Language development in children with Williams syndrome:
Genes, modularity, and the importance of development
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28.1 Introduction
One of the most intriguing and important facts about language is that it reliably emerges in
generation after generation of human children. Parents don’t need to teach their children
language, just as they don’t need to teach them how to walk or recognize faces. Walking, face
recognition, and language are all things that just happen on a relatively predictable
developmental timeline—at least in the typical case. The sheer reliability of the timetable and
end result of language learning is what tells us that it is part of the human genetic endowment.
The reliability of language in humans contrasts starkly with the absence of language learning in
other species. The most arduous training regimes in non-human species result in only very slow
vocabulary growth, a low ceiling for total numbers of words, and extremely limited means of
combining words (Hauser, Chomsky, & Fitch, 2002; Premack, 2004; Terrace, 1983). Our genes
are crucial for developing language, just as they are crucial for supporting our ability to walk and
recognize faces. Of course, that’s not the end of the story, but only the beginning. How exactly is
the capacity to learn language encoded in our DNA and implemented in nascent brain structures?
How does language develop from infancy to the mature state?

In this chapter, our test case for investigating the role of genes in language development
is Williams syndrome (WS), a genetic condition associated with the deletion of about 26 genes
(1.6 mb) on chromosome 7 (Morris, 2006). As adults, people with WS have sophisticated
language skills despite limitations in their overall cognitive ability and severe impairments in
spatial cognition (Bellugi, Marks, Bihrlle, & Sabo, 1988; Howlin, Davies, & Udwin, 1998; Mervis C. B., Bertrand, Morris, Klein-Tasman, & Armstrong, 2000). However, language learning is initially delayed compared to typically developing children (Mervis & Klein-Tasman, 2000; Thal, Bates, & Bellugi, 1989; Chapter 27, this volume).

To fully understand the relationship between the genetic difference and the nature and development of language in WS, we need to investigate it at many different levels. We could ask about the biological functions that are dependent on the missing genes, or about differences in brain structure and function that result from the missing genes. Here, we concentrate on knowledge of language at the cognitive level. Our goal is to characterize the language system acquired by people with WS, and ask whether it is in any fundamental way different from the system acquired by individuals without WS, who have a normal complement of genes.

This strategy capitalizes on the chief advantage of studying language compared to other cognitive domains: linguistic theory provides the tools to describe what ‘knowledge of language’ consists of. We can precisely characterize and explain the various symbolic representations at different levels—sounds, words, and structured groups of words—that a human would need to speak or understand any given sentence. As a result, we can ask focused questions about the development of linguistic knowledge. What kinds of linguistic representations are implemented in the nascent brain? How do linguistic representations change over the course of language learning? What information in the learner’s environment is available and relevant for deducing the nature of linguistic representations? Throughout the chapter, we emphasize how linguistic theory allows us to formulate detailed, testable hypotheses about the nature and development of language in WS.
Observations about language in people with WS should be interpreted with respect to two distinct questions. The first question concerns the existence and nature of linguistic knowledge: do people with WS acquire a language system that is characterized by the same structures and principles as typically developing individuals? We argue that this question can be answered simply by investigating whether people with WS show sensitivity to the same linguistic principles as typical adults. The second question concerns how that linguistic knowledge is acquired. If people with WS acquire the same system as typically developing individuals, do they do so in the same way, using the same learning mechanisms? One way to address this question is to investigate whether the order and timetable of language development is the same in WS as in typical development. For this reason, we argue that it is important to compare the performance of people with WS to that of typically developing children across a wide range of ages.

We start by providing a brief background on the initial observations of language among people with WS. We then lay out a debate that has organized much of the literature on this topic. The central question is whether language learning in people with WS results in a system of linguistic knowledge that has the key properties of the system acquired by typically developing people. Although the ongoing debate in the literature highlights a contrast between two sharply different points of view, we argue that the generation and interpretation of empirical data has not always been clearly related to evaluating true theoretical competitors.

In the end we argue that the available evidence strongly supports the idea that people with WS develop a computational system for language with the same properties as that of typically developing people. This conclusion has two important implications. First, the genes that are missing in WS cannot be those responsible for human language. Second, the genetically determined learning constraints that guide human language development are not easily disrupted
in the face of impairments in other cognitive domains. However, we will also argue that people with WS show a significantly prolonged developmental trajectory for acquiring many aspects of language—a fact that is likely the consequence of the genetic disorder, but one that is not specific to language per se and has no consequences for the structures or principles underlying language in WS.

28.2 Background

The earliest reports of language in adolescents with WS showed that they have a rich vocabulary and control complex sentence structures, and yet perform poorly on simple tasks like ordering objects by size and copying geometric figures (Bellugi, Marks, Bihrlé, & Sabo, 1988; Bellugi, Bihrlé, Jernigan, Trauner, & Doherty, 1990). This uneven cognitive profile led Bellugi and colleagues to propose that language in people with WS is ‘spared’ despite profound deficits in other areas of cognition—essentially, that the end result of language development is the same in WS as in typical children (Bellugi, Marks, Bihrlé, & Sabo, 1988; Bellugi, Bihrlé, Neville, Doherty, & Jernigan, 1992). They argued that this sparing of language could support the hypothesis that language development is largely independent of other non-linguistic cognitive functions (Fodor, 1983), and some linguists enthusiastically agreed (Jackendoff, 1994; Pinker, 1999). This proposal of ‘modularity’ challenged the Piagetian view that language emerges as the result of the development of a more general symbolic representation system, and thus depends on more general cognitive growth (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Piaget, 1963).

Another line of research demonstrated that early language development in young children with WS is substantially delayed (Mervis & Klein-Tasman, 2000; Thal, Bates, & Bellugi, 1989). For example, children with WS have significant delays in their vocabulary onset and
development, reaching a 100-word productive vocabulary at about 41 months on average, compared to 18-20 months for typically developing toddlers (Mervis & Becerra, 2007). If language were completely independent of other cognitive systems and spared in WS, we would not expect any disruption to the reliable developmental timetable observed in typical children. Based on this observation, and the fact that people with WS usually perform at or below the level of children matched in mental age when they are tested in the lab, some researchers have argued that language is not, in fact, spared in WS. Karmiloff-Smith and colleagues have proposed that no cognitive domain can be spared the effects of genetic deletion. In a developmental disorder like WS, the atypical starting point leads inevitably to atypical developmental trajectories and atypical endpoints (Karmiloff-Smith, 1998). This alternative, consistent with ‘neuroconstructivist’ views of cognitive development, maintains that the effects of genetic deletion hold at all levels of analysis, including brain changes and—most important for this chapter—accompanying changes in knowledge of language at the level of cognitive representations (Karmiloff-Smith, 1998; Thomas & Karmiloff-Smith, 2005).

In this chapter, we will examine the empirical evidence on language learning in WS in the context of the modularity hypothesis and the neuroconstructivist hypothesis. A Google Scholar search for papers on language in WS now returns nearly 300 hits, demonstrating the compelling nature of the topic for scientists and clinicians. Much of the scientific interest has arisen from theoretical stakes in the two hypotheses. Before we explain the debate, however, it is important to be clear about what we want to know about language in WS. That is, what questions are these two hypotheses supposed to address? The framework that we adopt makes certain (largely uncontroversial) assumptions, which we now lay out.
First, we assume that in order to study any aspect of cognition, we must choose a level of analysis that allows us to advance clear, testable hypotheses. In the domain of language, it is critical to distinguish between knowledge of language—often called language competence—and the use of that knowledge for learning, speaking, and understanding—performance (Chomsky, 1965). This distinction between knowledge and use may be easier to understand through an analogy to arithmetic. Most adults with an elementary education understand how multiplication works: they have knowledge of the principles underlying multiplication, or multiplication competence. They are able to use that knowledge in a variety of ways: they can answer questions like, ‘What is 24 times 3?’ or estimate how much they will have to pay if they buy two boxes of cereal instead of one. However, there are limits on their performance with multiplication. They may make mistakes in their calculations, or fail to answer question like, ‘What is 45 times 67?’ without using pencil and paper. These limitations have nothing to do with their multiplication competence. In the same way, people often demonstrate limitations in their language performance that have nothing to do with their language competence. To take a simple example, people of all ages have ‘tip of the tongue’ experiences, where they can’t remember a word, but we would not want to say that they have lost knowledge of that word.

Linguistic theory gives us the tools to characterize language competence. We can describe the properties of linguistic representations in great detail. For example, linguistic theory can explain the difference in meaning between the two rather complex sentences in (1) and (2).

(1) The cat who meowed did not get milk or cheese.

(2) The cat who did not meow got milk or cheese.

Reading these two sentences, we immediately understand that in sentence (1), the cat got neither milk nor cheese—he didn’t get milk and he didn’t get cheese. We also understand that in
sentence (2), the cat got *either* milk or cheese. Thus cat (1) goes hungry, and cat (2) gets something to eat. How do we know the difference in meaning between these two sentences? It cannot be the numbers of words (which are equal) nor the choice of words (which are roughly the same), nor any other superficial characteristics of the sentences. The answer concerns the interaction of the negation element (*not*) and the disjunction element (*or*) over syntactically-defined parts of the sentence structure. Although we do not formally learn these facts unless we take a linguistics course, 4-year-old typically developing children recognize the difference in meaning between the two sentences. As it turns out, so do people with WS (Musolino, Chunyo, & Landau, 2010). Knowledge of language—linguistic *competence*—accounts for our ability to interpret the two kinds of sentences appropriately and differently.

Thus, one thing we can ask about language in people with WS is whether it reflects the same competence that typically developing people have. Do their linguistic representations have the same complex structures?

Our second assumption is that many cognitive mechanisms that are not specific to language are involved in processing linguistic information for the purpose of learning, speaking, or understanding. Long-term memory, working memory, and controlled attention have been implicated in adult language processing (Caplan & Waters, 2013; McElree, Foraker, & Dyer, 2003; Novick, Trueswell, & Thompson-Schill, 2005). You can’t comprehend a sentence unless you can remember the words in the sentence long enough to compute the structure and corresponding meaning. For example, center-embedded sentences like ‘The sentence the linguist the psychologist saw produced sounded better’, are notoriously difficult to understand. The difficulty arises because we have limited ability to hold the different parts of the sentence in mind and keep them distinct as we attempt to compute the embedded structure, not because we
do not have the fundamental capacity to represent the sentence’s structure. Sentences with the same structure that place less burden on memory and control mechanisms (not by being shorter, but by reducing the similarity of the parts) are much easier to process, as demonstrated by the previous example in its original form: ‘Isn’t it true that example sentences that people that you know produce are more likely to be accepted?’ (De Roeck et al., 1982, cited in Lewis, 1996).

Variation in these non-linguistic functions due to normal development or impairment may be responsible for some differences in language ability between children, adults, and individuals with developmental disorders (Baddeley, 2003; Choi & Trueswell, 2010; Im-Bolter, Johnson, & Pascual-Leone, 2006; Mazuka, Jincho, & Oishi, 2009; Trueswell, Sekerina, Hill, & Logrip, 1999). Thus, we can also ask how language learning and language use—aspects of performance—are affected by the genetic and cognitive deficits associated with WS. Memory and executive function seem to be affected in WS (Brock, 2005; Rhodes, Riby, Park, Fraser, & Campbell, 2010; Vicari, Brizzolara, Carlesimo, Pezzini, & Volterra, 1996; Vicari, Carlesimo, Brizzolara, & Pezzini, 1996), so we might expect language development and processing to be slower or more error-prone. For our purposes, it is most important to determine whether these performance impairments also cause qualitative changes in the fundamental properties of the linguistic knowledge system that is acquired.

With these preliminaries in mind, we now turn to a review of the two frameworks that have guided studies of language in WS—modularity and neuroconstructivism. Following this, we present the empirical evidence, which we believe favors the modularity view.

28.3 Modularity and neuroconstructivism
These two hypotheses are at present the most widely cited theoretical options for explaining the nature of language in people with WS. As we will now see, they collide most significantly in
their proposed explanation of how core aspects of language, e.g. grammar, arise during development, and therefore make quite different predictions about the nature of the grammatical knowledge to be observed in people with WS.

28.3.1 Modularity

In Bellugi’s original framing of the modularity hypothesis, language development in WS is a test bed for a more general hypothesis about the nature of the human language capacity: “One long-standing model of the relationship between language and cognitive development asserts that the two are closely intertwined and that language is one manifestation of a more general symbolic representation system whose development causes and constrains the major events of language acquisition. … A second model argues for the existence of uniquely linguistic mental structures and learning mechanisms specific for language (e.g., Fodor, 1983)” (Bellugi, Bihrlle, Neville, Doherty, & Jernigan, 1992, p. 207).

Bellugi argued that the relative sparing of language in WS constituted evidence for the second model. If language development relied solely on general purpose representation systems and learning mechanisms, it would surely be seriously impaired in WS.

The modularity hypothesis is sometimes described in its most extreme version, in which language is completely spared in WS, developing exactly as it does in chronological age-matched, typically developing children. This version of the hypothesis is clearly false: we know that language development in WS is delayed compared to typical development, and that performance on language tasks is often worse than that of age-matched controls.

We prefer a version of the modularity hypothesis that is more theoretically and empirically plausible in virtue of distinguishing between language competence and performance. As we mentioned above, there is little doubt that language learning, comprehension, and
production all draw on cognitive mechanisms that are not ‘uniquely linguistic’, such as working memory and cognitive control, and these mechanisms are impaired in WS. For example, people with WS seem to have the phonological working memory capacity of children matched in mental age (Brock, 2005; Jarrold, Baddeley, & Hewes, 1999; Vicari, Carlesimo, Brizzolara, & Pezzini, 1996). These deficits will surely increase the difficulty of processing complex sentences under some conditions. However, such difficulties would have nothing to do with linguistic competence. Going back to our earlier examples, no one would argue that the difficulty of computing the product of 24 x 67, or understanding ‘The rat the cat the man saw chased jumped’, indicates fundamental damage to a person’s knowledge of arithmetic or language, respectively. We want to isolate the question of whether people with WS have intact linguistic competence from questions about impairments in their language performance mechanisms. We want to test the hypothesis that there are language-specific mental structures that are unaffected by abnormalities in the genes, brains, or experience of people with WS.

This version of the modularity hypothesis predicts the ‘sparing’ of some aspects of language, while allowing for delays and other variation in language learning in children with WS. Specifically, adults with WS should have the same knowledge of their native language as typical adults do. We assume that since the information available in the environment dramatically underdetermines the target system, the language-specific learning mechanisms are highly constrained—there are not many different routes to the right answer (Chomsky, 1965). Therefore, children with WS should not, at any point of development, have qualitatively different linguistic representations from the ones that form the target system. However, their cognitive

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1 By comparison, their spatial working memory is much worse than would be expected based on their mental age (Jarrold, Baddeley, & Hewes, 1999).
deficits may make language learning and language processing slower and noisier, so it would be natural to see delays and imperfect performance on language tasks and indeed, we might even expect these to a greater degree than for typically developing children. Critically, to test the modularity hypothesis, one must test language competence, factoring out the effects of other cognitive deficits on language performance.

28.3.2 Neuroconstructivism

Like the modularity hypothesis, the neuroconstructivist hypothesis also takes language development in WS as a test for a more general hypothesis about human cognition. Broadly, neuroconstructivists argue that human cognitive capacities—including language—emerge through ‘dynamic, multidirectional interactions between genes, brain, cognition, behavior, and environment’ (Karmiloff-Smith, 2009; Chapter 27, this volume). Since people with WS have genes and brains that are atypical in a number of ways, the interactions between brain and environment will also be atypical. These atypical interactions cascade forward in development, neuroconstructivists argue, such that the final product cannot be the same as in typically developing children and adults.

We take the broad argument of neuroconstructivism to be uncontroversial. There is no doubt that the complex interactions between genes, brain, cognition, behavior, and environment are essential to development. In that respect, neuroconstructivism is not in conflict with modularity (Barrett & Kurzban, 2006). To take the next step theoretically and empirically, we have to not only posit that such complex interactions exist, but actually investigate them. To understand a particular case—language development in WS, for example—we must have specific hypotheses about how these interactions play out. To our knowledge, such hypotheses have not been forthcoming.
Neuroconstructivists generally reject the distinction between competence and performance (Thomas, Karaminis, & Knowland, 2010, p. 164), arguing that any performance below chronological or mental age level is evidence that the relevant skill is not intact (Karmiloff-Smith, 2009; Thomas, Karaminis, & Knowland, 2010). However, as we have already discussed here and at length elsewhere (Musolino & Landau, 2010; Musolino & Landau, 2012), overall poorer performance than typically developing controls is not incompatible with the modularity hypothesis. The only way to put the two hypotheses on the same playing field is to consider a version of the neuroconstructivist view that acknowledges the competence-performance distinction.\(^2\) Under this more specific version of the neuroconstructivist hypothesis, the mechanisms responsible for language competence—the development of language knowledge—are not resistant to variation in the environment and other cognitive systems. That is, the hypothesis predicts that in people with WS, atypical interactions between genes, brain, cognition, behavior, and environment will lead to qualitatively different linguistic representations, unlike those acquired by typically-developing children. This hypothesis predicts that, in the absence of some alternative learning strategy, people with WS will not show the same language knowledge as typical adults.

28.3.3 Summary and caveats

Modularity and neuroconstructivism do not differ in supposing that a range of cognitive deficits could affect language processing and development. They do, however, differ in their

\(^2\) This move is actually consistent with some aspects of the neuroconstructivist approach. Neuroconstructivists want to have their cake and eat it by arguing that a skill cannot necessarily be assumed to be intact if performance is in the normal range, since normal performance might be achieved with atypical cognitive processes (Karmiloff-Smith, 2009, p. 57). Ironically, this argument relies on a distinction between competence and performance.
assumptions about cognitive architecture. Under the modularity hypothesis, it is possible for a cognitive function like language to be independent of other cognitive functions in some meaningful way. Therefore, language competence could be intact in a case like WS. Under the neuroconstructivist hypothesis, it is not possible for a cognitive function to be independent. Therefore, language competence could not be intact in WS.

It is an empirical question whether people with WS possess the same linguistic competence as typically developing individuals. Unfortunately, many published studies were not designed in a way that allows us to assess competence. Still, there are empirical studies that either directly or indirectly provide relevant data, and we will review this evidence shortly. We focus on a few illustrative cases so that we can fully explain the logic of each case. For a more exhaustive discussion of research on language in WS, see the comprehensive reviews by Brock (2007), Mervis and Becerra (2007), and Landau and Hoffman (2012). To foreshadow, we believe that the relevant empirical evidence supports the modularity view.

28.4 The empirical evidence
Our review focuses on cases where we can rigorously evaluate the acquisition and control of linguistic structure in people with WS. Syntax (sentence structure) and morphology (word structure) are good cases for testing the hypotheses of modularity and neuroconstructivism, for two reasons. First, linguistic theory allows us to precisely characterize the structures and rules that constitute competence in syntax and morphology. That is, we know what knowledge we’re looking for. Second, and more importantly, both domains offer examples of complex structure that typically developing children acquire by mere exposure to linguistic input, without formal tutoring. Because these systems are characterized by structures and rules that appear to be specific to human language, they offer prima facie cases of knowledge whose acquisition should
emerge relatively independently of other non-linguistic cognitive systems. Under the modularity hypothesis, the end result of the acquisition process should be knowledge that does not vary across learners, although performance factors like executive control and working memory may affect the level at which a child (or adult, for that matter) performs on a particular task tapping this knowledge and/or the chronological age at which the knowledge can be shown. By contrast, the neuroconstructivist hypothesis would predict that variations in non-linguistic cognitive functions should have significant impact on the nature of the system that is acquired. In this view, a learner with WS would be likely to construct syntactic and morphological systems that are qualitatively different from those of a typical learner.

Before we review the literature, however, it is useful to discuss some methodological considerations that are critical to interpreting the results. How do we actually determine whether language competence is intact, in people with WS or anyone else? There are several approaches to this problem, reflecting different assumptions about what counts as ‘intact’.

One option is to compare people with WS to typically developing (TD) individuals who are matched for chronological age (CA). Such control groups have been used in a number of studies (e.g. Bellugi, Marks, Bihrle, & Sabo, 1988; Tager-Flusberg, Boshart, & Baron-Cohen, 1999; Tager-Flusberg, Plesa-Skwerer, Faja, & Joseph, 2003). This approach assumes that ‘intact’ language competence means behavior that is indistinguishable from that of TD children and adults. There are two problems with this approach. First, almost anyone would agree that because individuals with WS are moderately retarded, this may be setting the bar too high; deficits in general cognitive processes such as working memory could easily affect performance even if the system of knowledge is intact. Second, even if people with WS show performance comparable to typically developing individuals of the same CA, TD individuals may have
achieved that level of performance at a much earlier age. If the same knowledge shown by TD and WS adolescents is also shown by TD 6-year-olds, then we should draw different conclusions about the performance of the individuals with WS (Karmiloff-Smith, 1998).

The first of these reasons has most generally led investigators to use comparison groups of TD children who are matched to the WS individuals in mental age, which is usually determined from raw scores on standardized IQ tests. In our own studies, the mental age matches for adolescents with WS usually turn out to be roughly 6 years old. This approach is thought to remove the effect of general mental retardation, leaving any differences between groups due to the variable of interest—in this case, knowledge of language. This approach also is problematic, because it assumes that we know what standardized measures of intelligence actually measure—an assumption we question. Even if one constructed control groups equated on a more specific variable of interest—say, working memory—one would need a clear idea of how working memory affects the language skill or task under study. Findings sometimes show equivalent performance to typically developing MA matches (e.g. Clahsen & Almazan, 1998; Perovic & Wexler, 2007; Thomas, Grant, Barham, Gsödl, Laing, & Lakusta, 2001), but other times do not (e.g. Karmiloff-Smith et al., 1997; Landau & Zukowski, 2003; Musolino, Chunyo, & Landau, 2010; Zukowski, 2004). Unless we think that mental age matching is meaningful, this comparison is not informative. We do not think it is meaningfully related to the question of whether people with WS have linguistic competence that is the same as typically developing individuals.

Another common approach is to compare people with WS with people who have developmental delays from some other cause. In some cases, such comparison groups may be equated on both mental and chronological age. However, in addition to the general problem with
MA matching cited above, this approach has the additional problem of introducing more unknowns. For example, in Bellugi's early studies (e.g. Bellugi et al., 1998), she compared language and spatial representation in people with WS and people with Down syndrome (DS). People with WS showed better performance on language tasks than MA-matched individuals with DS, leading to the conclusion that language in WS is a distinct strength. However, given what we now know, it is more likely that language in DS is a distinct weakness (see Chapter 27, this volume).

In our own research program, we take two approaches to addressing these issues. First, in cases where competence is well defined—as in the syntax and morphology cases we discuss below—we use tasks where the presence or absence of knowledge can be assessed without reference to a control group. We discuss these methods in more detail below. Second, when we want to assess performance in addition to competence, we compare people with WS to TD people across a range of ages, including adolescents and adults when appropriate. This approach emphasizes the importance of understanding typical developmental profiles in order to understand the atypical ones. We are able to ask whether developmental trajectories are qualitatively different in people with WS, including delays, slower growth trajectories, or developmental arrest (Landau & Hoffman, 2012; Rice, Wexler, & Hershberger, 1998; Rice, 2012). Although comparisons across a wide age range of typically developing children are rarely used as control groups within single studies, we can often compare data across studies to generate the appropriate comparisons.

28.4.1 Sentence structure (syntax)

Do people with WS eventually end up with the same grammatical competence as typically developing children and adults? How would we know? One way to assess someone’s language
ability is to observe the language they produce (e.g. (Levy & Eilam, 2013). However, although spontaneous production is a good indicator of a person’s overall level of language functioning, it is not necessarily informative about grammatical competence. Errors in spontaneous production are often due to processing limitations: even typical adults make speech errors on occasion, producing ungrammatical sentences. Seemingly perfect spontaneous production can also be misleading, as in the case of a child who fluently rattles off complex monologues memorized from television shows. Carefully controlled elicitation tasks can avoid the latter pitfall by requiring the speaker to generate a novel sentence.\textsuperscript{3} Even then, however, poor performance can be difficult to interpret.

A second strategy for investigating grammatical knowledge is to assess comprehension of complex sentences. One common type of comprehension task requires subjects to identify a picture that matches the meaning of a sentence. The Test for Reception of Grammar (TROG, Bishop, 1983) uses this strategy to assess comprehension of a number of complex structures. A well-designed picture-matching task must provide tempting alternative responses, to give the subject a chance to make a reasonable but incorrect choice. If this criterion is met, above-chance accuracy can be interpreted as evidence for grammatical competence. However, poor accuracy is not necessarily informative, as processing limitations can have negative impact on performance. For example, successfully choosing from multiple options requires the subject to systematically

\textsuperscript{3} Although sentence repetition tasks have also been used to evaluate grammar in production among people with WS (Grant, Valian, & Karmiloff-Smith, 2002; Vicari, et al., 2004; Volterra, Capirci, Pezzini, Sabbadini, & Vicari, 1996), neither success nor failure on such tasks is particularly informative about underlying knowledge of language. On the other hand, they may be quite useful for evaluating memory and its role in both comprehension and production.
evaluate each option and inhibit incorrect responses. This may be more difficult for children or people with cognitive deficits.

One technique considered by linguists to be the gold standard for assessing grammatical competence involves eliciting people’s judgments of acceptability or interpretation. Adults can demonstrate their knowledge of the complex structures of their native language by discriminating grammatically acceptable sentences from unacceptable sentences. For example, a competent speaker of English knows that although (3a), (3b), and (4a) are acceptable, (4b) is unacceptable (indicated with an asterisk), despite being superficially very similar. The only way to arrive at that judgment is through detailed knowledge of the relevant syntactic rules. Thus, even if a person’s responses are noisy due to processing difficulty, any performance that is reliably better than chance is evidence for underlying grammatical knowledge.

(3) a. Which race do you think John won?
   b. Which race do you think that John won?

(4) a. Who do you think won the race?
   b. *Who do you think that won the race?

Although acceptability judgments are a very efficient tool for assessing competence, they are sometimes difficult to elicit from people with low metalinguistic awareness, including children and people with WS. Truth-value judgments, which make use of the meaning of the sentence, are easier to embed in child-friendly tasks and adaptable for adults with WS. In these tasks, people are presented with a scenario through a story or a picture, and then hear a sentence

Judgments of acceptability and truth obviously involve comprehension. Here we distinguish judgment tasks, which elicit yes/no responses, from comprehension tasks, which require the participant to do something else with the meaning of the sentence (e.g. choose a matching picture).
about the scenario. For example, given a scene in which a horse is kicking a cow, the participant would hear either, ‘The horse is kicking the cow’ or, ‘The cow is kicking the horse’. They are then asked to judge whether the sentence is ‘right’ or ‘wrong’ about the scenario. The patterns of such judgments across carefully controlled sets of scenarios and sentences can yield insight into the participant’s knowledge of the sentence structures and corresponding meanings.

With this toolbox of methods in mind, we now review findings about three different aspects of sentence structure: the interaction of negation and disjunction, passives, and the interpretation of pronouns (binding).

28.4.1.1 Case 1: The interaction of negation and disjunction
Musolino, Chunyo, and Landau (2010; see also Musolino & Landau, 2010) considered a case in which two elements of meaning—negation (not) and disjunction (or)—are complexly modulated by grammatical structure (see Chapter 18, this volume). De Morgan’s laws of propositional logic state that when the logical relation of disjunction is modified by negation, the result will be conjunction, as shown in (5). This is easy to see with an example. ‘Barbara ate green eggs or ham’ is true if she ate either green eggs or ham (the disjunction of green eggs and ham). But if we apply negation, ‘Barbara didn’t eat green eggs or ham’, we mean she ate neither: she did not eat green eggs and she did not eat ham (the conjunction of no green eggs and no ham), as shown in (6).

\[
\neg(P \lor Q) \iff (\neg P) \land (\neg Q) \quad [\text{not} \ (P \ or \ Q) \iff (\text{not} \ P) \ and \ (\text{not} \ Q)]
\]

\[
\neg(\text{green eggs} \lor \text{ham}) \iff (\neg \text{green eggs}) \land (\neg \text{ham})
\]

When negation and disjunction both appear in the same sentence, we need to know the hierarchical structure of the sentence in order to determine whether the negation actually modifies the conjunction so that the two combine in this way. Consider the sentences in (7) and
Reading (7), we know that the cat will get neither food. Reading (8), we know that the cat will get one or the other.

(7) The cat who meows will not be given a fish or milk.

(8) The cat who does not meow will be given a fish or milk.

The structures of the two sentences are rather different, and most importantly, that they differ in the hierarchical relationship between the two elements *not* and *or*. In (7) (Figure 1a), *not* dominates (c-commands) the verb phrase ‘get a fish or milk’. In (8) (Figure 1b), the same element lies in a lower clause, and does not dominate the verb phrase. The disjunctive term *or* lies within the scope of the negation element *not* in (7), so the two combine according to DeMorgan’s law: the cat will not get a fish *and* it will not get milk. *Or* does not lie within the scope of negation in (8), so the disjunction remains: the cat will get a fish *or* it will get milk.

Typically developing children show sensitivity to these structural differences by age 5 (Lidz & Musolino, 2002), a striking example of how children acquire subtle linguistic knowledge from only informal exposure to grammatical sentences. Using this study as a backdrop, Musolino, Chunyo, and Landau (2010) asked whether children, adolescents and adults with WS are also sensitive to these structural differences and able to compute subtle differences in meaning from sentences with such properties. Musolino et al. presented 12 children and adults with WS (mean age 16;4, range 11;10-21;11) with sentences and scenarios that tested understanding of the logical elements *not* and *or*, and their interaction within sentences. The study included two experimental and four control conditions. Experimental conditions contrasted sentences such as those in (7) and (8). Control sentences tested each syntactic/semantic property
of the experimental sentences in isolation, e.g., relative clauses only, disjunction only, or negation only.

Participants were tested using the truth value judgment task. They were presented with an animated visual scenario, and asked to judge whether a sentence was right about the scenario. For example, in one scenario, two cats were shown, one meowing. The meowing cat was given a fish; the other cat was given milk. Then participants heard a recording of a woman saying, for example, ‘The cat that meows will not be given a fish or milk’ and were shown the animation again. They were then asked “Is she right?” (In this case, no, since the meowing cat got a fish.) Each of the six conditions included eight test sentences, half true and half false.

Participants with WS performed very well in both the experimental and control conditions. They were correct on over 85% of the trials in the control conditions, and over 75% of trials in the experimental conditions. This above-chance performance by itself demonstrates that the WS participants had control over the hierarchical structures of the different sentence types, that they represented the negation and disjunction elements correctly, and that they computed the different sentential meanings appropriately. The fact that people with WS showed disproportionate difficulty with experimental items, compared to control items that tested each component independently, suggests that the experimental items may have been especially difficult to process.

Although the data demonstrate that the WS participants had the syntactic and semantic competence to interpret sentences like (7) and (8), their absolute accuracy in the experimental conditions was worse than that of typically developing children matched for mental age (5-7 years). Differences in absolute levels of performance between the groups do not reflect differences in linguistic knowledge, but they could well reflect differences in non-linguistic
processes such as working memory, which would be challenged by the complexity of the sentences we tested. In fact, Musolino et al. found that typically developing 4-year-olds performed worse (60-65%) than the TD 6-year-olds (88-92%) on the experimental sentences, but not the control sentences. (The WS group’s performance fell between that of the TD 4- and 6-year-olds.) The improvement in performance on the more complex sentences from age 4 to 6 likely reflects the growth of ancillary resources such as working memory.

In summary, the WS group’s high accuracy demonstrates that they have knowledge of the linguistic structures required for appropriate semantic interpretation. This knowledge can be shown by typically developing children by around 5 years of age. There are clear improvements in performance between age 4 and 6 that likely reflect the development of processing mechanisms that are not specific to language.

28.4.1.2 Case 2: Passives

One core aspect of grammatical knowledge is the mapping between thematic (semantic) roles and their grammatical expression as subject, object, etc. Although roles such as agent often appear in a sentence’s surface structure in subject position and patient in object position, the mapping can vary, and learners need to be able to recover the underlying semantic roles from information appearing in the surface structure. For example, an active sentence with a transitive verb like (9) usually describes an event where an agent (here, the banker) performs some action on a patient (the evidence). The agent is the subject of the sentence; the patient is the direct object. In a full passive sentence like (10), the mapping of semantic roles (agent and patient) onto structural positions changes: the patient is promoted to the subject position, while the agent is demoted to a prepositional phrase. In English, the passive voice is indicated morphologically on
the verb, which appears as a past participle following the auxiliary be (e.g. was destroyed instead of destroyed).

(9) The banker destroyed the evidence before the trial.

(10) The evidence was destroyed before the trial (by the banker).

Thus, one way to describe what adults know about passive sentences is that the morphology on the verb determines the mapping between semantic roles and structural positions. However, linguistic theory provides a deeper analysis of the passive construction, revealing that the relevant grammatical competence consists of several independent pieces of knowledge, demonstrated in (11). The fundamental function of the passive is to suppress the expression of the agent as subject, as in (a). Since English requires all sentences to have a subject, the former object of the verb moves to subject position, as in (b) (Chomsky, 1981). A by-phrase expressing the agent can optionally be adjoined to the verb, as in (c).

(11) a. The banker was destroyed the evidence before the trial.
    b. The evidence was destroyed the evidence before the trial.
    c. The evidence was destroyed before the trial (by the banker).

To determine whether people with WS achieve this grammatical competence, we should of course begin by assessing their understanding and use of passive sentences. Ideally, however, we should go further, to investigate whether they represent passive constructions in the same way as typical adults.

To our knowledge, production of passives in WS has not been systematically studied, although Bellugi and colleagues (1988) report appropriate use of passives in spontaneous samples. Several studies have investigated the comprehension of passives using picture-matching tasks. For example using the TROG, Bellugi et al. (1990) report that participants with WS
achieved accuracy above 90% for items involving passive sentences. Clahsen and colleagues (Clahsen & Almazan, 1998; Ring & Clahsen, 2005) used a picture-matching task with four choices to assess comprehension of active sentences and three types of passive sentences, shown in (12), by ten adolescents with WS. Although accuracy was not at ceiling (about 83% on average), it was far greater than chance (25%). The accuracy rate also did not differ from that of 5-7 year-old children, approximately matched in mental age to the WS participants.

(12)  
   a. Full passive: The teddy is mended by the girl.  
   b. Short passive: The teddy is being mended.  
   c. Potentially adjectival passive: The teddy is mended.

Using a similar picture-matching task with three choices, Karmiloff-Smith and colleagues (1998) investigated comprehension of passives (among other constructions) in eight adolescents and adults with WS. The participants with WS achieved 83% accuracy on passives with agentive verbs, and 67% accuracy on passives with non-agentive (psychological) verbs. This performance is again far better than chance (33%). Interestingly, the participants with WS showed the same pattern of relative difficulty across different types of sentences as elderly participants. This suggests that their imperfect performance is likely to be due to factors other than grammatical competence.

Perovic and Wexler (2010) compared comprehension of passives with action verbs (kiss, hold, and push) and psychological verbs (remember, love, and see) using a picture-matching task with two choices. They tested 26 children with WS and 77 TD children in three groups matched to the WS participants on nonverbal IQ, receptive vocabulary, and receptive grammar, respectively. Participants with WS achieved above-chance accuracy for passives with action verbs (78% for short passives and 69% for long), although their performance was not as good as
that of TD controls. However, their performance with psychological verbs was strikingly worse (32% for short passives and 19% for long). Since it is well known that TD children also struggle with psychological passives at a younger age (Maratsos, Kuczaj, Fox, & Chalkley, 1979, among many others), it is likely that the asymmetry between action and psychological verbs in WS reflects a snapshot of typical development at an earlier age. The question remains, however, whether this pattern of performance reflects non-adult-like grammatical knowledge (Borer & Wexler, 1987; Perovic & Wexler, 2010), or some other limiting factor (for review, see Gordon & Chafetz, 1990).

28.4.1.3 Case 3: Interpretation of pronouns (binding)

The interpretation of a pronominal expression depends on its antecedent, usually a nominal expression. Mature speakers of a language know the principles governing which nominals in a sentence could be the antecedent for a given pronoun. For example, they know that in the sentences in (13), the antecedent of *herself* is always *the dancer*, while in (14) the antecedent of *her* is always *the teacher*. Although these restrictions may appear opaque or complex at first, they are based on the hierarchical syntactic structure of the sentence.

(13) a. The teacher was watching the dancer who accidentally kicked herself.
    b. The dancer who the teacher was watching accidentally kicked herself.

(14) a. The teacher was watching the dancer who had accidentally kicked her.
    b. The dancer who the teacher was watching accidentally kicked her.

The antecedent of a reflexive pronoun (e.g. *herself*) must be local to the reflexive. It must also dominate (c-command\(^5\)) the reflexive in the hierarchical structure of the sentence. The

\(^5\) In this case as well as the case discussed in section 28.4.1.1 (the scope of negation) we have abstracted away from the details of c-command. An element in a hierarchical structure c-
antecedent of a non-reflexive pronoun (e.g. *her*) need not be local. If it is in the same clause, it must *not* dominate the pronoun. Thus, in (15), *him* cannot be *Mowgli*, because *Mowgli* dominates *him* in the hierarchical structure.

(15) Mowgli tickled him.

Clahsen and colleagues (Clahsen & Almazan, 1998; Ring & Clahsen, 2005) used a picture judgment task to assess comprehension of reflexive and non-reflexive pronouns in sentences like those in (16) by ten adolescents with WS. Overall accuracy was very high (95%), and did not differ significantly from that of mental age matched 5- and 7-year-old children.

(16) a. This is Mowgli, this is Baloo Bear. Is Mowgli tickling *{him/himself}*?

b. This is Minnie the Minx, these are some dancers. Is every dancer tickling *{her/herself}*?

These results demonstrate that adolescents with WS interpret pronouns in the same way as older TD children and adults. Since TD children show a protracted period of improvement on this task (Chien & Wexler, 1990; for review, see Conroy, Takahashi, Lidz, & Phillips, 2009), it would be useful to investigate how the learning trajectory for people with WS aligns with that of TD children. Perovic and Wexler (2007) used a picture-matching task with two choices to investigate the comprehension of similar sentences in two groups of children with WS, aged 6-12 years and 12-16 years. The performance of the older group was near ceiling on all conditions—92% for reflexives and 84% for pronouns—and no different from TD children matched on non-verbal reasoning (8-year-olds), receptive vocabulary (9-year-olds), or receptive syntax (6-year-olds). The younger group was less accurate overall, and showed better performance on reflexives commands its ‘sister’ and all of its sister’s descendants. For a more complete explanation, see Musolino, Chunyo, & Landau (2010).
(77%) than non-reflexive pronouns (63%). However, this asymmetry was in line with the performance of TD children matched on non-verbal reasoning and receptive syntax. It is also consistent with a well known pattern in typical language acquisition (Chien & Wexler, 1990; Conroy, Takahashi, Lidz, & Phillips, 2009).

Thus, people with WS seem to have the same knowledge of the principles for interpreting pronouns as typical adults. The limited evidence about the trajectory of their learning of these principles also suggests that it mirrors typical development, albeit at a later age.

28.4.1.4 Summary: Sentence structure

The findings show that, for the areas of grammatical knowledge that we have discussed, people with WS have control over core aspects of sentence structure. The structural relationships among elements, the principles underlying these relationships, and the consequences for semantic interpretation reflect formal theories of linguistic knowledge that capture deep generalizations about language. Children with WS, like TD children, acquire these generalizations without any formal teaching, and despite moderate mental retardation and severe spatial impairment.

It should also be obvious from our review that the trajectory of the development of syntax in WS is not typical. TD children demonstrate reliable knowledge of sentence structure at a much younger age (4-5 years old) than children with WS. Although most studies do not test young children with WS on their knowledge of sentence structure, it is safe to assume that it is generally not in place by 4 years of age. As we will discuss briefly in the last section, the early stages of vocabulary acquisition are significantly delayed in WS, so many 4-year-olds with WS have the language skills of TD 2-year-olds.

Landau and Hoffman (2012) proposed that people with WS show very slow development followed by arrest sometime during adolescence or early adulthood. This hypothesis of slow
development plus arrest captures not only the data on language learning (some of which we have reviewed), but also data on the development of spatial and numerical capacities. The slow development plus arrest hypothesis makes specific predictions about the range of grammatical competencies that we should find among people with WS. It predicts that knowledge shown by very young TD children should also be shown by people with WS: early developing knowledge is still acquired prior to adolescence, even given a much slower developmental course. The hypothesis also predicts that competencies that arise late in TD children may never be fully acquired by people with WS. If development comes to a halt during adolescence or early adulthood, there may only be time for the early-developing competencies to appear.

We have little evidence on the acquisition of grammatical structures that are learned relatively late by TD children, and even less on the acquisition of these among people with WS. But some findings fit this prediction. For example, we have already mentioned Perovic and Wexler’s (2010) argument that passives for psychological verbs are learned late, and the poor performance of people with WS on these. We will return to this hypothesis in our concluding paragraphs.

28.4.2 Word structure (inflectional morphology)

In the previous section, we discussed knowledge of sentence structure. We turn now to word structure—morphology. Different languages use the forms of words to encode a variety of different syntactic and semantic relationships. Some morphology is primarily semantic, as in tense marking on verbs and plural marking on nouns. Some morphology is purely structural, as in subject-verb agreement and determiner-noun-adjective agreement. Some morphology combines syntactic and semantic purposes, as in case marking on nouns (e.g. nominative case for subjects and accusative case for direct objects).
Morphological systems bridge the divide between syntactic structure and words. Regardless of their purpose, most morphological systems have components that reflect the systematicity of syntax, as well as properties reflecting the arbitrariness of the lexicon. For example, as we will discuss below, English has a regular rule for marking past tense on verbs, but also a number of irregular verbs that are marked in arbitrary ways. French has a regular agreement system for noun phrases that incorporates an arbitrary division of nouns into two classes. This combination of systematicity and arbitrariness, in addition to phonological subtlety (compared to word order) poses special challenges for language learners. We could well imagine that people with WS, while competent with word order, might struggle with morphology. However, most of the evidence suggests that people with WS acquire normal competence with morphology.

28.4.2.1 Case 1: Regular and irregular inflection

Systems of inflectional morphology are often characterized by regular rules that apply to most words, and a number of irregular words where the inflection takes an arbitrary form. English has several such systems, including past tense marking on verbs (e.g., regular: walked, loved, linked; irregular: ran, thought, sank) and plural marking on nouns (e.g., regular: boys, kids, faces; irregular: men, children, feet).

Normal adult-like competence with morphology requires knowledge of the regular rule—both its form and its purpose. The regular rule is a finite piece of knowledge that can be applied to an unlimited number of novel cases. Adult-like competence also requires knowledge that irregular exceptions are possible, and how to identify them. However, it cannot require knowledge of every irregular word in the language, since that list is unbounded. Many English-speaking adults are probably unaware of obscure past tense forms like strode, tred, spoilt, smote,
and *bade*, but we would not say that their knowledge of English past tense is defective or incomplete.

Knowledge of regular and irregular inflection is generally tested using elicited production. For example, to elicit past tense, Clahsen and Almazan (1998) asked participants to fill in the blank in passages like, ‘Every day I play football. Just like every day, yesterday I _____ football.’ To elicit plural nouns, Zukowski (2005) showed participants pictures of a single object or animal and then a picture of several of the same kind, and asked, ‘And here are a bunch of…?’

People with WS overwhelmingly produce regular forms correctly, but tend to overregularize irregular forms. This pattern holds for past tense verbs (English: Clahsen & Almazan, 1998; Thomas et al. 2001; German: Krause & Penke, 2002) and plural nouns (English: Clahsen & Almazan, 2001; Zukowski, 2005; German: Krause & Penke, 2002; Hungarian: Pleh et al., 2003). For example, Thomas et al. (2001) tested 21 people with WS aged 10-53 years using the ‘fill in the blank’ task mentioned above. Participants with WS provided correct past tense forms for regular verbs 77% of the time—about the same rate as 6-year-old TD children (74%). They provided correct irregular forms only 52% of the time, which was better than TD 6-year-olds (42%) but worse than TD 8-year-olds (69%).

These results show that people with WS acquire normal competence with regular inflectional morphology, and recognize that some words have irregular forms. However, their mental database of irregular word forms does not surpass that of a typically developing 6-year-old. Clahsen and colleagues have argued that this evidence fits into a larger pattern in WS: knowledge of combinatorial linguistic operations seems to be intact, while lexical representations or lexical access procedures seem to be impaired (Clahsen & Almazan, 1998; Clahsen &
Temple, 2003). Alternatively, the evidence is also consistent with the hypothesis of slow development plus arrest, which would predict that forms that are typically acquired relatively late would never be fully mastered by people with WS. The studies cited above may have relevant data to test this hypothesis directly; alternatively, new studies that design test batteries to probe tense markings that are typically acquired relatively early vs. late could generate new data for a direct test.

28.4.2.2 Case 2: Grammatical gender

Many of the world’s languages have noun class systems. In these languages, every noun is a member of a class, or gender, which determines the morphological form of determiners and adjectives within the noun phrase. Although the membership of noun classes is ultimately arbitrary, there are often semantic or phonological properties that are probabilistically associated with different classes.

In French, for example, nouns are either masculine or feminine. The masculine class includes males (e.g. homme ‘man’, danseur ‘male dancer’), but also inanimates (e.g. papier ‘paper’, vélo ‘bicycle’) and animates with unspecified natural gender (e.g. professeur ‘professor’). Likewise, the feminine class includes females (e.g. femme ‘woman’, danseuse ‘female dancer’) as well as inanimates (e.g. bicyclette ‘bicycle’) and animates with unspecified natural gender (victime ‘victim’). In French, phonological cues are more reliable than semantic cues: about 80% of nouns can be classified on the basis of their endings. For example, 99% of nouns ending with /ã/ (written as –an, -ant, -emps, etc.) and 98% of those ending with /o/ (-eau, -au, -ot, etc.) are masculine (Lyster, 2006).
The gender of a noun affects the morphological form of words (determiners and adjectives) that associate with it, as shown in (17).

(17)  a. le danseur charmant ‘the charming dancer’
      b. la danseuse charmante ‘the charming dancer’

To acquire the grammatical gender system in French, a learner must recognize that determiners and adjectives take different forms depending on the nouns they appear with, and thereby infer the existence of multiple noun classes. As the learner hears nouns in context, she can assign them to a class based on the form of nearby determiners or adjectives. Eventually, after classifying enough nouns, the learner may develop implicit knowledge of the phonological regularities in the system. Some studies have shown that French-speaking adults and older children can use this knowledge to classify novel nouns without the aid of morphological cues (Tucker, Lambert, & Rigault, 1977; Karmiloff-Smith, 1979). However, guessing the class of a novel noun is usually not necessary, since morphological cues are often present. Children and adults alike probably rely on a strategy of assuming that a noun is masculine unless the context provides clear evidence otherwise (Boloh & Ibernon, 2010).

To determine whether a child has mastered French grammatical gender, we should test (1) whether they produce appropriate morphology on determiners and adjectives, and (2) whether they can use the morphology of determiners and adjectives to determine the gender of a noun, and generalize that knowledge to different determiners and adjectives. The ability to guess the class of a noun based on probabilistic phonological cues is less central, especially since it is questionable whether adults use these cues.

Karmiloff-Smith and colleagues (1997) tested people with WS (aged 9-22 years) and typically-developing 5-year-olds on their ability to learn the gender of novel nouns from
different cues and to produce appropriate agreement morphology on determiners and adjectives. They used a naturalistic task to elicit noun phrases from participants. For example, in a representative trial, the experimenter showed the participant a picture of an invented green animal (see Figure 2) and told the participant that it was *une podine* (‘a podine’). Then she showed the participant a picture of a gray *podine* and said, *Ça c’est une autre podine* (‘That’s another podine’). Note that both uses of the novel noun included the determiner *une*, which provides an unambiguous cue that the noun is feminine. Then the experimenter hid a ring under one of the pictures, and prompted the participant to say where it was: ‘I hid my ring…?’ The target response was a prepositional phrase including both a determiner and a color adjective: *Sous la podine grise* (‘under the gray podine’).

Participants with WS provided responses with correct gender marking in about 70% of such trials. In similar trials with known words, participants with WS were correct over 90% of the time. Their accuracy was lower when the gender marking on the determiner conflicted with the phonological cues on the noun: about 85% for real words and around 50% for nonce words. TD 5-year-olds showed a similar pattern—more difficulty with nonce words and conflicting cues—but their accuracy was higher overall. The pattern of errors was also slightly different across the two groups: participants with WS were more likely to produce a noun phrase with mismatching gender agreement, as in *la podine gris* (‘the[fem] gray[masc] podine’) or *le podine grise* (‘the[masc] gray[fem] podine’). Karmiloff-Smith et al. used these findings to argue that people with WS fail to develop a deep analysis of morphology that can lead to broad generalization.
Using a very similar paradigm, Monnery and colleagues (2002) found that their participants with WS (aged 5-21 years) produced noun phrases with appropriate morphology 77-79% of the time for real words, and 83-84% of the time for non-words.

Since participants with WS showed above-chance accuracy in most conditions, we can conclude that they had acquired adult-like competence with French grammatical gender. This contrasts with Karmiloff-Smith et al.’s conclusion, and makes a different set of inferences from the pattern of performance. In our view, the existence of non-random performance across the board shows that people with WS have acquired the relevant morphological principles. We believe that their poor performance in cases of conflicting syntactic and phonological cues is not necessarily indicative of an impairment within the linguistic system. Dealing with conflicting cues in any domain requires executive control, which is impaired in WS compared to mental age matches (Rhodes, Riby, Park, Fraser, & Campbell, 2010). However, the form of the performance errors in WS calls for further study. As a starting point, it would be useful to assess whether they can detect mismatching gender morphology.

28.4.2.3 Summary: Morphology

In most areas that have been tested, people with WS demonstrate the grammatical and lexical knowledge relevant for application of morphology, consistent with our version of the modularity hypothesis. Areas of performance that are worse than TD children—even 5-year-olds in Karmiloff-Smith et al. (1997)—call out for additional study. The hypothesis of slow development plus arrest would predict two things. First, the pattern of performance observed in people with WS should be shown by typically developing children at some age. As shown by Musolino et al. (2010; see also Musolino & Landau, 2010), it is possible that WS individuals perform worse than their mental age matches but quite like typically developing children who are
younger than these matches (see also Landau & Hoffman, 2012, for a large range of data bearing on this issue). Second, the hypothesis would predict that aspects of morphology that are typically learned late in development may never be fully mastered by people with WS. This is clearly an empirically testable hypothesis.

28.5 Summary and conclusions
Our goal has been to evaluate the empirical evidence relevant to the question of whether the genetic deficit in people with WS compromises their language development, resulting in an atypical or deficient system of linguistic knowledge. We claim that this question distinguishes the two principal frameworks that have been proposed to explain the facts about language in people with WS—modularity and neuroconstructivism—given the baseline assumption of a distinction between competence and performance. Across a range of examples involving different grammatical structures and principles, we argued that the evidence is positive: people with WS show the same linguistic competence as people who have a normal complement of genes. We also found that the developmental trajectory for these achievements is quite different from that of typically developing children. The linguistic knowledge we highlighted appears to emerge at much older chronological ages than for typically developing children, who master much of what we discussed by the age of 6 years or earlier. We proposed that for people with WS, language development, like many aspects of spatial development, proceeds very slowly, with arrest at some time during adolescence (when typically developing peers have acquired most if not all of the linguistic system). This hypothesis can explain both successes and some limitations on the part of people with WS. Those aspects of linguistic structure that are typically acquired early in development are likely to be acquired in WS, albeit over a much longer developmental timetable. By contrast, those aspects of knowledge that are typically acquired
relatively late in development may never be fully acquired. Although this hypothesis is in need of direct testing, we believe that the bulk of evidence is consistent with it.

Our review has focused on two aspects of language that form part of the linguistic knowledge system common to all humans. In the domains of sentence structure and morphology, we have seen that careful probing of linguistic knowledge in people with WS shows that they have acquired structures that characterize both simple and complex sentences, and principles that draw on variation in these structures to produce subtle changes in meaning. The acquisition of such knowledge resists explanations involving general cognitive development, formal learning of any kind, or even the presence in the linguistic input of both positive and negative exemplars in any simple sense. We view the set of findings as consistent with our version of the modularity hypothesis, in which we emphasize linguistic competence—or knowledge—as the key to a learner’s approach to language learning. We conclude that many core aspects of linguistic knowledge are part of the human language learning system, and that the genetic deficit of WS does not re-create, re-organize, or damage this basic learning system.

At the same time, we recognize that there are differences between learners who have WS and those who do not. The many cognitive mechanisms involved in the processing of linguistic input will inevitably affect the degree to which a learner with WS can show his or her knowledge. Weaknesses in working memory and executive function, for example, will affect overall scores on tests, especially if those tests particularly stress these quite general systems, which presumably apply across all knowledge domains. However, we believe the evidence shows that carefully constructed tests of linguistic knowledge in people with WS reveal strong evidence for linguistic competence in many areas.
Understanding the differences in performance between people with WS and typically developing individuals is important. In some cases, it may hold the key to accelerating development in these individuals. For example, in the little-studied area of vocabulary onset, we see significant opportunities to understand why early vocabulary is so delayed, and perhaps opportunities to reduce this delay. Although the evidence is sparse, there are several promising findings. First, the delay is likely to be caused at least in part by deficits in joint attention among toddlers with WS. Unlike typically developing toddlers, they do not point to things before they start saying words (Mervis & Bertrand, 1997; Mervis, Robinson, Rowe, Becerra, & Klein-Tasman, 2003). They are less likely than TD toddlers to follow an adult’s pointing gesture to focus on an object (Laing, et al., 2002), and often fail to understand the communicative significance of points and gaze direction (John & Mervis, 2010). Thus, early vocabulary growth—unlike aspects of grammar and morphology—is likely to be affected by deficits in the non-linguistic cognitive and perceptual systems involved in joint attention. However, past the early stages of vocabulary, it appears that most children with WS show sharp growth trajectories similar to TD children (Mervis, Robinson, Rowe, Becerra, & Klein-Tasman, 2003), although the data on this issue are limited to date. In unpublished work from our lab, we have found that people with WS continue to acquire new vocabulary through about age 20, after which it plateaus. This compares favorably with non-verbal measures of the KBIT, which appear to plateau at a much earlier age. Vocabulary in typically developing children and adults grows throughout the lifetime, of course, so it is possible that more sensitive measures might reveal a lengthier developmental timeline that we have detected. In any case, these measures confirm that vocabulary is a relative strength in people with WS, even though the early delays in vocabulary onset and growth are significant.
Given the degree of competence ultimately shown among people with WS, we think it is crucial to promote early learning of vocabulary. Many theories have stressed the importance of learning a first vocabulary in order to later make use of language itself in learning new words, e.g., via syntactic bootstrapping (Landau & Gleitman, 1985; Naigles, 1990; Yuan & Fisher, 2009). Our hypothesis of slow development plus arrest leads to the highly speculative suggestion that reducing the delay for early vocabulary could push the entire language-learning trajectory earlier, thus providing additional time for learning before the hypothesized period of arrest, in adolescence or early adulthood.

Suggestions for further reading


Series of three papers in Language Learning and Development:


References


Figure 1. These two sentences are superficially similar, but have different meanings. In (a), the element *not* dominates (c-commands) the disjunction element *or*, resulting in the interpretation that the cat will get neither fish nor milk (not fish *and* not milk). In (b), the *not* does not dominate the *or*, resulting in the interpretation that the cat will get either a fish *or* milk. People with WS are sensitive to the meaning differences between such sentences, proving that they are sensitive to structural differences and their semantic consequences (Musolino, Chunyo, & Landau, 2010).
**Figure 2.** Example of invented animal from Karmiloff-Smith et al. (1997), who tested French-speaking children's ability to generate the correct morphology for novel nouns. Children were told the name of one animal (e.g. *une podine*) and then told there was another (e.g. *une autre podine*) of a different color, and then asked to say which one had a ring hiding under it. The question was whether children could generate the gender-appropriate form of the prepositional phrase, including a determiner and the color adjective.