guide comprehension and production (Tomasello 1992 and see Ch. 5). For example, a young child might have a template for the verb *hit* that captures the knowledge illustrated in (5) and another template for *pinch*, illustrated in (6)

(5) \_\_\_<sub>X</sub> hit \_\_\_<sub>Y</sub>, where X = hitter, Y = hittee

(6) \_\_\_<sub>A</sub> pinch \_\_\_<sub>B</sub>, where A = pincher, B = pinchee

With these templates children would be able to interpret and produce new utterances with the same verb (such as *The taxi hit the delivery van*). But since the item-based templates do not include abstract syntactic and semantic relations, they would provide no guidance for interpreting utterances with novel verbs like that in (4). Thus, to evaluate children's linguistic representations, researchers typically examine children's comprehension and production of sentences with novel verbs. Almost two decades' worth of research has yielded mixed results and contrasting interpretations. Many novel-verb production studies show limited generalization in young children (Tomasello 2000c) but these results are contradicted by novel-verb comprehension studies that demonstrate robust generalization in children as young as 21 months of age (Gertner *et al.* 2006).

But both types of findings are open to alternate interpretations. Subtle aspects of verb meaning can constrain the use of verbs in sentence structures. For example, *Give me a cookie* is grammatical while *Pull me a cookie* is not (see Pinker 1989). Thus, children may fail at a novel-verb generalization task simply because they have failed to grasp the exact meaning of a new verb (Fisher, 2002a). Conversely, success at a novel-verb task could reflect the use of problem-solving strategies that are unique to novel stimuli, rather than the use of abstract representations (see Ninio 2005, Thoathathiri & Snedeker 2008).

Most of the concerns about novel-verb studies stem from their placing children in situations where they are faced with unfamiliar linguistic input. Structural priming is a method by which we can circumvent these issues to explore how utterances with known verbs influence one another. This technique has long been used to investigate the representations that underlie language production in adults (Bock 1986). For example, adult participants are more likely to produce a passive sentence (e.g. *The man was struck by lightning*) after reading a passive sentence (e.g. *The president was confused by the question*) than after reading an active sentence (e.g. *The question confused the president*). Since the two constructions express the same semantic relations, priming can be attributed to syntactic representations or mappings between syntax and semantics. Furthermore, since priming occurs despite the fact that the primes and targets use different nouns and verbs, we can infer that adults have

abstract representations that capture the similarities between these sentences.

Production priming has only recently been used to study the nature of children's linguistic abstractions. Some researchers have found evidence for abstract structural priming in three- and four-year-old children (Huttenlocher *et al.* 2004, Song & Fisher 2004). Others have not (Gamez *et al.* 2005, Savage *et al.* 2003).

Recently we developed a novel paradigm that combines structural priming and eye-gaze analyses to investigate priming during online comprehension. Since production tasks are often more difficult for children than comprehension tasks (Hirsh-Pasek & Golinkoff 1996), this may provide a more sensitive measure of children's linguistic knowledge. Because eye-gaze paradigms provide information about how an interpretation changes during processing, this method allows us to explore the locus of the priming effect and rule out alternate explanations that have been proposed for production priming (e.g. priming of the preposition *to*). Critically, this technique allows us to explore the representations that children use when understanding sentences with verbs that they already know. If children have item-specific representations (as assumed under the verb island hypothesis, see Ch. 5) then we would expect priming within verbs but not between verbs. In contrast if children have abstract syntactic or semantic categories, then we would expect to see between-verb priming.

The critical sentences in these studies used dative verbs. Dative verbs, such as *give*, *bring* or *send*, typically appear with three arguments: an agent, a recipient and a theme. In English there are two ways in which these arguments can be expressed, as shown in (7). In the prepositional object construction (7a) the theme appears as the direct object while the recipient is expressed by the prepositional phrase marked by *to*. In the double object construction (7b) the recipient is the direct object while the theme is expressed as a second noun phrase.

- (7) a. Tim gave a half-eaten pomegranate to Chris.  
 b. Tim gave Chris a half-eaten pomegranate.

Datives are well-suited for developmental studies of priming. The two dative constructions have the same basic meaning and differ only in how the semantic roles get mapped onto syntactic elements. Thus, priming using datives offers a reasonably clear case of structural priming independent of semantics. In addition, both dative constructions are acquired quite early; children appear to comprehend and produce both forms by age three (Campbell & Tomasello 2001, Gropen, *et al.* 1989).

Children were given sets of trials which consisted of filler sentences, followed by two prime sentences, and then a target sentence. The primes were either direct object or prepositional object datives and the final target sentence was also a direct object or prepositional object dative. Our goal

was to determine whether direct object and prepositional object datives would prime the interpretation of subsequent utterances that used a different verb and had no common content words. For example, would hearing *Send the frog the gift* facilitate comprehension of *Show the horse the book*?

To link this priming to eye movements we made use of a well-studied phenomenon in word recognition, the cohort effect (Marslen-Wilson & Welsh 1978). As a spoken word unfolds, listeners activate the lexical items that share phonemes with the portion of the word that they have heard. In the visual world paradigm, this process results in fixations to the referents of words that share phonemes with the target word (Allopenna *et al.* 1998). These effects are particularly strong at the beginning of a word, when all of the phonological information is consistent with multiple words (the members of this cohort). In our studies we used priming as a top-down constraint which might modulate the activation of different members of a phonological cohort.

The target trials were either double object (8a) or prepositional datives (8b).

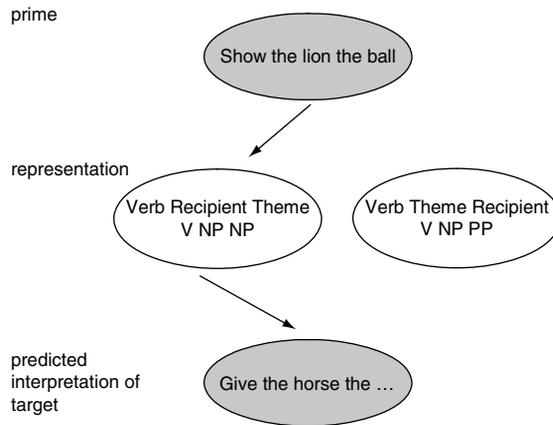
- (8) a. Bring the monkey the hat.  
b. Bring the money to the bear.

The set of toys that accompanied the utterance contained two items that were phonological matches to the initial part of the direct object noun. One was animate and hence a potential recipient (e.g. a monkey) while the other was inanimate and hence a more likely theme (e.g. some money). Thus the overlap in word onsets (e.g. *mon ...*) created a lexical ambiguity which was tightly linked to a short-lived ambiguity in the argument structure of the verb. We expected that priming of the direct object dative would lead the participants to interpret the first noun as a recipient, resulting in more looks to the animate match, while priming of the prepositional object dative structure would lead them to interpret it as a theme, resulting in more looks to the inanimate match.

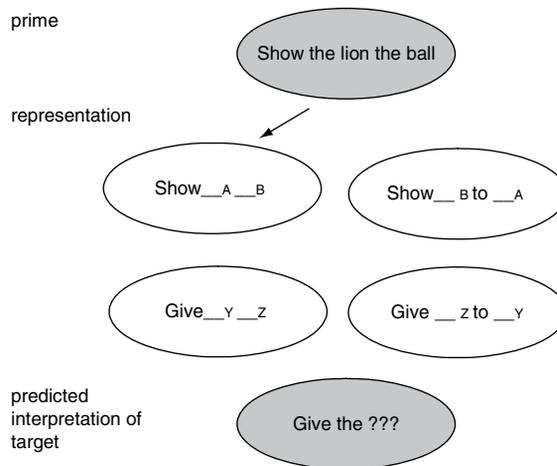
To validate our paradigm, we began by examining priming between utterances which shared the same verb (within-verb priming). Since both item-based grammars and abstract grammars posit shared structure between utterances with the same verb, within-verb priming would be consistent with either theory. We found that young four year olds showed robust within-verb priming during the ambiguous region. Young three year olds were slower in interpreting the target sentences, but when we expanded the analysis window to include the whole sentence, we found a reliable priming effect. Children who had heard double object primes were more likely to look at the potential recipient (the monkey) than children who had heard the prepositional object primes.

To examine the nature of the structures that children use, we conducted parallel experiments in which the prime and target utterances had no

(a) Abstract structural representations



(b) Item-based frames



**Figure 18.4** Predictions for the between-verb conditions in the priming experiment (Thothathiri & Snedeker 2008).

content words in common (between-verb priming). Under these circumstances the abstract grammars predict priming, while item-based grammars do not (see figure 18.4).

We found that both young four year olds and young three year olds showed between-verb priming. In the three year olds the effect of between verb-priming was almost as large as the effect of within-verb priming, indicating that there was no benefit gained when the two utterances shared a verb. This would suggest that abstract representations play a dominant role in online comprehension in this age group.

## 18.6 Current issues in children's sentence processing

In this chapter I have described a few studies which illustrate how eye-movement paradigms have been used to study children's sentence processing. The studies on ambiguity resolution demonstrate that four-year-old children, like adults, draw on information from multiple levels of linguistic representation to construct syntactic analyses. While children may fail to make use of some information (like referential context), they rapidly use both lexical and prosodic information to guide their interpretation of an ambiguous phrase. The priming studies demonstrate that children as young as three have abstract grammatical representations which they employ during online comprehension.

However both sets of studies leave many questions unanswered. What is the nature of these abstract representations? And do they shape comprehension in even younger children? Why do four and five year olds fail to revise syntactic misanalyses (Trueswell *et al.* 1999)? Do they fail to notice the error or are they incapable of fixing it? Do younger children also use lexical and prosodic information during parsing?

In the past decade, there has been considerable progress in the study of children's online language processing. In addition to the phenomena we describe here, other researchers have addressed word recognition (Fernald *et al.* 2008), morphological processing (Clahsen 2008), reference resolution (Sekerina *et al.* 2004, Song & Fisher 2005) and the calculation of pragmatic inferences (Huang & Snedeker, 2006), among other topics. Crosslinguistic work is gaining momentum (Choi & Mazuka, 2003; Clahsen 2008; Sekerina & Brooks 2007). New techniques are being developed. There is good reason to believe that the next ten years will bring us even closer to understanding how language comprehension develops.

### Suggestions for further reading

- Clahsen, H. (2008). Behavioral methods for investigating morphological and syntactic processing in children. In I. Sekerina, E. Fernández & H. Clahsen, (Eds.), *Developmental Psycholinguistics: Online Methods in Children's Language Processing*. (pp. 1-27). Amsterdam: Benjamins.
- Fernald, A., Zangl, R., Portillo, A. L., & Marchman, V. A. (2008). Looking while listening: Using eye movements to monitor spoken language comprehension by infants and young children. In I. Sekerina, E. Fernández & H. Clahsen, (Eds.), *Developmental Psycholinguistics: Online Methods in Children's Language Processing*. (pp. 97-135). Amsterdam: Benjamins.
- Snedeker, J., & Thothathiri, M. (2008). What lurks beneath: Syntactic priming during language comprehension in preschoolers (and adults). In I. Sekerina, E. Fernández & H. Clahsen (Eds.), *Developmental*

*Psycholinguistics: OnLine Methods in Children's Language Processing* (pp. 137-167), Amsterdam: Benjamins.

Trueswell, J., & Gleitman, L. R. (2004). Children's eye movements during listening: Evidence for a constraint-based theory of parsing and word learning. In J. M. Henderson & F. Ferreira, (Eds.). *The Interface of Vision, Language, and Action* (pp. 319-346). New York: Psychology Press.

